Children's Performance on and Understanding of the Balance Scale Problem: The Effects of Adult Support

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ABSTRACT

The present thesis investigated the Vygotskian notion that social influences are necessary for children's learning to take place, and that the process of conceptual development via Representational Redescription, described by Karmiloff-Smith (1992), occurs as a result of contingent scaffolding techniques. The aim of the research detailed in the thesis was to examine the effects of adult support on children's performance on and understanding of a Balance Scale task. Analyses of support focused on the extent to which language used by the adult could be appropriated and used subsequently by the child to complete the task and explain their actions. The adult providing support was either the child's parent (Study 1), or was

unknown to the child (Studies 2 and 3). Whereas Studies 1 and 2 focused on the impact of support on individual children, Study 3 looked at this impact on collaborating children working in dyads. All children worked on the Balance Scale task at three separate time-points.

In the first study, which looked at the impact of parental input at Time 1 on their children's performance on the Balance Scale task at this and the following two time-points, compared to children who worked on the task alone at all three sessions, it was shown that (a) supported children advanced in their explanations in a way not seen by those who were unsupported; (b) parental input varied considerably, although the most effective was that which combined explicit operationalisations of strategies to solve the task and explanations that explicitly stated the principles at work; and (c) as had been predicted, children benefited from this and other input differently depending on their initial level of ability on the task, with explicit accounts being readily appropriated by those with better understanding, whilst those with less understanding were assisted by more implicit prompts that directed their attention to the manipulation of weight and distance.

The second study focused on the impact of support depending on children's initial level of understanding, and the time-frame of support. Children were categorised as having lower or higher understanding based on an earlier classification task, and provided with support at the first time point only, or else for all three sessions. It was found that children of lower understanding benefited more from continuous support, which allowed more explicit input to be introduced over time, whereas those of higher understanding benefited more from support that focused on explicit explanations and was discontinued after Time 1.

Finally, Study 3 focused on the effects of adult support on children working in same-sex dyads. Children were identified as being lower or higher understanding based on an earlier classification test, as was the case in Study 2, and they were placed into dyads on this basis. There were three pair types used: Low-Low, High-High and Mixed (one child of lower and the other of higher understanding). Half of the dyads received support at Time 1 and then worked alone in their dyads for the remainder of the study, and the other half worked alone for all three sessions. It was found that support only made a sustained difference to those in Mixed dyads, the mutual support available in the High dyads acting as an effective substitute, and the Low dyads failing to make much gain in understanding whether support was available or not. In the Mixed dyads, the effect of support was found to be that the dyad member with higher understanding appropriated more explicit explanations of the problem from the adult at Time 1 (primary appropriation), and then used these with the lower understanding member at Time 2, who appropriated them in turn (secondary appropriation), both converging on their use at Time 3. The net effect of providing support to Mixed dyads therefore was to combine the process of one-off support for higher understanding children and continuous support for lower understanding children noted to produce the best outcomes in Study 2.

Overall, the three studies provided consistent evidence in line with the Representational Redescription-based tutoring model with regards to: a) supported children showed changes in explicit representation not seen among children who worked alone, and the characteristics of effective support differed in predicted fashion with initial representational level; and b) there is a need to extend the application of the model to different contexts, and to explore the effects of varying emphases in tutor input in more detail, given the inconsistencies in outcome, especially as regards the strength of the appropriation process amongst those with higher understanding.

Chapter 1

THE ORIGINS OF SOCIAL DEVELOPMENT THEORY

Over the past three decades much research has shown that both interpersonal and environmental influences must be considered when examining the cognitive development of young children (Conner & Cross, 2003; Freund, 1990; Grolnick & Slowiaczek, 1994; McNaughton & Leyland, 1990; Vygotsky, 1978; Wertsch, McNamee, McLane & Budwig, 1980; Wood, Bruner & Ross, 1976). This research has largely been influenced by the writings of Vygotsky (1962; 1978), who argued that historical, cultural and social factors are essential in establishing a child's mental (psychological) and cognitive growth. Whereas maturation is important to a certain extent in initially shaping children's early behaviour and development, it is secondary to the cultural and social aspects of the child's environment that are crucial in determining their transition from using primitive behaviours without proper use of language, to becoming social creatures who display unique human behaviours, such as speech (Vygotsky, 1978, p. 20).

1.1. Importance of Vygotskian theory to studying the growth of children's language and social development

1.1.1. <u>Fundamental components of Vygotskian theory</u>

Vygotsky agreed with theorists such as Buhler (1930) and Kohler (1925) who suggested that child psychology has much in common with animal psychology. For example, in both animals and children, basic psychological processes, such as the practical use of tools, occur independently of speech. But, when those processes in animals and children are studied together, they allow for and facilitate research into the biological, or elementary basis of human behaviour. Thus, the root of child behaviour arises from the connection between primary, or biological processes, and the social and cultural aspects of their higher psychological functions. Higher psychological processes, such as speech, have been classed as a continuation of corresponding processes in animals, but those processes are argued to now be completely unique to humans. Speech, in the form of signs, is children's first experience of social contact with other people, and, with both cognitive and communicative elements contained within speech establishing the foundation for a novel but superior path of development and behaviour, this sets children apart from animals.

Vygotsky's theories were inspired by Marx's concept of historical materialism. This concept postulated that historical changes that occur in society and "material life" produce changes in the individual's consciousness and behaviour, that is, their basic human nature. Vygotsky was also influenced by Engel's notion that human nature, along with the cultural environment, is transformed by human labour and tool use. Vygotsky extended this concept of tool use to include the use of signs also. He described signs as being the basic components of spoken and written language and numbers, which have been created and modified by different cultures throughout human history, changing as society changes. Furthermore, along with Engels, Vygotsky did not believe that intellectual abilities develop solely from biological or genetic properties, or are already present in the child and are only waiting to be manifested in some way. On the contrary, he argued that those intellectual abilities develop from the cultural and social experiences the child encounters with other people. In essence, the fundamental components of human development and change are embedded within society and culture, with the most important aspects of cultural behaviour, this being the use of tools and human speech, arising during infancy (Vygotsky, 1978).

The functions of sign and tool use differ in a number of ways, the most significant being the way in which they shape behaviour. Whereas the use of tools is externally regulated, as it controls how individuals influence and change the outlook of objects, signs are internally regulated, as they are concerned with facilitating the individual's control over their surroundings.

According to Vygotsky, tool use, in the form of practical abilities, and sign use, in the form of speech, develops simultaneously in children. This was one of the few areas in which he and Piaget agreed, as Piaget (1955) argued that this dialectic between practical skills and language leads to children's use of egocentric speech (directing their speech inwardly). Therefore, although practical skills (tool use) and speech (sign use) can function separately to one another in young children, together they form the essence of adult human behaviour. This process of distinguishing human intellect from that of animals, in terms of establishing the unique human capacity to think practically and theoretically, arises when speech and practical skills, initially two simultaneous but separate paths of development, join together.

This unity of practical and theoretical thinking begins when children, before acquiring control over their own behaviour, start to manage their surroundings through speech. This process is the basis for the development of their intellect and use of tools. As children work through a problem-solving task, they use speech to facilitate their progression towards the task goal. The speech occurs naturally and carries on over the course of the task. As the task increases in difficulty, the speech becomes more copious. In fact, the function of speech is vital to children in their attempts to achieve their goal, and the more complex the task is, the more important speech is to the procedure. This theory was supported in research by Fernyhough & Fradley (2005), who found that children's egocentric (or 'private') speech was much more likely to occur during the most difficult tasks as opposed to simpler activities.

Furthermore, as children progress through tasks, achieving a number of clear and logical subgoals, they may then encounter difficulty with a certain aspect of their task, and so turn to the adult for help. In this case, Vygotsky believed that they already have a plan visualised to solve the task, but just cannot perform all of the necessary procedures without this social influence to assist them. As a result of the combined elements of using private speech and the scaffolding process, the child performs successfully on the task when working on it subsequently alone (Winsler, Diaz & Montero, 1997). In essence, private speech is developmentally a half-way point between social and inner speech (Fernyhough & Fradley, 2005).

1.1.2. <u>Internalisation of speech</u>

Along with language, children use other functions to progress through problem-solving tasks, such as perception (using their eyes), sensory-motor actions (using their hands) and attention. Those functions start to work together, eventually leading to internalisation of the child's visual field. Following this, their speech which has initially been "socialised", that is, used solely for communication with adults during the problem-solving process, then becomes internalised, so that the child is now using it to guide their own actions, as opposed to letting their actions be guided by an adult. Vygotsky referred to this process as, "the internalisation of social speech" (Vygotsky, 1978, p. 27), with the term "internalisation" referring to the transformation of an external action into one that occurs within the child. This internalisation alters the entire cognitive process and allows the child to exert control over his or her actions. Ultimately, the whole basis of human psychology revolves around the internalisation of socially embedded, and historically evolved behaviours.

This internalisation procedure, therefore, suggests that higher psychological processes are actually dialogic in their nature (Fernyhough, 1996, Wertsch, 1990).

Vygotsky generally believed that any psychological procedure, whether instinctive or voluntary, changes as it is being observed, and this can occur over the course of a few seconds or fractions of seconds. Therefore, to successfully study the moment-by-moment (microgenetic) changes involved in development, those being generated from the problem-solving behaviours of children whilst completing a task, it is necessary to present difficulties into the activity that interrupts the child's constructive problem-solving procedures. Thus, by observing how children of different ages and working within different levels of task complexity, adapt to those difficulties Vygotsky tried to map out the changes in their intellectual processes occurring throughout their development. To be precise, Vygotsky studied performance as it was happening, as opposed to only focussing on the end result. His main question was not, "What has the child done?" but "What is the child *doing?*"

He believed that children have already begun their learning by the time they start school, and whatever learning they experience always has a prior history. In fact, Vygotsky argued that children's learning and development are interrelated from the day they are born.

1.1.3. <u>Zone of Proximal Development</u>

The course of development, according to Vygotsky, occurs at two levels. The first level is comprised of what the child is able to do at that present time, that is, their 'actual developmental level'. He argued that researchers make the mistake of believing that it is only what the child can do independently that determines their overall mental abilities, and pay no attention to what might be achieved with help from other sources. In support of this, Vygotsky found that if leading questions were offered to the child, or a demonstration was given of the correct way in which to solve the task, the child was able to successfully complete it. This showed Vygotsky that even children of the same chronological age may not work at the same age mentally. In other words, they are at different stages in their mental abilities. Thus, what one child is capable of doing at seven years old, another child of the same age may not.

Most cognitive developmental researchers (for example, Conner & Cross, 2003; Kermani & Brenner, 2000; Rogoff, 1990; Wertsch, McNamee, McLane & Budwig, 1980; Wood and Middleton, 1975; Wood, 1986) have been very influenced by Vygotsky's theory of the zone of proximal development, which he defined as, 'the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers' (Vygotsky, 1978, p. 86). In other words, the 'zone' is the phase between what the child is capable of achieving independently, and what they are as yet unable to achieve without guidance and support from an adult or more capable peer. The role of the 'tutor' is, thus, to effectively induct the child into the use of sign operations (i.e. speech), to control their actions explicitly. The adult achieves this by working with the child on two levels, the *interpersonal* and then the *intrapersonal*. At this first level (interpersonal), the adult uses speech to control the children's actions, as this allows the child to appropriate this sign usage, firstly in the form of private speech, and then by internalising it. When internalisation occurs, the child is now functioning on the intrapersonal level. With this close guidance and appropriation of sign usage, children are able to successfully complete certain aspects of the given task which they could previously not accomplish (Pratt, Kerig, Cowan and Cowan, 1988). Therefore, "the actual developmental level characterises mental development retrospectively, while the zone of proximal development characterises mental development prospectively" (Vygotsky, 1978, p.86).

Using this theory allows researchers to study the child's cognitive development in a deeper, more complex form than is possible from the abilities they are showing at that present time. That is, it enables them to examine the child's potential development achievable through interaction, collaboration and support from the environment, such as teachers, parents or peers. However, Vygotsky believed that children would only benefit from collaborative problem-solving activities when the activity was focused towards advancing their present state of development. For example, although imitation as a method of teaching children within the zone of proximal development may be an effective means of advancing their learning, it only does so when the child is imitating that which is already within his or her current level of development. Vygotsky gave the example of a child having difficulty with an arithmetic puzzle, which he or she overcomes through imitation of the teacher's solution on the blackboard. However, if the teacher were to demonstrate the solution to a higher mathematical puzzle on the board, such as algebra, the child may never understand the answer, even after many imitations of what is on the board.

Vygotsky's zone of proximal development theory was in complete contrast to that of Piaget, who postulated that children's development relies on biological processes to ensure their transition through set, universal stages. Although Piaget recognised that imitation was a factor in children's development, he argued that it only led to mechanistic learning where the child did not actually learn or understand what they were doing. In other words, Piaget believed that any attempts to teach children skills that they were not yet able to do, led to frustration and the learning of 'empty procedures' (in Wood, 1998).

It can be concluded from Vygotsky's theories therefore, that the fundamental component of learning is that it generates the zone of proximal development. In other words, learning stimulates many internal developmental procedures that can function only during interactions that occur between children and their environment, this being made up of parents, teachers and other peers. When those procedures become internalised, they can then be recognised as contributing to the child's autonomous developmental success.

1.2. The Scaffolding Relationship between Child and Parent

1.2.1. Early Scaffolding research

Wood and colleagues (Wood & Middleton, 1975; Wood, Bruner & Ross, 1976) later developed the concept of 'scaffolding', which is the process in which 'tutors' and children work together within the child's Zone of Proximal Development, to increase the child's understanding and development of skills on the particular activity. However, it is not only the adult who determines their level of involvement on the task but the child also who, along with the adult, establishes the degree to which help is required (Bjorkland, 2000). For example, if the child is less able to progress through the task, they will request more support from the adult, with the opposite being true for more able children. (Plumert & Nichols-Whitehead, 1996). On the other hand, children who are highly skilled on one task may be less able in another, and so the level of support needed and given to the child also depends on the specific task being undertaken (Bjorkland, 2000). Therefore, the complexity of the task does not independently affect the child's ability to complete it. Essentially, the difficulty of a task is dependent on the child's perception of its difficulty, the degree of support given by the tutor, along with the child's present capabilities (McNaughton & Leyland, 1990).

From observing the scaffolding behaviours executed by mothers in their study, Wood and Middleton (1975) found that mothers differed quite considerably in the way in which they interacted with their children on a task in which they had to help them assemble a wooden pyramid structure. They devised a series of levels of control measures to highlight those behaviours. Level 1 – General Verbal Instruction, involved the least amount of intervention from the mother. It was concerned with the parent trying to encourage her child to reach a specific goal or subgoal, but without specifying how the child should progress, for example, "Well done, now can you make another part like that?" Level 2 – Specific Verbal Instruction, involved the mother offering a specific hint as to how to progress to meet a goal or subgoal, for example, "Now you have to find a block with a hole in the middle." If the mother not only drew her child's attention to a specific part of the task but also showed him or her the materials that now had to be used by pointing to them, she would be working at Level 3 – Mother Indicates Materials. An example of this Level may be, “You need to use that block there” (points to block). If the mother not only indicated the materials to be used but also selected the appropriate items and prepared them for construction she would be working at Level 4 – Mother Provides Material and Prepares it for Assembly. The final and highest Level of Intervention was Level 5 – Mother Demonstrates an Operation. At this level the mother took full control of the task by both selecting and constructing the materials whilst the child only looked on. Thus, as the Levels increased, so did the mothers’ control of the task and situation. Assessing the amount of difficulty that the child was having initially with the task, and structuring the scaffolding relationship accordingly, led to the most effective use of those Levels. That is, if the child was having much difficulty with the task, it was more beneficial to work at a higher level with them until they were more aware of the task goals and how to achieve them. For example, it was found by Wood, Bruner & Ross (1976) that when children who found a pyramid-building task difficult were only asked to carry out a certain action they tended to ignore the researcher’s requests, even if the outcome of their potential actions were achievable. In contrast, when those children were shown the materials (i.e., the blocks) they were required to use for specific parts of the task, they often did manage to complete the action.

1.2.1.1. Region of Sensitivity

Within the concept of scaffolding, Wood and Middleton (1975) found that the most effective adult interventions were structured in the ‘region of sensitivity’ (pp. 182). This was achieved when the adult (referred to by Wood as the ‘tutor’) was aware of the parts of the task the child could complete independently, what elements they understood but could not complete without help, and what components of the task they could not perform at all without support. Once this region was established the tutor would help the child to complete a part of the task in which they understood the components but could not proceed alone. The child would then internalise this part of the task and thus be able to progress to the next stage or sub-goal. This would continue until the child had successfully internalised the task components, and therefore was able to reach their ultimate goal.

1.2.1.2. Contingency Rules of Intervention

In addition, Wood (1986) found that successful interactions between mothers and their children, as measured by children's success on subsequent independent trials, resulted from the mother following two 'contingency rules' of interventions. One of the two rules was concerned with her taking a higher level of control over the parts of the tasks in which the child failed to accomplish. Thus she may have shifted from using Level 2 – Specific Verbal Instructions, to Level 3 – Indicating Materials. The other rule stated that when the child successfully completed an instruction or sub-goal of the task, the mother should decrease her level of intervention, for example, shifting from Level 3 back to Level 2. This allows the child to develop their skills independently and leaves space for further success (along with errors). This has been supported by later studies measuring both intervention behaviours within the region of sensitivity and use of contingency rules (Conner & Cross, 2003; Conner, Knight & Cross, 1997; McNaughton & Leyland, 1990; Pratt *et al.*, 1988).

Conner & Cross (2003), for example, conducted a longitudinal study in which they tested children from the age of 16 months to 54 months. Their problems involved parents and children building a tower using two sets of blocks in a specific sequence. Familiar objects were used, and no explicit instructions were given to the parents or children about how they should attempt to reach the overall goal. They used the scoring system developed by Wood & Middleton (1975) and modified by Pratt *et al.* (1988). Pratt *et al's* Levels of Intervention commenced at Level 0 - No Parental Intervention. Level 1 comprised of a General Verbal Start, such as, "You move a block". Level 2 consisted of Verbal Hints, such as, "It's too small". Specific Verbal Instructions, such as, "You should use another smaller block", comprised Level 3. Level 4 consisted of Identifies Material or Placement, for example, pointing to a block, and telling the child, "That block will fit". Parents who Specified both Material and Placement, such as telling the child to retrieve a block and put it in a specific place, worked at Level 5. Finally, Parents who only Demonstrated how to build the tower worked at Level 6.

They found that parental support began at the highest Level of Intervention when the children were very young (16 months), and gradually decreased as the children became older. In other words, mothers (and children) showed an increase in the complexity of their behaviours during problem-solving activities at consecutive ages. For example, when the children were very young, mothers tended to be more physically involved, and gave more information about the task (Levels 4 to 6). However, as children's ages increased, mothers shifted support towards being more verbally mediated, and giving less information about the task (Levels 0 to 3). This pattern of adults varying the nature of their interaction during joint problem-solving activities depending on the age of the child has also been found in other studies, with adults being more directive, giving more guidance, and offering more specific information to younger children (Kontos, 1983; Rogoff, Ellis & Gardner, 1984; Saxe, Guberman & Gearhart, 1987; Wertsch *et al.*, 1980).

1.2.2. **Guided Participation**

The general concept of scaffolding was extended by Rogoff (1990), who believed that both the child and adult (or more capable peer) work together through 'Guided Participation' in their quest to develop and regulate the child's independent learning. This concept allows researchers to observe the numerous ways in which children learn as they take part in and are guided by their society (Rogoff, 2003). Furthermore, the actual process of 'guidance' and 'participation' between child and adult increases the child's present understanding and abilities by coordinating and constructing the level of participation by the young learner in different activities. Rogoff (1990) along with Garton & Pratt (2001) believed that the most important element of Guided Participation (Rogoff) and an important factor within Vygotsky's Zone of Proximal Development (Garton & Pratt) was the process of intersubjectivity. Intersubjectivity occurs when the parent and child both realise the nature of the task, and share the same idea about how to reach the goal. In other words, they share a "meeting of minds" (Garton & Pratt, 2001, pp. 308), which facilitates the cognitive learning process in the child and allows him or her to complete the activity independently.

This approach differed to that of Wood (Wood & Middleton, 1975; Wood, 1986), as despite guided participation being based on a more qualitative analyses of dialogue between teacher and 'apprentice', Rogoff did not make clear exactly how appropriation is finally achieved. In other words, she did not detail the *type* of linguistic exchange that takes place between tutor and learner to facilitate learning and understanding. Wood's research, on the other hand was much more detailed, and focused on the step-by-step changes occurring throughout the problem-solving process between parent and child. His detailed account of the type of dialogue uttered by the parent made it very clear to see how this linguistic exchange led to the child appropriating the necessary strategies and understanding of the task to enable them to undertake it subsequently alone.

1.2.2.1. Cognitive self-regulation

In spite of the different approaches to the study of children's cognitive learning, the underlying premise remains consistent. That is, as children undertake tasks over a period of time they shift from being a passive learner, that is, allowing the problem-solving process to be adult-regulated (by which the adult takes control of the task demands) to being cognitively self-regulated. This concept of 'cognitive self-regulation', highlighted by Baker & Brown (1984) and Wertsch (1977), refers to the child's use of control processes that are vital for successful accomplishment of a task. Those processes may involve planning task activities, observing success or failure of actions, staying aware of task goals, and orchestrating strategies to achieve those goals (Baker & Brown, 1984; Wertsch, 1977).

This change from adult-regulation to self-regulation of problem-solving strategies has been studied using microgenetic methods (Chen & Siegler, 2000; Siegler & Svetina, 2002; Wertsch & Hickman, 1987; Wertsch, McNamee, McLane & Budwig, 1980; Winsler, Diaz & Montero, 1997). This method involves recording change processes as they occur during problem-solving activities, as opposed to only observing the products of this change. In other words, microgenetic approaches to studying development focus on "real-time" or "moment-by-moment" (Lavelli, Pantoja, Hsu, Messinger & Fogel, 2005) change as it happens during interactions or independent performance on a cognitive activity. For example, Wertsch & Hickmann (1987) investigated children's changing development and use of strategies on problem-solving tasks as they were acquired during the problem-solving process, and found that the shift from adult-regulation to child-regulation occurred "as the joint problem-solving activity unfolded during the session" (Wertsch & Hickmann, 1987, pp. 259).

Cognitive self-regulation is also thought to be a component of *metacognition*, a concept incorporating two separate forms of cognition. Those are, firstly, knowledge about an individual's own cognitive processes, and secondly, being in control of those processes (Baker & Brown, 1984). Hartup (1985) proposed that metacognitive skills, such as planning strategies on a task, are facilitated by the process of social interaction. In addition, Gearhart (1979) suggested that when planning strategies, children may learn about their own and each other's cognitive activities, the term 'planning' referring to the process of formulating and coordinating actions aimed at accomplishing a goal, and of assessing the effectiveness of the actions for reaching the goal as the plans are implemented (Gauvain & Rogoff, 1989).

It has been suggested that cognitive self-regulation develops through early social interactions between young children and more competent individuals such as parents (Vygotsky, 1978). During parent-child activities, the parents largely control the child's behavioural responses, such as guiding their attention to specific areas, reminding them where they are in the task and what the goals are, and evaluating the child's success or failure in terms of their actions. When those scaffolding techniques are employed contingently by an adult, this leads to successful self-regulation on the part of the child.

Radziszewska and Rogoff (1988) found, for example that when children worked on a route planning task with a parent who employed contingent scaffolding techniques they performed more sophisticated planning strategies when working on the task subsequently alone than those who had worked originally with a peer. One parent who encouraged the child to verbalise their thoughts throughout the task by constantly asking questions about how to plan the next move, worked towards short-term sub-goals and justified ideas, resulted in the child internalising those strategies and using them in the subsequent post-test. Thus, at post-test, the child demonstrated exploration of all the strategies available to successfully complete the task, and made sophisticated decisions regarding planning moves that would not have been possible without his parent's guidance.

Children who had originally worked with a peer on the route planning task did not tend to explore the various options available but concentrated on planning each move in a step-by-step process, only planning their next move from the location they had just arrived at. This less sophisticated strategy led to a poor performance at post-test, especially compared to those who were supported by a parent.

Therefore, the cognitive self-regulatory processes the child must acquire to solve problems independently are triggered by parental input, and those processes are similar to the regulatory acts previously set by the parent during joint activities (Vygotsky, 1978). Cognitive development continues when those regulatory acts set by the parent become internalised by the child to the extent that he or she is able to regulate their own cognitive processes independently. As mentioned earlier in discussion of Vygotsky's (1978) theory of the zone of proximal development, this process of internalisation is made easier by three actions undertaken by the adult during joint problem solving with a child. Firstly, the adult takes responsibility for the parts of the task that are outside the child's capabilities. Secondly, they limit their control of the child's behaviour, for example, guiding the child's attention to the parts of the task that are just beyond their ability level. The third and final action undertaken by the adult to facilitate internalisation, is noting the areas of the task in which the child has successfully mastered and transferring responsibilities to the child in that part of the task (Kermani & Brenner, 2000). The adult's understanding of the 'zone' between what the child can do with assistance and what the child has mastered is a primary factor within Vygotsky's theory of cognitive development (Conner & Cross, 2003; Freund, 1990).

This does, however, take for granted the notion that parents will scaffold their child's problem-solving contingently. As found by Hess & McDevitt (1984) and Wood & Middleton (1975), those mothers who did not employ contingent support techniques, for example, constantly using Level 5 intervention strategies of showing the child how to do the task and then asking them to replicate their methods (c.f. Wood & Middleton), did not facilitate their child's learning on the task at all, resulting in those children performing very poorly when having to re-do the task subsequently alone. Therefore, for successful self-regulation to take place, it is crucial that parents are sensitive to what their child is able to do presently and what is just outside of their abilities, and provide support accordingly.

Hess & McDevitt (1984) suggested that as a child becomes able to successfully complete problem-solving tasks independently, and thus becomes self-regulated, they also develop a sense of pride, self-confidence and the belief that they can consistently succeed in tasks.

Therefore, it can be suggested that understanding how a parent interacts with the child during joint problem-solving activities will provide insight into not only how the child will perform later while problem solving on his or her own, but also of their own expectations and self-appraisal of their later performances.

1.2.3. Scaffolding Techniques in Relation to Age

There is much evidence to support the notion that parents structure their scaffolding style according to their child's age. That is not to say they do not use the same type of contingent scaffolding techniques highlighted by Wood & Middleton (1975) but contingency takes place at a different level. That is, the parents use broader strategic decisions in relation to their child's ability, rather than the moment-by-moment approach used by Wood & Middleton (1975). Thus, mothers of younger children give more help than those assisting children who are older (Baker, Sonnenschein & Gilat, 1996; Freund, 1990; Gauvain & Rogoff, 1989; Rogoff, Ellis & Gardner, 1984; Wood, Bruner & Ross, 1976), even if the younger ones do not actually need the assistance (Baker *et al.* 1996). Furthermore, many studies have found that the way in which parents structure their scaffolding may depend on their own perception of the task in terms of its difficulty, and the role that they should adopt in working with their children to progress through the interactive session (Freund, 1990; Gauvain & Rogoff, 1989; Renshaw & Gardner, 1990; Rogoff, Ellis & Gardner, 1984).

Rogoff, Ellis & Gardner (1984) studied mother-child interaction with children aged 6 years and 8 years. They argued that children at those ages are at a critical period in terms of their familiarity with formal schooling. That is, younger children have only just started school, whereas the older children have very much settled into their school lives. They predicted that adults would respond more to how practiced the younger and older children were in different tasks, than to the children's ages and nature of the task per se. The dyads worked in one of two tasks, one of which was a home activity where they had to place grocery items on shelves in a mock kitchen. The other task was a school activity, which involved sorting photographs of common objects into a divided tray. Both of the tasks were conducted in a room made up to resemble a kitchen, consisting of appliances and cupboards, kitchen curtains, and decorations. The mother's job was to teach her child the location of a number of items. Rogoff, Ellis and Gardner found that the younger children in the school task received more instruction than either the younger or older children in the home task. In addition, the amount of directives, open-ended questions, nonverbal instruction, child's involvement in the task, and time spent reviewing was greater for the younger children in the school task than for the younger children in the home task or for the older children in either task. However, the amount of time spent organising items did not significantly follow this pattern. In other words, there was more regulated instruction in terms of directives given, open-ended questions, nonverbal instruction, reviewing time and child involvement for 6-year olds in the school task then for any other condition.

It was found that more instruction was given in the school task than the home activity as parents expected the school task to be more difficult, although it was arranged to be similar in difficulty to the home task. Parents were found to generally expect tasks conducted at school to be more difficult than those undertaken at home. Due to this belief, dyads adopted a more formal stance toward the school task.

Freund (1990) studied children's abilities to sort 36 pieces of household furniture and appliances, found in a typical home, into two to six rooms in a one-level, doll house-like structure. For example, a towel rack, bath, sink and toilet would be placed in a room that would then be labelled the bathroom. There were also six same-scale distracter items that are not found in typical houses, such as a deer and a boat. There was a difficult and easy version of the task. The difficult version encompassed a six-room doll-house with 35 furniture items and six distracter items. However, although the 5-year old children could adequately cope with this configuration, 3-year olds found the task too difficult, and could not complete it. Thus, for the 3-year olds the six-room house was reduced to four rooms with 24 pieces of household furniture and four distracter items. The easy version of the task comprised cutting in half the number of room groupings to be sorted by each age group. There were three phases.

Phase one consisted of the children undertaking the difficult version of the task independently. Phase two comprised of two conditions. One condition involved children and their mothers working together on the easy and difficult versions of the task. In the other condition, control (corrective feedback) groups completed both versions independently. The third and final phase consisted of all children completing the difficult version of the task, again independently.

Freund (1990) found that children who interacted with their mothers performed more effectively on the task than children in the corrective feedback condition. In fact, parental support greatly improved both 3- and 5-year olds' sorting performance. Furthermore, when working independently the second time, children who belonged to the interaction group performed more effectively than those who worked alone at Phase 2. However, there was no relationship found between children's initial independent performance and the level of control taken by mothers for the item-and room-selection components in the interaction condition. There was also no evidence that mothers of children belonging to one age-group spoke more than the other mothers, even though 5-year olds had more items to sort than the 3-year olds.
This finding supports that by Baker, Sonnenschein & Gilat (1996), but contradicts Kontos (1983) and Kontos & Nicholas (1986), who found that children did not perform any better individually after initially working with their mothers on a task than those who had previously worked alone. This may be due to the fact that the puzzles used in the two latter studies were highly challenging, unique, and certain to be unfamiliar to the child. Thus, although the categorisation task in Freund's (1990) study and the matching concepts used by Baker *et al.* (1996) were also challenging, the items were familiar to the children and were contained within a context that was familiar to both the child and mother. In addition, Baker *et al.* (1996) suggested that this contradiction in findings could have been due to the fact that puzzle tasks such as those used by Kontos (1983) may be learned independently through practice and repeated performance, for example, if a certain puzzle piece does not fit into a certain hole, that pairing will not be re-attempted. However, in other tasks that require specific knowledge that is only acquired through instruction, for example, the activities used in Baker *et al's* (1996) study along with that of Freund (1990), adult support is very important. Therefore, it has been suggested by Rogoff (1987) that the effectiveness of parental support on problem-solving tasks is dependent upon the

situation and type of task being undertaken, and if the circumstances are not appropriate then the social relationship will not facilitate the child's cognitive development. In other words, the task has to involve a shared perspective of thinking between the parent and child (Freund, 1990).

Freund also found that mothers took more responsibility and controlled their children's performance during the difficult version of the task, but only for the most important component, that being room selection. Furthermore, they gave less general verbal instruction during the difficult version of the task than the easy. Mothers of 3-year olds also controlled the main task component (room selection) to a higher extent than mothers of 5-year olds along with using more planning, goal directing, and monitoring verbalisations. Freund argued that her study provided support for Vygotsky's social interaction theory of cognitive development, and suggested that it is important to evaluate both child and adult activity during joint problem-solving tasks to fully characterise the child's cognitive development. This suggestion mirrored that of Hoogsteder, Maier & Elbers (1996), who believed that as both child and adult (parent) bring their own experiences of similar or comparable situations, motivation towards the task, and relationship history to their interaction on the task, it is important to analyse the behaviour, performance and understanding of each dyadic member.

1.2.4. **Parental Support Versus No Parental Support**

1.2.4.1. Effects of working with a parent compared to working alone

Research undertaken by Baker, Sonnenschein & Gilat (1996) focused on the effects of mother-child interaction on a perception task where the children had to match opposite concepts. Children aged 3- and 5- years of age underwent 3 trials, each of which contained a different series of both easy and difficult levels of matching pictures. They were firstly given a pre-test where they all worked alone on the task, which incorporated easy and difficult matching concepts. Half then worked with a parent whilst the other half continued to work alone. Finally, all children again worked on the task alone.

Baker *et al.* found that children who had worked with a parent performed better both during the interactive trial and at post-test, as well as from pre-test to post-test, than those children who had worked alone throughout the study, in terms of matching correct concepts on the difficult version, along with providing correct explanations for their matches. In line with Freund (1990), and Plumert & Nichols-Whitehead (1996), it was found that mothers of the younger children tended to offer more support and instruction than the older children's parents, some even doing so when the younger children appeared to be coping with the task independently. The findings that more support was given on the complex task than the easier one, along with mothers' perceptions of the difficulties of the task (especially mothers of the younger children) affecting the way in which they scaffolded the session, also replicated those by Freund.

Research comparing the results of children who are supported compared to those who are not presents a strong case for the importance of an adult (in many cases, the child's parent), during the children's problem-solving process (Baker *et al.*, 1996; Dimant & Bearison, 1991; Freund, 1990; Murphy & Messer, 2000; Radziszewska & Rogoff, 1988). The majority of studies appear to provide evidence that supported children consistently outperform the unsupported when working subsequently on individual post-tests, with not only their performance improving, but their understanding of the task demands also (Murphy & Messer, 2000; Tolmie, Thomson, Foot, Whelan, Morrison & McLaren, 2005; Radziszewska & Rogoff, 1988). Support is only effective, however, when it involves an adult, as peer interactions tend to have the same subsequent effects as children working independently (Gauvain & Rogoff, 1989; Radziszewska & Rogoff, 1988; Tolmie et. al, 2005).

1.2.4.2. <u>Effects of working with a parent compared to working with a peer or working alone</u>

Gauvain & Rogoff (1989) studied collaborative problem-solving among peers using 5- and 9-year olds. Their first study involved those two age-groups working independently and then with a peer in planning efficient routes through a model grocery store. The second study then examined the planning skills of 5-year old children, working both independently and with a parent or peer. Therefore, both social and independent planning processes were researched. Findings from the first study suggested that children were no more successful when planning with peers than when they planned alone, although they devised and implemented their plans more effectively in pairs than when they worked alone. This was found to be more noticeable in the younger children as they took significantly longer to carry out the task than older children. Older children also planned more effective routes through the grocery store than younger children. In contrast, mother-child dyads tended to concentrate more on defining the task and completing it as efficiently as possible, and so completed it more effectively than the children who worked alone or with a peer. From later tasks conducted alone, however, there were no differences found between children who had previously worked with a parent (or a peer) and those who worked alone.

Gauvain & Rogoff (1989) argued that, in line with Wood & Middleton's (1975) non-contingent parents, this may have been due to the mothers taking over most of the responsibility for the task, thus not giving the child much scope to perform effectively whilst undertaking the task independently later on. In addition, as the mothers were unaware that the children were to undertake the task alone at a later stage, they may not have involved the child in the task as much as they could have done if they had known. This conclusion arose from findings from previous studies (see Ellis & Rogoff, 1982; Radziszewska & Rogoff, 1987), in which parents had been told that the child would be undertaking the task alone at a later date. The parents had involved their children in the task (more so than peers), and when the children undertook the task at a later date alone, they were found to perform more effectively than those that had worked with a peer. In contrast to this however, it has been found that children do learn through observation (Bandura, 1977); and Goncu & Rogoff (1987) observed no significant differences in learning between 5-year old children who actively worked with an adult, and those who were given a lesson with full demonstration of the task.

Gauvain & Rogoff (1989) further suggested that the previous findings, showing that shared responsibility on a task may be more important than just having a partner present, could help to explain other findings that development of cognitive skills do not always arise from working in social interactions. This was further supported by

Conner, Knight & Cross (1997), who found that the less the parent interacted with their child in a scaffolding context (for example, spending more time off-task), the poorer the child performed whilst undertaking the same task independently later on. In contrast, the more scaffolding behaviours used, for example, working within the region of sensitivity, the better the performance in later independent trials.

1.2.4.3. Pre-interaction competence

Conner & Cross (2003) also stated that although previous studies found a positive link between parents' instructional behaviours during parent-child interactions and later independent child success (Conner, Knight and Cross, 1997; Wood & Middleton, 1975), they had not looked at children's pre-interaction competence as a predictor of future success. Although Conner & Cross (2003) found that pre-interaction scores did not, in fact, predict later independent success, Baker, Sonnenschein & Gilat (1996) found a very significant improvement from pre- to post-test in children who had worked with a parent, compared with no improvement in children who worked alone on all three trials.

1.2.5. Assessing the Cognitive Processes that take place in Children during Scaffolding

Although the studies outlined above reported the effectiveness of scaffolding in children's problem-solving, they did not highlight exactly how the scaffolding process works. For example, Wood & Middleton (1975), along with Pratt *et al.* (1988) explained the different levels that the parents scaffolded at during problem-solving sessions, but did not illustrate what was actually happening to the child cognitively in both scaffolded and later independent trials. In other words, they did not investigate whether the child was learning through mechanisms such as observation alone, internalisation of strategies as a result of parental instruction, appropriation of control stemming from their active involvement in the task, and whether the children restructured their own existing knowledge of concepts from this scaffolding experience.

1.2.5.1. Legitimate peripheral participation

Lave & Wenger (1991) believed that people learn skills simply through observation. For example, in their examination of career apprentices (e.g. midwives, tailors and quartermasters), Lave & Wenger found that novices learn their trade through firstly watching the expert working on a task until they have finished the whole procedure, and then, through guidance and support from their master, along with plenty of practice, the apprentice increasingly follows and learns what the master does. Through purely observing the master at work initially, the apprentice gradually acquires the theoretical and practical basis of the task before they begin to put their new skills into practice (Resnick, 1989). Lave & Wenger termed this process "legitimate peripheral participation". The skills learned by apprentices initially are basic, but increase in complexity as they become more comfortable and efficient with the tasks. Learning, in this case, occurs in a smooth, gradual process, with the apprentices progressing from being 'newcomers' to 'old-timers' (Lave & Wenger, 1991, pp. 56) over time.

1.2.5.2. Exploration of strategies

Supported learning does not always progress in such a simple, straightforward way, however. In research by Philips (2003), for example, parental support on tasks (in this case, the Tower of Hanoi) did not only lead to the child becoming more efficient on the task, but also encouraged them to explore different strategies and moves when completing the activity at a later time. This exploration of strategies appeared to be more important to the child than achieving the end goal, and was in contrast to children who worked on the task alone and tried to complete it in as little moves as possible at both time-points. This evidence suggested that children who received parental support would have, at a third time-point, begun to perform faster and more efficiently than those children who did not receive parental assistance, as through their exploration techniques they would have discovered the optimum route in reaching the end goal.

1.2.5.3. Autonomous learning in the presence of the parent

When examining the levels of intervention used by the parents during the scaffolded session outlined above, it was found that they tended to let the child work on their own without much assistance, only prompting them occasionally (Philips, 2003). Even when incorrect moves were made the parents did not correct them but allowed their child to rectify the moves themselves. Thus, as both supported and unsupported children completed the task in an average of ten moves (the optimum number was seven), it could be suggested that they possessed some implicit knowledge of how to do the task.

This suggestion of children being able to initiate novel problem-solving tasks using implicit knowledge and strategy-use was also found by Wood, Bruner & Ross (1976) in their pyramid-building task. Although the younger children (aged 3) in the study dismantled nearly as many constructions as they had assembled, when they did take a correct construction apart, they reassembled those parts in the same way around two-thirds of the time. In contrast, there were very few instances in which they reassembled incorrect constructions. In fact, the 3- and 4-year olds were both very similar in the way that they reassembled correct constructions and left apart those that had been inappropriately constructed. As those actions took place in the absence of adult intervention, it led Wood, Bruner & Ross to suggest that even young children have an idea of how correct constructions look.

Thus, it could be argued that, as the child does appear to hold some implicit knowledge of problem-solving, then parental support may not be paramount to the child's learning after all. This argument would support Karmiloff-Smith's (1992) theory that children develop mainly through endogenous mechanisms, with the environment only acting as a catalyst to enable the individual to choose the appropriate action to take. However, the studies outlined above do maintain that parental support is in fact vital to children's problem-solving whether the child is very young, as in Wood, Bruner & Ross's (1976) study, or slightly older as with Philips's (2003) seven year old participants, where parental help on the activity led to the child gaining understanding of the tasks, as opposed to just trying to get through them and solve them as quickly as possible (Philips, 2003).

In the above study children of one age-group only were examined, and parental support was only given in one task. Rogoff, Ellis & Gardner (1984), however, found discrepancies in the type of support given depending on the child's age and type of task used. Mothers tended to give more directive and instructional support to the younger children in the school-task than in the home-task or the older aged children in either task.

1.3. Representational Redescription (RR) Model

1.3.1. Definition of RR model

Karmiloff-Smith's (1992) theory of Representational Redescription postulated, in complete contrast to Vygotsky (1978), that children's cognitive development is mainly endogenous. Knowledge, to Karmiloff-Smith, is acquired primarily through innate mechanisms as a result of evolutionary processes, but has to become redescribed into a representation that the child can understand explicitly.

Representational Redescription (or the RR model) is "a process by which implicit information *in* the mind subsequently becomes explicit knowledge *to* the mind" (Karmiloff-Smith, 1992, p. 18). To be precise, it is the way in which children's representations develop from being unconscious, that is, having no understanding of what they are doing in regard to problem-solving activities, to being accessible to consciousness, allowing the child to explain their cognitive processes throughout the task. This permits the child to formulate theories about the task and its underlying nature. The notion of representational redescription may explain Karmiloff-Smith's argument and findings that children do not just strive for success on problem-solving tasks, but attempt to understand the logic behind them in terms of how they can be solved.

1.3.2. The RR process

The RR process is thought to occur in four phases or levels, the first of those being the Implicit level (I). At this level, the child is data-driven and has no awareness or understanding of his or her actions, due to information being encoded in procedural form and so not being available to consciousness. They have to rely on proprioceptive feedback mechanisms in order to successfully work through activities.

As the child continues working on this activity, information or representations of the task become redescribed into Level E1, which forms the base on which new theories can be constructed. This level is not as restricted as Level I, where the representations only act in response to external stimuli. By now the innate knowledge, previously only rooted within the child's procedures, is explicitly defined, with the procedures now apparent and represented internally. However, although it is known as the first explicit level, information, or the representations, are still unconscious and the child is still not able to explain his or her actions. By the second explicit level, E2, the representations are now conscious, although the child can still not explain their procedures. Level E2 is thought by Karmiloff-Smith to be the phase in which unconscious spatial representations from Level E1 are recoded into conscious spatial representations, but with those representations still not accessible through verbal means by the child. The final RR phase, Level E3, incorporates both conscious awareness of task procedure, along with the ability to explain those procedures verbally.

1.3.3. Karmiloff-Smith Versus Vygotsky

This model appears to explain children's cognitive development of problem-solving skills as occurring in the opposite direction to Vygotsky's theory of how children use speech to facilitate their problem-solving (Vygotsky, 1978). Vygotsky argued that children shift from using speech explicitly in their initial attempts to acquire help from adults, to using speech as an internal aid to guide themselves through the problem-solving process. Karmiloff-Smith, on the other hand, believed that children's language starts off as being an internal, implicit process, where they may have the knowledge of how to solve the problem, but are unable to verbalise their methods to adults. Eventually, they develop the ability to explicitly verbalise their progression throughout the task.

Whereas Vygotsky based most of his theories on purely conceptual grounds however, Karmiloff-Smith did conduct many experiments to reach her conclusions. Furthermore, Vygotsky had been discussing children shifting from using speech to ask for assistance on the task, to using "egocentric" speech to guide themselves through the activities. Karmiloff-Smith's Representational Redescription model, on the other hand, was concerned with explaining children's development from using implicit, unconscious methods to complete problems, to using explicit, verbal methods to explain their procedures.

1.3.4. **Representational Redescription in relation to Age and Task**

1.3.4.1. Different Ages, Different Representations

The four levels contained within the representational redescription model were observed from balance beam experiments conducted by Karmiloff-Smith & Inhelder (1974). They tested children aged between 4 and 9 years on their ability to balance various wooden blocks placed on a narrow metal base. They found that 4 and 5 year olds found the task very easy as, relying on their proprioceptive feedback mechanisms, they effectively moved the blocks up and down the beam until they could tell from what direction the imbalance came from, and then moved the block back to a state of equilibrium. Although they were successful at the task, those children were found to work within Level I in the RR model. That is, their actions on each trial were unconnected, leading to the children viewing every block as if it were a novel activity with every one being different to the next. Even when they had just accomplished a block balance, they did not then select an identical one to repeat the successful move.

In contrast, 6 and 7 year olds were not as successful at the task, as they positioned each block at its geometric centre and had difficulty balancing blocks that did not have an evenly distributed weight. Even when they found that their methods were unsuccessful they made no effort to change them, instead trying harder to balance the blocks at their geometric centre. Those children were described as being in the process of developing "theories-in-action" (Karmiloff-Smith & Inhelder, 1974, pp. 196). Those theories were concerned with the children's growing implicit knowledge about the fundamental processes and sequences needed to successfully balance the beams. As this knowledge was still implicit and thus unconscious, the child was believed to be working at Level E1 in the RR model.

By age 8, children were able to successfully balance both symmetrically and asymmetrically weighted blocks. However, although they used the same techniques as the youngest children, their representations of their methods were very different. That is, the older children now had explicit knowledge of the properties of balance. This implies that their representations were now present in Level E2 to Level E3 in the RR model.

It can be concluded from Karmiloff-Smith's balance beam studies that development was found to follow a U-shaped curve with performance appearing to become poorer before improving. This pattern was argued to be the result of the children's developing redescription of their representations from Level I to Level E1, where they overgeneralised their prior data-driven knowledge in their quest to try and construct a new, but as yet naive theory of the balance beam. Ultimately, their new theories were modified, allowing them once more to successfully complete the balance activity, but now within a Level E2/E3 format. Those results have also been observed in other studies (see Philips, 2003).

1.3.4.2. <u>Different tasks, different representations</u>

However, as discussed earlier, a child who is at the Implicit Level on Karmiloff-Smith's balance beam task does have the ability to give explicit explanations on other balance tasks (Messer, Butler & Pine, 2003). On the other hand, children who offer explicit explanations on Karmiloff-Smith's beam apparatus do not tend to regress back to implicit explanations on other tasks (Messer, Butler & Pine, 2003).

1.3.5. Karmiloff-Smith Versus Piaget

Karmiloff-Smith drew a distinction between her RR model and that of Piaget's, stating that hers was a phase model as opposed to Piaget's stage paradigm. For example, she argued that whereas Piaget's stage theory involved mapping the crucial cognitive changes that occur as a child ages from birth to 11 years and over, representational redescription takes place frequently and similarly across children (and adults) within 'microdomains'. To be precise, a child could be working within Level I in a certain task, and Level E3 on another activity.

1.3.6. Criticisms of RR Model

Although Karmiloff-Smith's Representational Redescription model has been widely evaluated and accepted (Murphy & Messer, 2000; Peters, Davey, Messer & Smith, 1999; Pine & Messer, 1999; Pine & Messer, 2003), her suggestion that children actually formulate their own theories about their environment have come under much criticism. Gellatly (1997), for example, disagreed with her assertion that children had the desire and ability to formulate their own theories about their world. He particularly refuted her view that children tend to work isolated from social contexts. For example, in the balance beam experiments he argued that children could have had social guidance outside the laboratory, for example, the parent telling the child beforehand to move the block along the beam until they felt it balance (Gellatly, 1997, p. 37). Furthermore, he also stated that adult support may encourage the child to explore their knowledge, which may in turn, lead to redescription. Thus, representational redescription is not specifically an endogenous process, but may be influenced by parental, or other environmental sources. In essence, he contended that although Karmiloff-Smith argued towards endogenous learning and development, she had no proof that children did not develop and learn from exogenous sources. He stated that everything children do and learn is socially mediated, and even the laboratory environment that the children worked in was contrived in a certain manner leading to socially manipulated methods.

1.3.7. Defending the RR Model

In spite of this assertion, Spencer & Karmiloff-Smith (1997) stated that children have to work alone to properly understand their cognitive processes, and are not just content to imitate answers or actions mechanistically. That is, although they may be successful in reciting information given to them by adults (she did acknowledge that children learned through interaction with others), if they do not understand the principles behind the information, in this case, having implicit knowledge about balance, they cannot process it, cannot follow it effectively and thus, would not have been able to successfully complete the task. In terms of the Representational Redescription model, they have to redescribe their implicit procedural representations into a more explicit format. The child does not have to already hold experience with that particular task, as long as they are familiar with other forms of gravity and balance, but they do have to differentiate between the source and content of their knowledge, and the ways in which that knowledge becomes embedded into their minds (Spencer & Karmiloff-Smith, 1997).

Furthermore, Karmiloff-Smith (1992) and Spencer & Karmiloff-Smith (1997) stated that her balance experiment was valid, as it had been constructed, not from previous studies conducted in a laboratory, but from the observation of a child in his natural environment spontaneously trying to balance an unevenly weighted knife on a support.

1.3.8. Is Cognitive Development the result of Innate or Environmental Factors?

Karmiloff-Smith's reluctance to accept the idea of social interaction and tuition in facilitating children's cognitive development has been evaluated extensively by David Messer and Karen Pine (Murphy & Messer, 2000; Peters, Davey, Messer & Smith, 1999; Pine & Messer, 1998; Pine & Messer, 2000; Pine, Messer & Godfrey, 1999; Pine, Messer & St. John, 2002).

Pine, Messer & Godfrey (1999), for example, challenged Karmiloff-Smith's suggestion that children at Level E1 in the RR model do not respond to instruction on tasks, instead relying on their internal representations to assist them in their development. They tested Karmiloff-Smith & Inhelder's (1974) findings that children aged 6 and 7 years cannot balance unevenly weighted blocks, as they believe that all blocks should balance at their geometric centre. They found that adult interaction and tuition did, in fact, facilitate children's performance on this task. However, in line with Karmiloff-Smith's suggestions and findings, children had not maintained their new skills at post-test one week later.

In spite of the important implications from this research, there is one crucial factor that has been missing in previous studies along these lines, and that is the role of language with respect to how it impacts on performance and cognition. Gellatly (1997), for instance, pointed to the role that adult presence might have in structuring children's activity productively, in much the way that Lave & Wenger (1991) characterised Legitimate Peripheral Participation. However, the possibility that adult speech directed at control of children's activity might actually serve as a key mechanism for redescription has not been examined, despite the centrality of acquisition of sign operations for Vygotsky, and the lack of clear accounts of the process of redescription within the RR model. Put simply, if redescription involves making representations more explicit, eventually leading to encoding in language, it is hard to see why the process of guiding and explaining action engaged in by tutors should be expected to have no impact. At the very least, it invites empirical testing.

1.4. Present Research

1.4.1. <u>General outline of studies</u>

The studies that follow look at the effects of adult support on seven-year old children's performance and understanding on a problem-solving task, with particular focus on the variation with regards to children's initial level of understanding. The adults in the first study are the children's parents, whereas studies 2 and 3 comprise an adult who is unknown to the children. Whereas previous studies have looked only at the outcome of children's subsequent actions after either working with their parent or gaining feedback from the researcher (Murphy & Messer, 2000), this research also explores the differences in the way the adult interacts and works with the child depending on whether they are the parent or unknown adult and the impact this has on the child's actions and understanding. The type of support given is scrutinised carefully, and involves analyses of the language used both by the adult in terms of prompts and explanations, and the child in terms of their post-task explanations (studies 1, 2, and 3) and on-task dialogue with their peer (study 3). As with many previous studies, the impact of the adult is further analysed by studying children who do not receive support on the task. Finally, the effects of adult support on children who are of differing levels of understanding about balance properties (i.e. weight and distance), are also examined. One main task is used throughout the research, and this is a Balance Scale task based on that used by Siegler (1976).

1.4.2. Balance Scale task

The Balance Scale task was initially devised by Inhelder and Piaget (1958) and took the form of a "see-saw balance" (pp.164), consisting of a crossbar at the top of and perpendicular to a vertical stand. Weights (or baskets containing dolls as weights) were hung at various uneven points on either side of the crossbar, and the child's task was to move the weights along the crossbar to make the scale balance. This task was reviewed and modified in the mid 1970s and now took the shape of a long base containing eight pegs placed at right angles to the base, and a fulcrum in the centre separating the pegs into four equally spaced on either side of the scale (Siegler, 1976). Metal disks were used as weights and placed on various pegs on either side of the fulcrum by the experimenter. Children were asked, from observing different configurations of weights on both sides of the scale, to predict what would happen to the scale if the fulcrum were removed. That is, they were asked whether the scale would fall to the left, the right, or would stay level. However, children were now not permitted to move the weights (and on many occasions only worked from pictures of configurations), and were not required to explain their thoughts or predictions about why they chose their answers.

Both Inhelder and Piaget (1958) and Siegler (1976) discovered that, depending on their age, children use very similar strategies when trying to work out how weights will balance on a scale. Both researchers developed a series of stages (Inhelder and Piaget) or Rules (Siegler) to explain the processes that children work through in balance problems. However, as described earlier, whereas Piaget believed that his stages applied to children of approximately the same age in any task, Siegler's age-dependent rules were specifically found in children only in his Balance Scale task.

1.4.2.1 Stages in Balance Scale Task (Inhelder and Piaget, 1958)

Inhelder and Piaget identified three main stages that children progress through, with Stages 1 and 2 each split into two sub-stages. Stage 1 is evident, as a whole, in children aged between three and eight years, with Sub-Stage 1-A (Failure to Distinguish Between the Subject's Action and the External Process), apparent in children between the ages of three and five years. At this stage, children do not really understand the notion of how a Balance Scale works, and they have no conceptual knowledge of either weight or distance. In one example, a four-year old boy, when presented with a scale which did not balance, believed that if he raised the arms to a horizontal position and let go, it would stay in that position. Even when he placed two weights on one side and none on the other, he expected the scale to be in a state of equilibrium (Inhelder & Piaget, 1958).

At around five years of age, children progress to Sub-Stage 1-B (Integration of Intuitions in the Direction of the Compensation of Weights), where they now have intuitive knowledge that weight is needed on both sides to achieve equilibrium. However, they are still unsure how to achieve equilibrium methodically.

Children normally progress to Stage 2-A (Concrete Operations Performed on Weight and Distance but Without Systematic Coordination Between Them) at around seven years of age. At this stage, children are comfortable with equalising weight on both sides of the scale, and having symmetry on the scale, but they still cannot integrate both weight and distance together. They may discover that a small weight at a further distance from the centre, and a large weight at a closer distance to the centre balances, but only through trial-and-error methods. This finding actually supported Piaget's initial theory that it is possible for a child to learn without having any understanding of the actual processes of the task (Wood, 1998). In other words, the children have now learned how to make a scale balance by moving weights closer to or further away from the centre, but have no conceptual understanding of how this occurs. This stage also supports Karmiloff-Smith & Inhelder (1974), who stated that when children reach seven years of age, they consider weight to be a significant property in problems involving balance, but not until later do they differentiate between weight as an absolute property, and weight as a force.

By the time children reach Sub-Stage 2-B (Inverse Correspondence of Weights and Distances), at around ten years of age, they can coordinate unequal weight with unequal distance, but not through proper 'weight multiplied by distance' calculations. Instead, qualitative correspondence is used where children are just on the verge of discovering that a weight that is too heavy should be moved further towards the centre of the scale.

By the final Stage 3 (Discovery and Explanation of the Law), children – aged around twelve years - now fully understand the relationship between weight and distance, and can use it, and explain their methods appropriately. In other words, they know that they have to calculate, "weight-left with weight-right" and "distance-left with distance-right" (Boom *et al.*, 2001, pp. 718).

Critics of Piaget have argued that his theory and findings were seriously flawed due to the language used to the child whilst instructing them to partake in a certain task. For example, the way in which questions were phrased (e.g. "why does that weight go there?") may have been difficult for the child to understand. Thus, the child may have been able to answer the question if it had been asked in a simpler fashion, using a different structure and linguistic format. So, although they may have known the answer to the question, they could not respond, as they did not understand what the researcher was actually saying (Wood, 1998).

1.4.2.2 Rule Assessment Approach (Siegler, 1976)

Siegler developed four rules to account for the stages that children follow when solving balance problems. As those terms remain static, they are referred to as rules as opposed to strategies.

Rule 1 is evident in children aged around five years. At this stage, children only compare the number of weights on either side of the scale, and predict that the side with more weight will fall. This implies that they have not yet learned that distance is as important a concept as weight in balance problems.

By nine years of age, children have progressed to Rule 2, and can now compare the distances at which the weights sit, but only when the weight is equal on both arms on either side of the scale. Thus, they predict that the side with the weight nearer the end of the scale will go down. However, although they have knowledge of weight and distance, they still do not know how to link the two concepts together. This differs to Inhelder and Piaget's findings in the sense that children had reached this stage by seven years of age, implying that Siegler's Rule 3 (below) does not have any proper empirical basis.

By rule 3, children now recognise that both distance and weight are important factors in balance. However, they do not know how to combine them and so "muddle through" and guess the answer. Again, nine year olds were found to commonly use this rule.

When children finally reach Rule 4, they have learned to use the torque rule, which involves multiplying the number of weights on each side by their distance from the fulcrum, and predicting that the scale will fall to the side with the largest product (Siegler, 1976).

There are a number of similarities between Siegler's rules and those of Inhelder and Piaget, although the latter researchers explain their rules in a more in-depth and detailed manner. For example, Siegler's Rule 3 states only that participants do not have any conceptual knowledge of unequal weight and distance. As children are not required to give verbal explanations for their predictions, this rule does not even question whether the child may have implicit or explicit knowledge of the correct answer. In other words, if they are correct with their answers, it is interpreted solely as a guess, with no scope for attempting to discover whether the child used specific strategies or not.

Furthermore, Siegler reported that children did not often reach rule 4. In fact, even adolescents were unable to fully integrate weight and distance. That is, they could not accurately predict the answer to problems in which one side of a scale had more weight and the other had more distance. Thus, although he spoke of children always using one of four rules, they really only followed one of three, as even at seventeen years of age, they had problems articulating solutions at Rule 4.

This differed from Inhelder and Piaget's (1958) findings in which all "formal-operational" children between the ages of twelve and fourteen years were able to form a relationship between weight and distance (Stage 3). However, when Siegler later used a Piagetian type balance scale in the form of a "pan balance" in which pans of different weights were hung from hooks at various distances from a central fulcrum, he found that the same adolescents who failed at his standard balance task, excelled at the latter (Siegler, 1976).

At first glance, it appears that this discovery could throw Siegler's whole study into question, as children failing in his balance task were succeeding in another type of balance design. However, as his study also differed from Inhelder and Piaget's in other ways, doubts should be cast on whether the two studies can be compared at all. For example, whereas participants in Siegler's study were asked only to predict what side a Balance Scale would fall from observing pictures or models of weights on both sides, Inhelder and Piaget allowed their children to experiment with the weights on the scale, manipulating where they were placed on the crossbar in the children's quest to make it balance. More importantly, whereas Inhelder and Piaget encouraged their participants to experiment with the scale and then explain their methods and thoughts about why it balanced or not, children in Siegler's study were not. Boom, Hoijtink, and Kunnen (2001) stated that Siegler actually "ignored verbal justifications" by his participants (pp. 719), and did not give any feedback to their answers whether wrong or otherwise.

Those, along with other factors, have caused Siegler's Rule Assessment Approach to be widely criticised (see Boom *et al.*, 2001; Halford *et al.*, 2002; Jansen & van der Maas, 2002; Normandeau, Larivee, Roulin & Longeot, 1989; Surber & Gzesh, 1984; Tudge, 1992; and Turner & Thomas, 2002). Tudge (1992), for example, found during his pilot study, that Siegler's rules were not appropriate in explaining the varied array of strategies used by the children, and a higher number of more detailed rules were needed. Thus, he developed seven rules, the first of which (Rule 0), was very much like Inhelder and Piaget's Stage 1-A, as here, the child had no understanding of the nature of the balance scale, and so had no idea of what would happen when one side had more weights. However, in contrast to Inhelder and Piaget, the children in Tudge's study were dropped if they appeared to be at this stage. Tudge also found that children were unable to work within Rule 6, which equated with Siegler's Rule 4, even when they collaborated with a more able peer (Tudge, 1992).

As with Inhelder and Piaget (1958), and Tudge (1992), but in contrast to Siegler (1976), Karmiloff-Smith and Inhelder (1974) stated that they were not purely interested in whether the child succeeded or failed in their task, but the implicit processes they used in conducting the tasks, that is, their "theories-in-action". They found that among the children who were successful at this task, there were marked differences in their ability to explain their methods. Whereas some children were successful in balancing the beams, it was through simple trial-and-error processes, with no conceptual understanding of what makes items balance. Conversely, others who were successful also had full explicit understanding of the factors affecting balance, and could verbalise their methods. In other words, children were found to be working at different levels in Karmiloff-Smith's (1992) Representational Redescription Model.

The present research combined elements of the approaches used by Piaget (the active manipulation of weights), Siegler (Balance Scale format) and Tudge (categorisation of strategies). This research is the first, using Siegler's scale, to allow the children to actually place weights on the opposite side of the scale to that on which weights already lie. Thus, the purpose of the following studies was not to ask children to predict what would happen to the scale, but to observe how they formulated strategies to try to make the scale balance, along with being encouraged to explain their methods. The aim was to provide a detailed mapping of performance and degree of explicit understanding, and the changing relationships of those with each other along with the verbal guidance of adults over time.

Thus, the key issues for investigation were, firstly, whether it was possible to characterise the effects of adult scaffolding on Balance Scale performance in terms of the kinds of representational change specified by Karmiloff-Smith's (1992) RR model. If so, the question arose regarding whether those effects would be consistent with the kinds of processes highlighted by Vygotsky and more contemporary theorists, in terms of the appropriation of language/sign operations and shift of control. With regards to children's initial level of understanding, the research aimed to investigate the impact on these processes outlined above in terms of both the nature (i.e. degree of contingency) and the effect of tutors' input. Finally, the impact, if any, of altering the timing and context of tutor support, was examined. Specific hypotheses for investigation will be articulated in the outline of each individual study.

In essence then, Study 1 focused on the impact that parental support had on children's performance and subsequent understanding of the Balance Scale task, compared to those who did not receive support. It explored the notion that children's progression on the task and transition to a higher representational level would vary primarily as a direct function of their parents' explicit procedural actions and explanations. Finally, the impact of support depending on children's initial representational level prior to undertaking the task was explored.

Study 2 focused on investigating how support on the Balance Scale task would impact on children's actions and understanding depending on two main factors, those being their understanding level prior to the study, and time-frame of support. Thus, children were split into those who had little or no understanding (I-level representations), and those who had at least some prior understanding (E1/2 level representations) of the weight/distance properties of balance; and support was either provided at the first time-point only, or throughout each of the three sessions. Contrary to Study 1, support here was administered by an adult previously unknown to the children who was trained in contingent scaffolding techniques.

Finally, Study 3 examined the effects of adult input on children working together in pairs. Children were put together into dyads depending on whether they were both of lower understanding (Low-Low); higher understanding (High-High), or one each of lower and higher understanding (Mixed), with regard to the weight/distance properties of balance. The study explored how dialogue used by the adult at Time 1 would impact on both the dyads' concurrent and subsequent performance and understanding of the task, with this being compared to those dyads who did not receive adult support. The dialogue used by each member of the dyad during each session was also analysed to find whether appropriation was taking place either from the adult (primary appropriation) or between dyad members (secondary appropriation), where appropriate.

*Chapter 2**

STUDY 1

2.1. Introduction

Evidence confirming the theories that parental assistance on a task does not only increase the child's ability to complete it, but also facilitates their development of knowledge and understanding of it, were highlighted in the previous chapter. However, the majority of those studies tended to focus on outcomes rather than what was happening *during* the problem-solving process.

Rogoff's (1990) account of guided participation focuses more on task-related intersubjectivity than precisely definable regulatory sequences. The role of language is more central here, partly in terms of its role in negotiating a "meeting of minds" (Garton and Pratt, 2001) about the nature of the task and how to proceed. In addition, though, as adult and child work through a task together, it is claimed that their "dialogic exchange" (Fernyhough, 1996) becomes internalised by the child and facilitates his or her ability to employ similar strategies on subsequent occasions.

There are in fact few empirical studies that focus systematically on the impact of external assistance on children's learning in terms of the relationship between the content of linguistic exchange and children's progress. Indeed, much research has tended to focus on whether external assistance leads to positive outcomes, and the factors that might affect those outcomes (e.g. Baker, Sonnenschein and Gilat, 1996; Conner, Knight and Cross, 1997; Kermani and Brenner, 200l; McNaughton and Leyland, 1990), rather than on the process of learning or the mechanisms involved (cf. Chen and Siegler, 2000). Where process-oriented research has been conducted, it is characteristically qualitative in nature, and focused on specific exchanges rather than attempting to extract more general principles across a range of cases (e.g. Gonzalez, 1996). In addition, there are almost no studies that examine the impact of external assistance over time, despite the fact that most

* This study has been published in the Infant and Child Development Journal: Philips, S., & Tolmie, A. (2007). Children's performance on and understanding of the Balance Scale problem: The effects of parental support. *Infant and Child Development, 16*, 95-117

theorising characterises this as the initial phase of a trajectory of change involving subsequent cognitive restructuring.

The need to refocus research into scaffolding onto the role of linguistic mediation and the trajectory of change is highlighted by attempts to integrate it with Karmiloff-Smith's (1992) more general representational redescription (RR) model of the cognitive changes that occur as expertise in a given area of functioning increases (see e.g. Murphy and Messer, 2000). This model proposes a four-level sequence of development, in which initially context-bound procedural knowledge (implicit or I level representations) is transformed into increasingly explicit and more coordinated or general formulations (E level representations), making it available in a growing range of other contexts, first to the self (E1 and E2 levels) and then to others via encoding in language (E3 level). The appeal of this model as a framework for thinking about scaffolding is that it makes a deliberate connection between cognitive change and the process of rendering the form of actions explicit and, ultimately, subject to full linguistic mediation. In doing so, it carries the implication that scaffolding may be an important means by which representational redescription can be achieved (see Tolmie, Thomson, Foot, Whelan, Morrison and McLaren, 2005; Tomasello, 1999).

Not only does this framework move the role of linguistic mediation in scaffolding back to centre-stage, it also points at the forms that are likely to be important. At a root level, successful scaffolding should shape performance on an activity into an effective strategy that can be recreated on different occasions. In terms of representational redescription, this ought to be assisted by input that not only helps *operationalise* that strategy (i.e. helps the child enact a sequence of actions which the tutor knows to be expedient), but which, as part of this, provides linguistic markers or tags for its key features so that these can be recaptured subsequently (cf. E1/E2 representations, which have similar properties, according to Karmiloff-Smith, 1992). For instance, in the context of scaffolding the solution of a jigsaw puzzle, the tutor might prompt the child to "*start* by looking for the *edge pieces*, and try to *fit those together*" (key features italicised). Beyond this, what also ought to be important is provision of more abstract or higher-level *explanations* of underlying principles, from which strategies might be recreated across a wider range of circumstances in more flexible fashion. For example, in the jigsaw puzzle context, the tutor might explain that "the basic idea is to collect pieces that have something in common, and work on fitting these together, building up the puzzle in sections". Such explanations ought to directly promote E3 level representations, since they provide a verbal formulation that subsumes a range of more specific, context-dependent strategies.

There has been little detailed research on these possibilities so far. Evidence relating to a role for linguistic mediation in promoting improved performance has focused on explicit operationalisations rather than more abstract explanations, and the distinction between the two in terms of their range of applicability has rarely been clearly drawn. The research that has been conducted is generally supportive, however. Pine, Messer and Godfrey (1999), for example, found that children who saw demonstrations and heard explanations of a number of specific balance beam solutions (i.e. explicit operationalisations) progressed more than those who worked independently, although the latter children had caught up at a delayed post-test. This input apparently served at least to accelerate progress, then, suggesting that such operationalisations do facilitate learning. Similarly, Murphy and Messer (2000), found scaffolding that focused primarily on contingent application of object-specific strategies was more effective in promoting transfer of understanding of balance beam solutions than unresourced group discussion or working alone. Peters, Davey, Messer and Smith (1999) found comparable effects for structured tuition focused on explicit operationalisations in the form of statements about strategies to be applied to different types of balance beam.

Evidence on the impact of more abstract explanations is limited. However, work by Tolmie *et al.* (2005), in the context of training children's pedestrian skills, found clear evidence that such higher-level explanations were central to progress amongst 5- to 8-year olds working one-to-one with an adult. In the course of assisting children through computer simulation exercises designed to sensitise them to features critical to road-crossing decisions, adults' prompts were initially accompanied by general explanations of the significance of features to which they had drawn attention (e.g. "if he can't see what's coming, it's not safe"). Over the course of four sessions, however, children began to provide these explanations themselves, and the extent to which they did so directly predicted pre- to post-training improvements in performance, both on simulations and at the roadside. The generalised nature of the gains, and their association with explicit higher-level explanations, led Tolmie *et al.* to conclude that the appropriation by children of adults' explanations had effected redescription of their representations of the road-crossing task to E3 level. A second study found less evidence of this effect, and signs that explicit operationalisations (i.e. scaffolding of context-specific strategies; cf. Murphy and Messer, 2000) were more predictive of progress. The children in this study had lower initial ability than those in the first, though. It was thus inferred that higher-level explanations might only be facilitative where children already possessed reasonably well-developed representations, at E1/E2 level, to provide a basis for more abstract redescription.

Whilst suggestive, however, the limited extent and disparate focus of past research makes firm conclusions about the impact of linguistic mediation of either type hard to draw. The present research was designed to address the need to track representational change in detail in relation to the provision during scaffolding of both explicit operationalisations (explicit guidance through an effective strategy for solving a specific problem) and higher-level explanations of general principles. Rather than imposing the occurrence of different forms of input within separate conditions, they were left free to vary within a semi-naturalistic setting (cf. Wood and Middleton, 1975; Tolmie *et al.*, 2005). Children aged 6 to 8 years were asked to complete a series of Balance Scale problems plus the Tower of Hanoi task at three successive time-points, a few days apart. Approximately 30% of the sample received assistance on the Balance Scale at Time 1, from a parent who had received prior instruction on the principles involved, but no other guidance as to their input. The remaining children provided two forms of control condition, assistance on the Tower of Hanoi task (30% of the sample), and assistance on neither task (40%). This permitted not only the gains associated with scaffolding to be assessed, but also differences in the trajectory of change with repeated experience. The Balance Scale task was based on that devised by Siegler (1976), but in the present study children were allowed to manipulate weights on a series of pegs to achieve balance, rather than simply predicting outcomes. This task was preferred to the Balance Beam, because it permitted more precise specification of weight/distance relationships.

Data analysis centred on the impact of parents' input on problem-to-problem change in children's attempts to achieve balance and in the explanations offered for solutions over successive time-points. Attention was directed in particular at how far children's performance varied depending on whether parental input provided a) scaffolding of the weight x distance computations necessary to determine balanced configurations for specific problems (explicit operationalisations), and b) statements of the torque rule specifying that balance depends in general on weight x distance products on either side of the fulcrum being equal (higher-level explanations).

It was anticipated that children who received assistance on the Balance Scale task would outperform (i.e. require fewer attempts to arrive at solutions) and display greater understanding of the task than children in the control conditions, at least initially (cf. Pine *et al.*, 1999, on the acceleration of gains). It was also thought likely that effects on understanding would be lagged, as a result of the time taken for appropriation to occur. Whilst it was anticipated that parental input would not be uniform, and would be contingent to some extent on children's actual performance (cf. Wood, 1986), more precise predictions with regard to the scale and effects of such variation were harder to make. The degree of benefit evidenced by children was expected to vary, though, as a direct function of parents' provision of explicit operationalisations and higher-level explanations. It was predicted in particular that gains in explicit representation, as measured by children's own explanations, would be directly related to parental provision of both types of scaffolding. However, in line with Tolmie *et al.* (2005), it was expected that higher-level explanations would only promote gains among those who evidenced some explicit grasp of problem solutions, equivalent to E1/E2 level, at the outset. For these children alone, it was predicted that such explanations would result in E3 level representations which would be applied consistently across different problems.

2.2 Method

2.2.1. <u>Design</u>

The study employed a two-way mixed design, with a repeated-measures factor of time-point of testing (three sessions over the course of a week, at each of which children completed both Balance Scale and Tower of Hanoi tasks), and a between-subjects factor of type of assistance provided by parents (Balance Scale only, Tower of Hanoi only, and none). The Balance Scale task required children to solve four problems at each time-point (the content of these being modified on successive occasions), by setting up and testing possible solutions for a given problem until balance was achieved. Assistance was provided only at the first time-point, with all children working alone at the second and third time-points. The sequence in which children carried out the Balance Scale and Tower of Hanoi tasks at each time-point was systematically varied to control for order effects. Data analysis focused on the impact of parental input on Balance Scale performance, in terms of 1) the number of attempts children made until success on a problem was achieved; 2) the proportion of attempts where performance was close to being accurate; and 3) the explanation they offered for successful attempts. Parental input was examined with regard to a) provision of explanations of the factors at work, especially via statements of the torque rule, and b) the nature of the assistance they provided for determining problem solutions, particularly in terms of making weight x distance computations.

2.2.2. Participants

Participants were 144 children from 10 primary schools within East Ayrshire, Scotland (see Appendix 1 for local education authority permission) . There were 65 boys and 79 girls, aged between 6 years, 11 months and 8 years, 4 months, with a mean age of 7 years, 8 months. Of these, 42 children, 17 boys and 25 girls, were assisted on the Balance Scale task; 40 children, 20 boys and 20 girls, were assisted on the Tower of Hanoi; and 62 children, 28 boys and 34 girls, received no assistance. Children whose parents also volunteered to take part in the study were randomly assigned within school to one or other of the first two conditions; the remaining children were assigned to the no assistance condition. All children had English as their main or only language, and participated with full written consent (see Appendix 2). The participating parents comprised 71 mothers and 11 fathers, of whom 34 mothers and 8 fathers provided assistance on the Balance Scale task.

2.2.3. Materials

The Balance Scale apparatus can be seen in Figure 1. It comprised a wooden base with two wooden blocks situated in the centre, and a beam held between the two blocks via a screw that provided a fulcrum. Eight circular pegs were positioned along the beam, with four situated at equally spaced intervals on either side of the fulcrum separated by a central space. A wooden rest fitted into the centre of the scale on either side of the wooden blocks, to prevent the beam moving when weights were placed on it. The weights were eight hexagonal-shaped, metal nuts with a circular hole in the middle. The beam was 45cm in length. Materials for the Tower of Hanoi control task consisted of a similar wooden frame for the standard three-peg/three-disk version of the task, and this task can be seen in Figure 2. A video camera was used to record children's performance.

Figure 1. Balance Scale apparatus

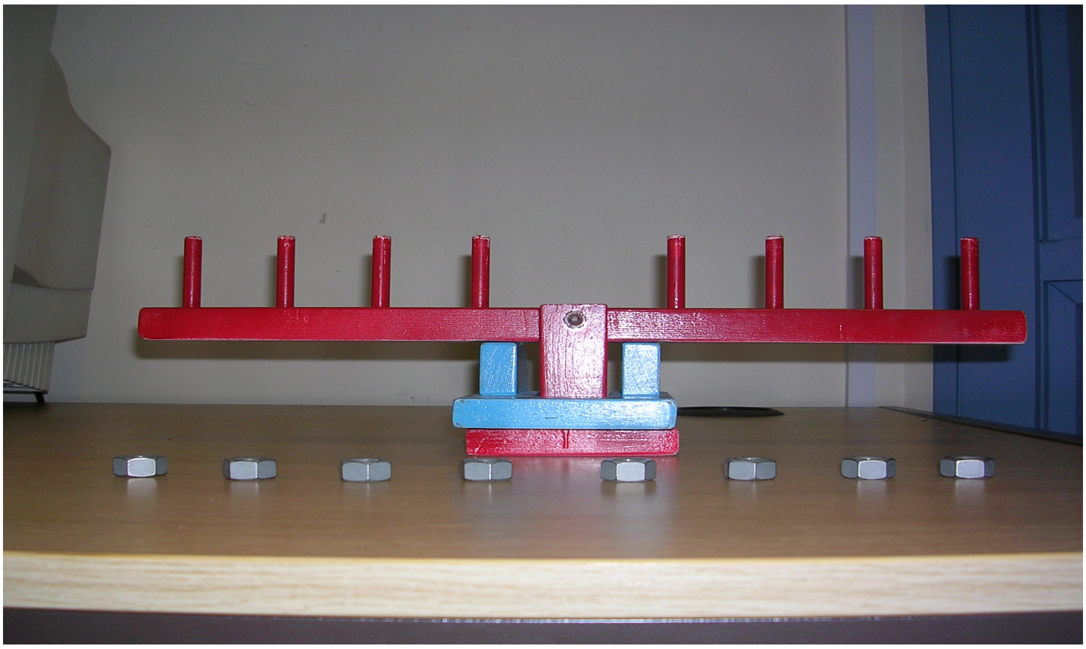
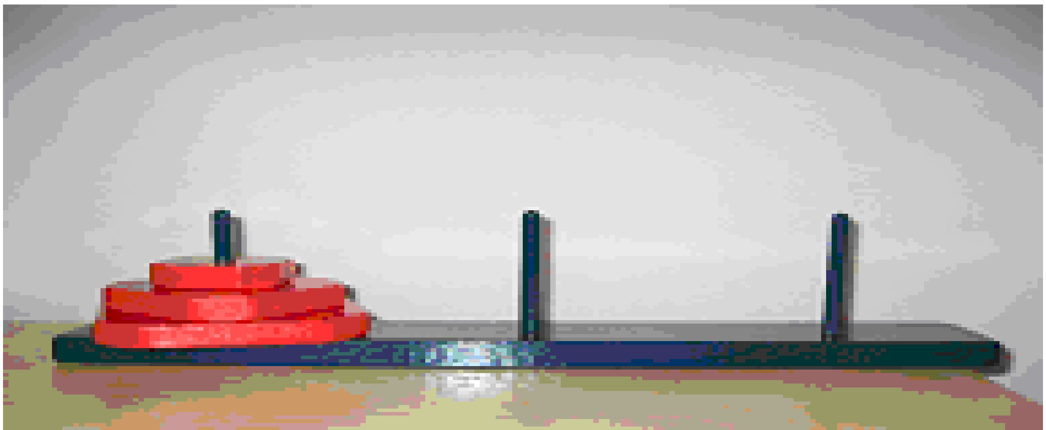


Figure 2. Tower of Hanoi apparatus



2.2.4. <u>Procedure</u>

All testing took place individually in a separate room within the child's school. Parents providing assistance on the Balance Scale were shown the apparatus immediately prior to the first time-point of testing, and instructed that the goal of the task was to make the beam balance when nuts were placed on it. They were told that the researcher would put an arrangement of nuts on "her side" of the scale, and the child was then to make it balance solely by arranging nuts on "their side", but without simply reproducing the researcher's arrangement, as this would make the task too easy. The parents were then given a brief explanation of the torque rule, whereby distance multiplied by weight had to be the same on both sides of the scale for balance to be achieved. Possible correct solutions for the first and second of the Time 1 problems were given as an examples. Parents were informed that their child would be asked to solve four problems of this kind in total, and that they could help their child in any way they considered appropriate.

Table 1. Configurations of nuts for Balance Scale problems at Times 1, 2 and 3.

Problem	Time 1	Time 2	Time 3
1	Two nuts on peg 1*	Two nuts on peg 1	Two nuts on peg 1
2	One nut on peg 2 One nut on peg 4	One nut on peg 1 One nut on peg 3	One nut on peg 1 One nut on peg 3
3	Four nuts on peg 2	Four nuts on peg 2	Four nuts on peg 2
4	One nut on peg 1 Two nuts on peg 3	One nut on peg 1 Two nuts on peg 3	Three nuts on peg 2 One nut on peg 4

*Peg 1 is nearest the middle of the scale, and peg 4 is at the end of the scale.

The four problems used at Time 1 are shown in Table 1. When the parent understood their role, the researcher brought their child to the room (half of the children having already completed the Tower of Hanoi task independently immediately beforehand).

The child was introduced to the task and what they had to do was explained to them. When the child understood, the camera was switched on and the researcher set up the arrangement of nuts for the first problem. The child proceeded by arranging nuts on their side of the scale in a configuration they thought appropriate, and then removing the rest to see if that solution worked. Parents assisted decision-making as they saw fit, but the process typically involved some degree of negotiation between child and parent, with the former making suggestions and the latter indicating potential modifications, until agreement on a solution to try out was arrived at. Each such effort was counted as a completed attempt, and if the scale did not balance the rest was inserted back into the equipment and the child tried again. Attempts continued until a correct solution was achieved. The only time the researcher intervened was to remind the child about the task rules if they made an illegal attempt (i.e. moving the nuts on the researcher's side of the scale, or reproducing the same arrangement). Immediately after the children had achieved a correct solution for a problem, they were asked, "Can you tell me how you made it (the scale) balance"? Once they had responded, the arrangement of nuts for the next problem was set up. The researcher provided no feedback on solutions or explanations at any time.

Parents who assisted on the Tower of Hanoi task were similarly shown that apparatus prior to assisting their child, and informed of the goal of the task and the rules regarding the movement of disks. As before, when the parent was happy with their role in the task, it was introduced to their child and the goal and rules explained. In view of the number of moves involved, children completed only one trial per session, at the end of which they were asked to explain how they had completed the task. On completion of assisted tasks, the parent was thanked and shown out. If this was the child's first task they were then introduced to the second, and completed that before returning to their class. Children who received no parental assistance also completed both tasks as part of a single session. In terms of administration, unassisted tasks were completed in identical fashion to assisted tasks.

A break of two days was given prior to the second time-point, and then again before Time 3. At Times 2 and 3, all children were taken out of class to work on the tasks alone, which were administered as before. As Table 1 shows, one new problem was introduced at Time 2 for the Balance Scale, and a further one was brought in at Time

3. As at Time 1, the children worked until they completed both tasks before returning to class.

2.2.3.1. Scoring

The videotapes of each session were transcribed to provide a written record of children's attempts, together with their explanations, and, where pertinent, parent-child dialogue. All coding was based on these transcripts.

Coding of attempts. Each attempt children made to solve a given Balance Scale problem was coded as being one of seven types, increasing in level of sophistication. These were based on the coding scheme used in Siegler's (1976) study. The seven levels are shown in Table 2.

Table 2. Levels of scoring for children's attempts on the Balance Scale task.

Level	Description
1	Illegal moves I: manipulating the weights on the researcher's side
2	Illegal moves II: reproducing the researcher's arrangement of nuts
3	Different number and/or different arrangement of weights on different pegs to those on the researcher's side, but with unit x distance values being substantially inaccurate (<.67 or >1.5 times that of the researcher's configuration), indicating a trial-and-error attempt, and no conceptual understanding of the factors affecting balance
4	The same number and same arrangement of weights on different pegs to that of the researcher, implying that although the pattern of weights matter to the child, distance does not
5	A different number and/or different arrangement of weights on the same pegs to that of the researcher, indicating that distance matters to the child whereas the pattern of weights does not.
6	Different number and/or different arrangement of weights on different pegs to that of the researcher, with unit x distance values close to that on the researcher's side (=>.67 or =<1.5 times the researcher's arrangement), indicating an awareness that both weight and distance matter
7	Successful balance

Since children made attempts at each problem until they were successful, they had to display a response at the highest level eventually. On the basis of this coding, two dependent measures were derived for performance on each individual problem across the three time-points: 1) *the number of attempts made*; and 2) *the proportion of attempts at either level 6 or 7*, in other words, the extent to which attempts indicated an appreciation of the need to manipulate both weight and distance, albeit without the child necessarily being able to determine their exact relationship. Since a perfect performance would be a single attempt at level 7, fewer attempts and a higher proportion at level 6/7 were indicative of better performance.

Coding of explanations. Children's explanations after they had successfully solved each problem were also coded individually for level, according to the criteria below:

0 – no explanation was given (e.g. "don't know")

1 – *weight explanations*: weight/number is important (e.g. "I've got as many on my side as you have"; "it was too heavy before, but now it's the same")

2 – *distance explanations*: distance/position is important (e.g. "I moved it in to the middle and it worked"; "mine are either side of the peg yours are on")

3 – *weight/distance explanations*: weight/number and distance/position are both important, but the relationship between the two is unclear (e.g. "if I put one there it would be too heavy, so I put it there instead and it balanced"; "when there were two and they were on top of each other it was too much, so I put them one apart")

4 – *torque rule explanations*: weight/number and distance/position both matter, and the need for equivalent unit x distance values on both sides of the scale is explicit (e.g. "two times one for that peg is the same as one on peg 2 for my side"; "if you count the numbers for each peg and add it up, it's the same on both sides").

It should be noted that scoring was based on *reference* to the constructs defined at each level (i.e. their explicit salience), rather than their correct usage. In line with the system used for coding attempts, explanations that focused solely on weight were treated as being less advanced than those that referred to distance. Both Inhelder and Piaget (1958) and Siegler (1976) report that children characteristically perceive weight as salient to balance before they recognise the relevance of distance.

Coding of parental input. Parental interventions were coded according to a) the assistance they provided in children's efforts to formulate attempts at problem solutions; and b) the explicit references to underlying factors they provided as part of this assistance. Interventions did not necessarily take the form of the explicit operationalisations or higher-level explanations that were the subject of theoretical interest. These were therefore differentiated from other types of assistance and explanation, so that the relative impact of each on children's performance could be ascertained. Instances of parental explanations were coded at Levels 1 (weight), 2 (distance), 3 (weight/distance) or 4 (torque rule) of the system outlined above for children's explanations, with torque rule statements being defined as the higher-level explanations that were of focal interest. Elements of procedural assistance were coded as being one of four main types:

Direct control – interventions that directed the child to carry out a specific action without any explicit indication of the strategy being used ("put those two on peg 4", "take that off and put one on peg 2"), or else involved the parent carrying out such actions themselves

Non-specific prompts – statements reminding the child of the general rules (e.g. "you can't do the same on your side as on that") or otherwise blocking a move without specifying an alternative ("no, don't do that"), prompting an unspecified or general course of action ("make a start then", "try taking one of them off", "how about putting one nearer the middle"), or focused on broad comparison ("she's got three and you've got four")

Nut/peg prompts – statements drawing attention to the peg arrangement and/or the position of nuts, but without indication of how this information might be used to solve the problem ("if we count out from the middle, this is peg 1, 2, 3, 4", "how many nuts are on peg 2?", "there's two on her peg 3 and how many on yours?")

Weight x distance prompts – statements focused on nut x peg computations and comparisons involving these ("if there are four on peg 2, what does that make?", "four times two is eight, and two times four is…?", "so what does that come to on each side?"); these were defined as constituting explicit operationalisations of strategies for solving a problem.

For each parent, a count was made of the number of times each type of assistance and explanation was used across the attempts relating to an individual problem. Scores on these eight variables (i.e. four assistance and four explanation codes) for the Time 1 problems formed the raw data for subsequent analysis.

<u>Reliability</u>. The reliability of the coding systems was checked via independent inspection of eight (approximately 20%) of the Time 1 transcripts. Since parental input was scored in terms of frequency of each assistance and explanation code type, reliability was evaluated by computing correlations between judges' scores for each category across the jointly coded instances. The mean correlation for the four assistance codes was +.99, with values ranging from +.99 to +1.00; for the

explanation codes it was +.96, with values between +.89 and +.99. All values were significant at $p < .005$. The agreement rate for children's explanations was 100% (kappa = 1.00, $p < .001$). The coding of children's attempts was objective.

2.3 Results

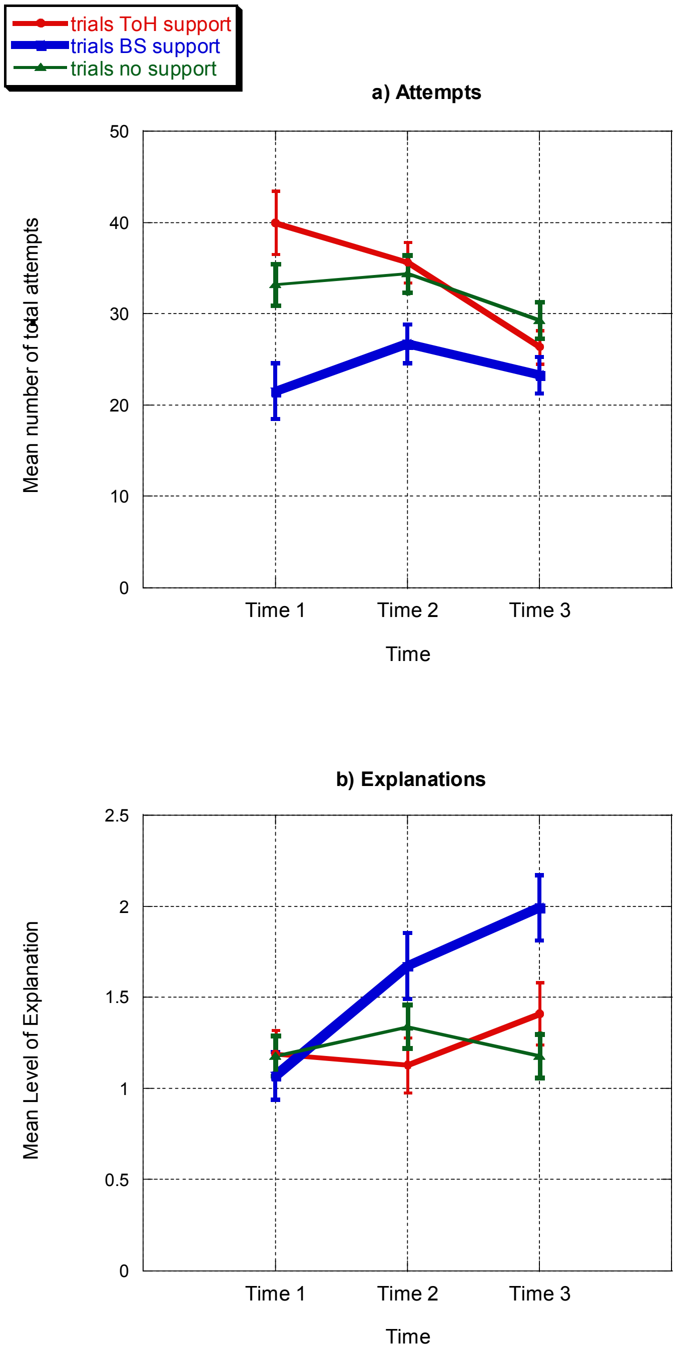
2.3.1. <u>Overview of analyses</u>

Data analysis took place in four distinct stages. The first stage examined the profile of children's performance on the Balance Scale task across assistance condition (Balance Scale-assisted, Tower of Hanoi-assisted, and no assistance) and time-point. The objective here was to establish how far assistance on the Balance Scale task led to improved performance and understanding, and what the trajectory of change was relative to the two control conditions. The second and third stages focused on more in-depth analysis of the data relating to children in the Balance Scale-assisted condition. Stage two concentrated on the nature of the help provided by parents, how far this varied across children, and whether such variation was contingent upon children's performance. Stage three focused on examination of problem-to-problem changes in children's performance and level of explanation, and the relationship of these changes to specific elements of parental input at Time 1, especially explicit operationalisations and higher-level explanations. Finally, the fourth stage of analysis examined the differential effects of these key elements of parental input on the performance and explanations of children at different initial levels of task understanding. Results are presented below in this order.

2.3.2. <u>Comparison across assistance condition</u>

Figure 3 shows, for each time-point, the average number of attempts across all the Balance Scale problems made by children in the different assistance conditions. It also displays the mean level of explanation provided for solutions once these had been achieved. The error bars show the standard error for each data point. It can be seen from Figure 3a that Balance Scale-assisted children required fewer attempts to arrive at solutions at both Times 1 and 2, compared to those in the control conditions, who received no assistance on this task. At Time 3, control children had caught up to some extent, with some overlap between the three conditions now being apparent. A two-way mixed Anova (time-point x assistance condition) confirmed main effects of condition ($F(2,141) = 9.91$, $p < .001$) and time-point ($F(2,282) = 7.02$, $p < .01$), but also a significant interaction between the two ($F(4,282) = 3.05$, $p < .05$). Follow-up tests established that Balance Scale-assisted children made fewer attempts both overall and at Times 1 and 2 than those in the Tower of Hanoi-assisted and no assistance conditions ($p < .05$, Bonferroni), but that the latter two conditions did not differ from each other at any time-point. The interaction was attributable to the two control conditions exhibiting a decline in number of attempts Time 2 to Time 3 ($p < .05$ in both cases), whilst the performance of the Balance Scale-assisted children remained constant within the bounds of normal statistical variation. There were no differences between conditions at Time 3.

Figure 3. Performances across time-points by parental support condition.



Explanation levels had entirely the opposite pattern. All three conditions exhibited similar levels of understanding at Time 1, but the Balance Scale-assisted children then showed steady improvement across Times 2 and 3, whilst the control conditions remained more-or-less static. A two-way mixed Anova found no main effect of assistance condition, but a highly significant main effect of time ($F(2,282) = 16.50$, $p < .001$) and interaction between time and condition ($F(4,282) = 10.35$, $p < .001$). Follow-up tests showed significant increases Time 1 to Time 2 and Time 2 to Time 3 for the Balance Scale-assisted children ($p < .01$ for both), but no change for those in the no assistance condition, and change only Time 2 to Time 3 in the Tower of Hanoi-assisted condition ($p < .05$). Differences between conditions were not quite sufficient to achieve significance at Time 2, but at Time 3 the Balance Scale-assisted children differed from both the control conditions ($p < .05$). The Tower of Hanoi-assisted and unassisted children did not differ from each other in explanation level at any point.

The data establish clearly the general benefits of scaffolding for children's performance on the Balance Scale task, but also underline a degree of disjunction between the effects on ability to generate solutions to the different problems, and on explicit understanding of the factors at work. As far as the first was concerned, parental assistance appeared to be effective in developing children's skills at Time 1, with the impact of this sustained over later time-points. Growth in explicit understanding tended to lag somewhat behind this, however, not manifesting fully until Time 3. Children in the control conditions showed slower improvement in solving the Balance Scale problems, but little apparent gain in explicit grasp. The implication is that scaffolding had benefits over simple experience in terms of accelerated task performance, but perhaps more importantly in paving the way for growth in explicit understanding.

2.3.3. Detailed analysis of change in the Balance Scale-assisted condition

2.3.3.1. Patterns of parental assistance

Parental input showed substantial and apparently systematic variability in provision of procedural assistance and explanations at Time 1. Only 15 parents made use of explicit operationalisations in the form of weight x distance prompts, of whom only 13 also made use of the higher-level torque rule explanations. No other parent provided explanations at this level. Of these 13 parents, 4 gave other less specific explanations more frequently than torque rule statements, potentially diluting their impact (although all did refer to both weight and distance as factors). These 4 parents, and the 2 who used explicit operationalisations without torque rule explanations, also made more use of the less explicit nut/peg and non-specific prompts than weight x distance prompts. These characteristics defined two categories of input style, as follows:

1) *Fully explicit input*: procedural assistance via a focus on weight x distance prompts (explicit operationalisations), with torque rule (i.e. higher-level) explanations predominant (n = 9) (See Appendix 3a for an example of one parent's use of this input style)
2) *Partially explicit input*: procedural assistance via nut/peg and non-specific prompts predominantly, with weight, distance, and weight/distance explanations most frequent (n = 6) (See Appendix 3b for an example of one parent's use of this input style)

Of the remaining 27 parents, 16 gave non-specific prompts for 30% or more of their input, and weight explanations for 10% or more, with a clear preponderance (60% or more) of all their input being of these two kinds. For the final 11 parents, input was characterised by a substantial percentage of input (20% or more) taking the form of direct control. Some, though not all of these also gave substantial numbers of weight explanations. These characteristics defined two further categories of input style:

3) *Minimally explicit input*: primarily non-specific procedural assistance, with weight explanations predominant (n = 16) (See Appendix 3c for an example of one parent's use of this input style)
4) *Implicit input*: substantial direct control, with some weight explanations (n = 11) (See Appendix 3d for an example of one parent's use of this input style).

No parent was assignable to more than one category, but in order to confirm the validity of the categorisation, the data were subjected to a discriminant function analysis. This used the four categories defined above as the target grouping variable, and frequency of the four procedural assistance and four explanation codes as raw input. The analysis identified three significant discriminant functions accounting for 100% of the variance, with the first loading on weight x distance (.42) and nut/peg prompts (.78), the second on torque rule explanations (-.69), and the third on direct control (.84) and weight explanations (-.29). It will be noted that the first function reflects the distinction between fully or partially explicit input and minimally explicit or implicit input, the second between fully and partially explicit, and the third between minimally explicit and implicit. Of the 42 cases categorised as described above, only one was identified by the analysis as a potential misclassification (the implicit input case with the lowest percentage of direct control, which might equally have been classed as exhibiting a minimally explicit style). Relevant means for each category of input style on the eight variables are shown in Table 3.

Table 3. Mean frequency of elements of procedural assistance and levels of explanation provided by parents (total across problems), by input style category (standard deviations in parentheses).

Input style	Direct control	Non-specific prompts	Nut/peg prompts	Weight x distance prompts	Weight explns	Distance explns	Weight/ distance explns	Torque rule explns
Fully explicit (n = 9)	1.89 *(1.62)*	8.67 *(5.98)*	11.00 *(4.12)*	24.89 *(21.17)*	1.00 *(1.12)*	0.00 *(0.00)*	0.89 *(1.54)*	5.11 *(3.02)*
Partially explicit (n = 6)	2.17 *(2.32)*	17.00 *(9.74)*	17.33 *(9.31)*	12.67 *(10.31)*	2.33 *(3.44)*	0.67 *(1.03)*	3.17 *(4.87)*	1.50 *(1.87)*
Minimally explicit (n = 16)	2.12 *(2.58)*	12.81 *(10.42)*	1.06 *(1.65)*	0.00 *(0.00)*	7.37 *(4.41)*	0.94 *(1.69)*	1.37 *(1.54)*	0.00 *(0.00)*
Implicit (n = 11)	15.91 *(17.48)*	12.45 *(11.34)*	0.54 *(0.82)*	0.00 *(0.00)*	4.91 *(5.15)*	0.64 *(1.12)*	0.54 *(0.69)*	0.00 *(0.00)*

The high standard deviations associated with many cells reflect the fact that whilst *relative* occurrence of input of different types within style categories was of the pattern specified, the exact *extent* of input varied from parent to parent. Analysis of relationships between elements of parental input therefore controlled for this variation.

Despite the variation between parents in input style, there were only limited signs that they varied their approach from problem to problem, although this might be expected if the type of assistance offered were contingent upon children's performance (cf. Wood, 1986). Two-way mixed Anovas (problem x input style) on each of the parental codes found a main effect of problem and a problem x input style interaction only for weight x distance prompts ($F(3,114) = 6.36$, $p < .01$, and $F(9,114) = 3.68$, $p < .001$), and a further main effect of problem for torque rule explanations ($F(3,114) = 5.36$, $p < .01$). Parents who used these elements (i.e. those with fully and partially explicit input styles) provided them more often on later problems, especially problem 3 (for weight x distance prompts, mean = 1.00, 1.59, 2.31, 2.24 for problems 1 to 4;

for torque rule explanations, mean = 0.21, 0.29, 0.55, 0.26), perhaps indicating a ‘hammering home the point’ strategy. Even then, they were broadly consistent in the scale of their use of weight x distance prompts across problems, with significant correlations being identified between problems 1 and 4 ($r = .68$, $p < .01$) and 2 and 4 ($r = .78$, $p < .01$), controlling for overall level of input (one-tailed values with df =12 in both cases).

For torque rule explanations, consistency of deployment across problems was less, with significant correlation only between problems 2 and 3 (partial $r = .46$, df = 12, $p < .05$, one-tailed). Since such explanations were only correlated with weight x distance prompts on problem 1 (partial $r = .79$, df = 12, $p < .001$, one-tailed), the data indicate that parents who used both explicit operationalisations and higher-level explanations tended to provide the whole framework of assistance and explanation on problem 1. They then persisted primarily with the first element, only providing explanations as they felt necessary to reinforce the rationale for the weight x distance computations. Variation in input that might indicate contingency upon children’s performance was thus only apparent for torque rule explanations. No effects of problem were found for any of the other elements of parental input, and use across problems was generally well-correlated.

2.3.3.2. Problem-to-problem changes in children’s performance and level of explanation.

Table 4 presents a detailed breakdown of each child’s number of attempts and explanation level on problems 1 to 4 at Times 1 to 3. To help clarify effects of parental input, children are grouped according to which input style their parent exhibited. Means across children and problems for each time-point are shown in Table 5. The presence of systematic trends within these data was examined by means of doubly-repeated three-way mixed Anovas (problem x time-point x input style), coupled with specific correlational analyses.

a) Attempts. As far as number of attempts was concerned, this analysis revealed a main effect of input style ($F(3,38) = 4.35$, $p < .05$), with follow-up tests showing that children made fewer attempts if their parent adopted a fully explicit input style than if they adopted an implicit style ($p < .05$, Bonferroni; all other difference ns). As can be seen from Table 4, the former style dramatically constrained attempts at Time 1, where the modal performance was a single correct effort. Even at Times 2 and 3, though, this remained a frequent outcome for children in this grouping, despite the substantial increase in attempts shown by some. Children whose parents used a partially explicit style also made fewer attempts at Time 1, but this initial constraint was not as marked. Children whose parents used minimally explicit or implicit styles in contrast showed no corresponding constraint at Time 1, and this difference gave rise to an interaction between input style and time-point ($F(6,76) = 2.24$, $p < .05$) in addition to the main effect of input style (see Table 5).

Table 4. Number of attempts and explanation level for correct solution for each child in the Balance Scale-assisted condition, on Problems 1 to 4 (P1 to P4) at Times 1, 2

and 3, ordered by parental input style. Obvious peaks in number of attempts (2+ > minimum for a given time-point) are shown in bold.

	Time 1								Time 2								Time 3							
Parenal	*Attempts*				Exp level				*Attempts*				Exp level				*Attempts*				Exp level			
input style	*P1*	*P2*	*P3*	*P4*	tP1	P2	P3	P4	*P1*	*P2*	*P3*	*P4*	P1	P2	P3	P4	*P1*	*P2*	*P3*	*P4*	P1	P2	P3	P4
Fully explicit																								
H1	1	2	1	1	1	0	0	1	**7**	1	5	4	4	4	3	4	1	1	1	1	4	4	4	4
H10	1	1	1	1	0	0	0	4	2	1	**7**	2	2	2	3	3	1	**4**	1	2	3	2	3	3
H12	1	1	1	1	0	0	0	0	10	**22**	14	9	3	0	3	0	7	1	3	**10**	0	2	3	0
H14	2	1	1	1	0	4	4	0	**11**	4	1	5	2	0	4	4	4	1	**37**	6	3	3	0	0
H15	1	1	1	1	0	4	4	4	1	1	1	1	4	4	4	4	1	1	1	2	4	4	4	4
H16	1	1	1	1	0	1	0	3	1	1	**3**	1	4	4	4	4	1	1	1	2	4	4	4	4
H20	1	2	1	1	1	3	4	1	**7**	2	6	**7**	4	4	3	3	**18**	2	3	3	4	4	3	3
H21	1	2	1	2	0	0	0	0	**8**	4	3	1	0	3	3	1	**13**	9	4	3	0	1	3	3
L6	2	**4**	1	1	0	0	0	0	**30**	6	16	1	0	1	0	1	9	**19**	7	2	0	0	0	0
Mean	1.2	1.7	1.0	1.1	0.2	1.3	1.3	1.4	8.6	4.7	6.2	3.4	2.6	2.4	3.0	2.7	6.1	4.3	6.4	3.4	2.4	2.7	2.7	2.3
Partially explicit																								
H11	1	2	2	**7**	3	3	3	1	4	1	**12**	1	3	3	0	3	**3**	1	2	2	2	4	3	3
H18	**5**	2	1	1	0	0	1	0	19	1	**22**	4	3	0	0	1	**19**	5	11	12	1	0	2	3
H22	1	2	**5**	1	0	3	3	3	2	2	**6**	4	3	3	3	3	2	1	**9**	3	3	3	3	3
L9	**3**	2	1	1	1	0	4	4	**19**	6	2	6	3	3	3	3	1	1	7	**14**	4	3	3	3
L14	2	**4**	**4**	1	0	0	0	0	9	1	1	**15**	0	0	0	0	1	2	**11**	8	0	0	0	0
L20	**6**	3	5	2	0	1	3	0	**8**	5	1	2	3	1	3	0	1	4	3	**11**	3	3	3	0
Mean	3.0	2.5	3.0	2.2	0.7	1.2	2.3	1.3	10.2	2.7	7.3	5.3	2.5	1.7	1.5	1.7	4.5	2.3	7.2	8.3	2.2	2.2	2.3	2.0
Minimally explicit																								
H2	3	5	**16**	2	3	1	3	0	2	2	**11**	1	3	1	3	1	3	1	1	**14**	3	3	3	3
H4	2	6	2	**9**	1	1	0	0	3	2	**4**	2	3	3	3	3	2	3	5	**6**	3	3	3	3
H6	1	**7**	2	3	0	0	0	0	**13**	6	7	10	0	0	0	0	1	2	**5**	4	3	0	0	0
H7	2	**9**	4	4	0	2	0	3	**11**	6	2	2	1	3	0	0	**19**	5	14	8	3	0	0	0
H8	2	**6**	4	4	0	0	0	0	4	1	1	**7**	0	1	3	0	**8**	**8**	5	2	1	0	3	0
H9	2	2	3	**6**	1	3	3	3	6	5	**8**	2	3	3	3	3	3	1	1	**4**	4	3	3	3
H13	2	5	6	**11**	1	0	1	1	5	**6**	3	1	3	3	3	3	**7**	4	5	4	4	3	3	3
H17	1	1	4	7	0	3	0	3	**19**	14	5	2	1	3	3	2	**13**	3	2	7	3	3	3	2
H19	3	6	7	**12**	3	1	2	0	4	1	7	**8**	0	1	0	0	3	4	1	**10**	3	0	0	0
L2	4	2	5	**8**	0	1	0	1	**7**	**7**	5	1	3	0	3	0	**40**	12	8	8	1	1	3	3
L5	4	**17**	1	3	1	0	1	0	**6**	3	**6**	3	1	0	0	0	1	3	3	**4**	0	0	0	0
L7	4	**18**	2	3	0	0	1	0	14	3	5	**19**	1	3	1	1	4	**19**	1	7	1	0	3	1
L12	3	**16**	8	7	0	1	3	3	**27**	7	1	12	0	1	0	1	10	2	2	**17**	1	1	3	3
L13	**36**	11	17	19	3	2	3	0	5	**8**	6	5	3	2	1	3	5	**7**	1	2	3	3	3	0
L16	4	**9**	7	8	3	0	0	0	**15**	4	7	14	1	1	1	3	5	5	2	**12**	1	3	3	3
L18	2	**7**	5	5	0	0	3	3	2	4	**12**	10	3	0	0	0	1	4	1	**5**	3	3	3	3
Mean	4.7	7.9	5.8	6.9	1.0	0.9	1.2	1.1	8.9	4.9	5.6	6.2	1.6	1.6	1.5	1.2	7.8	5.2	3.6	7.1	2.3	1.6	2.2	1.7
Implicit																								
H3	2	1	1	**4**	0	0	0	0	4	4	3	**6**	0	0	3	0	1	**16**	1	2	1	0	2	0
H5	1	3	3	**5**	3	0	0	0	**10**	2	2	6	2	0	0	0	**12**	2	1	11	1	0	3	0
L1	**13**	5	2	8	4	1	0	0	5	2	**11**	2	0	0	3	3	9	2	**14**	2	3	0	3	3
L3	2	**16**	1	3	1	0	2	0	**16**	1	4	7	0	2	0	2	5	**9**	1	5	0	0	2	2
L4	6	**10**	1	5	0	3	3	3	**26**	8	7	4	0	3	2	0	**13**	2	1	4	1	3	3	3
L8	**22**	15	5	5	3	0	0	0	12	**19**	12	3	1	3	1	0	11	**16**	5	11	3	0	0	3
L10	36	7	8	**45**	3	1	0	3	6	3	5	**17**	3	3	2	3	5	1	7	**12**	1	1	3	1
L11	4	5	5	**6**	1	0	1	1	5	**10**	4	2	0	0	0	0	4	3	4	**12**	0	0	0	0
L15	**11**	7	**11**	5	0	1	0	1	**19**	4	13	6	2	0	0	0	3	2	**8**	3	0	2	2	2
L17	2	4	**20**	17	0	1	1	3	6	**16**	5	4	0	0	1	1	2	4	**20**	10	1	3	3	1
L19	**36**	13	3	5	0	0	0	0	**29**	4	15	3	0	0	2	3	**18**	2	3	3	1	3	3	3
Mean	12.3	7.8	5.4	9.8	1.4	0.6	0.6	1.0	12.5	6.6	7.4	5.4	0.7	1.0	1.3	1.1	7.5	5.4	5.9	6.8	1.1	1.1	2.2	1.6

Table 5. Mean number of attempts and explanation level at Times 1, 2 and 3, by parental input style (standard deviations in parentheses).

	Time 1		Time 2		Time 3		Overall	
	Attempts	Exp level	Attempts	Exp level	Attempts	Exp level	Attempts	Exp level
Fully explicit	1.25_a (0.33)	1.08 (1.10)	5.72 (4.66)	2.67_a (1.24)	5.08 (3.99)	2.53 (1.46)	4.02_a (2.57)	2.09 (1.15)
Partially explicit	2.67_{ab} (0.78)	1.37 (1.10)	6.37 (3.07)	1.83_{ab} (1.18)	5.58 (3.31)	2.17 (1.24)	4.87_{ab} (1.97)	1.79 (1.15)
Minimally explicit	6.34_{bc} (4.14)	1.06 (0.75)	6.42 (2.86)	1.48_{ab} (1.02)	5.92 (3.79)	1.97 (1.07)	6.23_{ab} (2.09)	1.50 (0.79)
Implicit	8.84_c (6.27)	0.91 (0.68)	8.00 (3.04)	1.02_b (0.73)	6.41 (1.95)	1.50 (0.78)	7.75_b (2.95)	1.14 (0.57)

Where values within the same column have no different subscripts, they are significantly different at p < .05 (Bonferroni).

The analysis also revealed a main effect of problem ($F(3,114) = 3.43$, $p < .05$), and an interaction between problem and time-point ($F(6,228) = 2.53$, $p < .05$). These effects were attributable to the average number of attempts tending to be higher on problem 1 (means = 7.23, 4.67, 5.41, 5.51 for problems 1 to 4, averaged across time-point), and to this pattern becoming more pronounced at Time 2 (means = 10.05, 4.73, 6.64, 5.10). As Table 4 makes clear, there was in fact substantial variation in this effect, with children who experienced implicit or minimally explicit assistance showing erratic variation problem-to-problem in number of attempts at Time 1 in particular. The average pattern held better at Time 2, with 17 out of these 27 children especially tending to make their peak number of attempts on problem 1 or problem 2. At Time 3, the majority of children made their largest number of attempts on either problem 1 or problem 4, the latter being somewhat more likely among those who had originally experienced minimally explicit or implicit assistance. These children also exhibited some tendency to make their peak number of attempts at roughly the same point in the problem sequence across successive time-points.

The broad picture, then, was that parental input constrained attempts, but only if it was at least partially explicit in style. In the absence of such assistance, children often spent at least one problem of a session, frequently the first, exploring or reorienting to the task before making more targeted efforts, though gains were often not sustained in any systematic fashion through to the next session. The relationship between attempts and degree of targeting was borne out by the proportion of attempts at level 6/7, since these were significantly negatively correlated with the number of attempted solutions for every problem, except the fourth at Time 1 (r ranged between -.22 and -.71, average = -.46). The greater the focus, the fewer the attempts needed to arrive at a solution, and conversely, the less clear children were about where to focus their efforts, the more attempts they made.

b) Explanations. The pattern for change in explanation level differed in as much as systematic shifts took place solely in relation to time-point. Analysis showed a main effect of time-point ($F(2,76) = 23.50$, $p < .001$), in line with the upwards trend seen in Figure 3b, but also an interaction between time-point and parental input style ($F(6,76) = 2.82$, $p < .05$). As can be seen in Table 5, children who were assisted by fully explicit input showed a steep increase to Time 2, whereas progress was more gradual, and to a somewhat lower level, for those whose parents gave partially or minimally explicit assistance. For children whose parents relied on implicit assistance, progress was delayed till Time 3.

Inspection of the individual data in Table 4 bears out the general trends. First, in terms of consistency of explanation level across problems, virtually all children gave at least two explanations at the same level at all three time-points, with exactly half giving three or more the same at Times 1 and 2, and nearly two-thirds (27) doing so at Time 3. Secondly, with regard to the effect of parental input, whilst the pattern was not uniform, children whose parents gave fully explicit assistance were the only ones who themselves gave torque rule explanations at Time 2. Moreover, the presence of explanations at this level at both Times 1 and 2 (as measured by the number of problems for which children gave them) was significantly correlated with the total number of torque rule explanations provided by *parents* ($r = .26$, $p < .05$ and .36, $p < .01$ respectively) and the number of weight x distance prompts they made ($r = .37$, $p < .01$ for both), the two defining characteristics of this style of input. Children's torque rule explanations at Time 3, in contrast, were only significantly correlated with their *own* use of these explanations at Time 1 ($r = .40$, $p < .01$) and Time 2 ($r = .91$, $p < .001$; all analyses one-tailed with $n = 42$), providing clear evidence of the predicted process of appropriation.

It should also be noted that the effect of parents' provision of torque rule explanations and weight x distance prompts appeared to be cumulative and lagged, again consistent with a process of appropriation. Whilst total provision predicted total child use of torque rule explanations at Time 1, this association was absent on any individual problem. Instead, weight x distance prompts and parental torque rule explanations typically predicted child use of torque rule explanations on *subsequent* problems. Thus problem 1 usage by parents was associated with child torque rule explanations on problems 2 and 3 (for weight x distance prompts, $r = .49$ and .65 respectively; for parental torque rule explanations, $r = .67$ and .56, $p < .001$ in each case). A similar relationship was present for weight x distance prompts on problem 2 and child torque rule explanations on problem 3 ($r = .52$, $p < .001$). Conversely, the only sign of parental usage being contingent on children's performance was that child torque rule explanations on problem 3 predicted weight x distance prompts and parents' torque rule explanations on problem 4 ($r = .60$, $p < .001$ and .36, $p < .01$ respectively; all analyses one-tailed with $n = 42$). However, the relationship was *positive*, consistent with 'hammering home the point', not a response to faltering on the part of the child.

c) Relationships between attempts and explanations. The difference in pattern of change for performance and explanations begs the question of what relation, if any, the two had to each other. The data in fact indicate a complex relationship that shifted across problems. At Time 1, children's explanation level was inversely related to attempts and proportion at 6/7 on problem 1, i.e. the higher the explanation level, the *more* the attempts ($r = .38$, $p < .01$), and the *less* the focus ($r = -.29$, $p < .05$). On problem 2, the relationship was in a more expected direction ($r = -.27$ and .30 respectively, $p < .05$ for both), but on problems 3 and 4, there was no significant relation at all. At Time 2, the pattern was similar, explanation level being strongly related to attempts and proportion at 6/7 on problem 1 ($r = -.42$ and .40, $p < .01$), but the effect weakening to zero by problem 4. At Time 3, the impact of explicit grasp was maintained until problem 3 ($r = -.37$, $p < .01$ and .34, $p < .05$; all analyses one-tailed with $n = 42$), and only lost at problem 4. Since attempts generally *improved* across problems as the relationship to understanding weakened, this suggests that performance typically ran in advance of explicit grasp, though the two were better coordinated by Time 3.

This pattern was different for children who received fully explicit assistance, though. At Time 2 the relationship of explanation level to attempts maintained until problem 4 (as at Time 3 in the overall sample), whilst at Time 3 the relationship persisted after problem 1 ($r = -.38$, ns, $-.85$, $p < .01$, $-.74$ and $-.69$, $p < .05$ for both; $n = 9$, all one-tailed). The evidence is thus consistent with appropriation of torque rule explanations by these children having accelerated relationships between understanding and performance, and for these children having finally generated genuine E3 level representation capable of consistently guiding decisions.

Children who did not receive fully explicit assistance also benefited from intervention relative to children in the control conditions, however. The general pattern suggests progress for them occurred primarily via increasing approximation of attempts to correct solutions (perhaps based on attention to the rate at which the scale fell on unsuccessful efforts). This appeared to be followed by consolidation of the lessons learnt from such experience prior to the next set of trials, this grasp being superceded gradually by further exploration during those trials. The implication is that attempts at level 6/7, which indexed such approximation, were central to progress. If parental input had a positive effect for these children, then, it must have been via an impact on the proportion of such attempts. The only element of parental input that had this relationship was nut/peg prompts, totals of which were correlated with mean proportions of level 6/7 attempts at Times 1 and 2 among those not in the fully explicit grouping ($r = .36$, $p < .05$, and $.56$, $p < .01$, $n = 34$, both one-tailed). These prompts were of course present in all input styles, although only infrequently so for those who received minimally explicit or implicit assistance.

2.3.3.3. Effects of explicit explanation on higher- and lower-performing children.

It had been predicted that the impact of higher-level explanation by parents would differ according to whether children's initial understanding of the task was at level I or E1/E2. To examine this, the Balance Scale-assisted children were divided into two groups, according to whether or not they made attempts scored at level 3 or below (see Table 2) during the first problem at Time 1. Since these essentially constituted trial-and-error activity, they were unlikely to have been promulgated by parents, and would not be expected to be produced by children at level E1/E2: explicit representation should lead to more systematic behaviour, even if this is limited in terms of the principles manipulated. Of the 42 children, 20 produced attempts at level 3 or under on the first problem, and were categorised as lower-performing; whilst 22 produced attempts only at level 4 and over, and were categorised as higher-performing.

Children's classification as higher- or lower-performing is indicated by the prefix H or L in Table 4. It will be apparent from this table that while the four input styles were all found among parents of both higher-performing and lower-performing children, there was nevertheless considerable difference in their exact distribution. In particular, fully explicit assistance occurred predominantly among higher-performing children, whereas implicit assistance occurred mostly among the lower-performing. This association was significant (chi-square = 10.08, df = 3, $p < .05$), and does not appear to be explicable in terms of input style itself creating the basis for children's categorisation, as it predicted neither the number of attempts at level 3 and under, nor at level 4 and above on problem 1 at Time 1. The implication is that whilst problem-to-problem contingency between children's performance and parental input was broadly absent, it appeared to operate at the more general level of children's initial capability on the task.

One consequence of this difference in distribution was that lower-performing children had significantly less exposure to torque rule explanations (mean = 0.45 vs 2.09; $F(1,40) = 4.73$, $p < .05$), since these only occurred in input styles that were less common among their parents. Thus the evidence on the key point of interest is restricted. As far as it is available, however, it is supportive of the hypothesis that appropriation is dependent on level of grasp. The positive correlations between parental torque rule use and child use at Times 1 and 2 were maintained at the same level when the higher-performing children alone were considered ($r = .32$ and .31 respectively, $n = 22$, $p < .1$ for both), but not among the lower-performing ($r = -.10$ at Time 1, $n = 20$, ns; Time 2 value is not computable as torque rule explanations were not given here by these children). The same pattern obtained for weight/distance explanations, where there was no difference in exposure between the two sub-groups.

For the higher-performing children, parental use of these was correlated with their own use at Time 1 ($r = .49$, $p < .05$) and to a lesser extent at Time 2 ($r = .35$; $p < .1$). For lower-performing children, these correlations once again disappeared ($r = .16$ and $-.04$ respectively, both ns).

2.4. Discussion

The data reveal a complex interactive relationship between type of parental input, children's attempted solutions and their explanation level, the precise nature of this relationship shifting over time, with the impact of parental input still being felt at Time 2, but dwindling at Time 3. Despite this complexity, in most respects the data were in line with the effects of linguistic mediation predicted to occur when parents provided assistance via explicit operationalisations of weight x distance computations and higher-level explanations.

To take the various points of correspondence in turn, the Balance Scale-assisted children showed an initial gain in focus in their attempted solutions, needing fewer efforts to arrive at answers than those in either control condition. In this respect, though, the controls caught up by Time 3 (cf. Pine *et al.*, 1999). However, the unassisted children showed none of the gains the assisted made by Time 3 in terms of *explanations*, with these gains being present regardless of style of parental input, albeit to differing extents. There was, moreover, some indication that they were still on an upward trend at this point. The implication is that, on the basis of simply exploring the task over three time-points, children could improve in terms of task performance and begin to carry over understanding from one problem to another, but only at a relatively inarticulate level, perhaps equivalent to E1 level representation (cf. Pine and Messer, 1999; 2003, on implicit understanding in the context of balance beam performance). Persistent gains in more explicit, E3 level representation over this time period were entirely dependent on parental input, and it was in this respect that scaffolding had its predominant impact, consistent with the proposed role of linguistic mediation.

Parental assistance was, as noted, variable in character (cf. Wood, 1986), with only two of the four broad styles identified making use of higher-level explanations that explicitly specified the relationship between weight and distance (see Appendix 3). In both cases, provision of such explanations co-occurred uniquely with explicit operationalisations of weight x distance computations. It was these two elements together that were associated with the most pronounced gains in children's performance and more especially their explanations, consistent with the predicted effects of these types of linguistic mediation on representational level. This was not simply a function of rote memorisation of explanations and solutions, since children's use of the torque rule went through a subsequent period of coordination with their performance before its impact was fully felt. By Time 3, when this coordination – and E3 level representation – had been achieved, child torque rule use was only associated with their own prior use, indicating that gains occurred by means of the predicted process of appropriation and redescription. In other words, then, adult input *resourced* growth rather than promoting wholesale adoption of a new perspective.

Two other points should be noted here. One is that it was the combination of explicit operationalisation and higher level explanation that led to progress, not the latter on its own. One example of this can be observed in Appendix 3a, where a parent is supporting her child on the second problem, which contained one nut each on the second and fourth pegs (see Table 1). An excerpt of this interaction can be seen below:

> *Parent: "that's number two and that's number...?"*
> *Child: "Twelve."*
> *Parent: (pointing at peg 2), "No."*
> *Child: "Two...four." (after (parent then points to peg 4 and looks to her)*
> *Parent: "And what's that?"*
> *Child: "And that makes six."*
> *Parent: "Right, you need to make (the other) side make six to be the same as that."*
> *Child: "Five and one."*
> *Mum: "You can't make up a five."*
> *Child: "Three add...three".*

This indicates that to be effective, reference to more abstract principles has to be connected to concrete instantiation, as Tolmie *et al.* (2005) suggest. The other is that the effect of parents providing these two elements of input was not only lagged, as had been anticipated, but also cumulative rather than being dependent on contingent deployment, as Wood's (1986) account of scaffolding would predict. In particular, it was *total* usage that predicted gains, suggesting that consistent emphasis on the need for weight x distance computation and the principle underlying this was of greater consequence than strategic targeting of this input. Given that parental input in general tended to show consistency across problems rather than variation, and that even the less explicit styles of input were associated with progress, the data raise the question of whether the importance of contingency in previous accounts of scaffolding may have been overstated. Wood himself notes that it is difficult to achieve with any consistency, and the present data indicate that, at minimum, the process of learning via scaffolding is widely tolerant of its absence, at least at any fine-grained level.

The data are consistent with the anticipated effects of linguistic mediation in two further respects. The first is that as far as evidence was available, appropriation of higher-level explanations was dependent, as predicted by Tolmie *et al.* (2005), on children displaying an initial level of performance consistent with at minimum E1/E2 level representation. As far as torque rule explanations are concerned, confidence in this effect is necessarily restricted by the uneven distribution of their occurrence across higher- and lower-performing children, which renders the comparison potentially unfair. The same effect was also observed, however, for weight/distance explanations, which share with torque rule explanations an explicit reference to the combined importance of weight and distance, and thus a core aspect of the general principles at work. This comparison was not subject to concerns about uneven distribution. The implication is that, as suggested earlier, it is difficult for children to jump straight from implicit to E3 level without establishing interim representations.

The presence of this effect is an important one for various reasons. One is that it signals the capability of the linguistic mediation account to make detailed predictions that are meaningfully consistent with the general framework of the RR model, underscoring the potential power of this approach. Another is that this success in differentiating between processes that operate for children at different initial levels of representation indicates ways in which the linguistic mediation approach may go beyond the established contingency account of scaffolding. Wood (1986) emphasises the notion that scaffolding is only possible when the task is within the ambit of what the child is close to being able to do, rendering it essentially a unitary process. On the present data, though, scaffolding is also possible when the task is more removed from children's competence, but it needs to take a different form to be productive.

This point becomes evident when it is remembered that children who did not receive fully explicit input still managed to progress. They appear to have done so primarily via an approximation strategy that led to more targeted attempts in the area of a correct solution. Indeed, several children explicitly stated that this was what they were doing (e.g. "it was just another guess because of how slowly it was moving"; "that one there was too heavy cos it was too near the side so I moved it along one"). In this respect, these children may have been working in much the same way as those in the control conditions, but with one advantage. Once children start to adopt this strategy it opens the way for derivation of explicit weight/distance and even torque rule explanations, since it involves deliberate manipulation of number and position. To achieve this shift, however, these factors have to be disembedded from the background of potential variables, and made salient. Few unassisted children managed to do this. For lower-performing assisted children, on the other hand, parents not only helped increase their focus on the range in which correct solutions might be found via nut/peg prompts, but perhaps also, by using these, explicitly indicated the features to which they needed to attend; in other words, these also served as a form of explicit operationalisation, which helped promote E1/E2 level representations. Thus even at this level, it was possible to detect a process of linguistic mediation, albeit a different one to that operating for higher-performing children.

The data still leave two issues unclear. The first is that parental provision of weight x distance prompts and torque rule explanations appeared to be *necessary* for accelerated growth in understanding, in as much as only those who received this input exhibited such change. It cannot be regarded as *sufficient* in itself, though, since it did not uniformly produce this outcome even among higher-performing children. The reasons for this individual variation are not evident on present data, though wider language ability may be a plausible factor. This requires further investigation.

The second is the rather intriguing self-selection of parental input styles, contingent upon children's initial level of representation, rather than more moment to moment variation in performance. The tendency for parents to use different styles is itself well established (see e.g. Rogoff, Matusov and White, 1996; Wood and Middleton, 1975), but this targeted adoption has been less commonly reported. The problem in the present case is that while this variation was well-predicted by children's performance level, the criteria used to categorise children were subtle, and not on the face of it very likely to have been detected by parents. This begs the question of whether the determining factor might not in fact have been a more general (if reasonably accurate) *expectation* on the part of parents about how their child would perform. A precedent for this is provided by Rubie-Davies (2007), who reports that teachers with high expectations of their pupils provided them with large numbers of instructions and explanations about the concepts they were teaching, whereas teachers with low expectations made far more procedural statements and asked fewer questions.

This opens up the possibility that the differential pattern of behaviour and consequent impact of parental input for the lower- and higher-performing children is in part a function of a history of past parental support, and that this might therefore have been an additional source of influence on outcome in the present research. To clarify this, data from the present study need to be compared with one in which children at different initial levels work with the same, previously unknown adult. Initial level of understanding might also perhaps be established without risk of contamination (or reduced risk) by pre-testing on a closely-related, but different task, the balance beam (Pine *et al.*, 1999).

Chapter 3

STUDY 2

3.1. Introduction

The initial finding in Study 1, that children who were supported on the Balance Scale task completed it in fewer attempts and developed a higher level of understanding of the task than those belonging to the two control conditions, confirmed that adult input on problem-solving tasks is a substantive influence on children's successful cognitive growth. However, when the actual nature of input was examined, parents were found to differ greatly in the type of support strategies they employed, with this being only partially associated with children's apparent grasp of the task. It was suggested that this might have been due to the parents basing their support styles on their prior expectations of their child's ability level, and their belief about how they would perform, rather than their actual capabilities and limitations. This may, in turn, have led to an unforeseen influence on outcomes, creating uncertainty about whether the pattern of effects observed in Study 1 reflected scaffolding processes more generally or something more specific to the dynamic of parent-child relationships and the past history of interaction between the two. This issue is of particular concern with regard to the effects of fully explicit support, as those effects were in line with the hypothesised impact of representational level on children's appropriation of explanations.

Study 2 therefore set out to replicate Study 1, by again exploring the role of scaffolding and explanations provided by an adult giving assistance on the Balance Scale task. However, in contrast to Study 1, the adult in this second study was previously unknown to the child they were working with, and thus, their actions would not be open to contamination by prior expectations of the kind held by parents. If the results mirrored those in the previous study, this would confirm that the processes in operation are general and not a function of the adult-child relationship.

However, this study was only a partial replication. In Study 1, the freedom to support their child in any way they saw appropriate led to a large amount of variation in parental input, as already noted. For example, assistance ranged from that which was very ‘hands on’ with parents taking direct control of the task, to that which employed indirect guidance involving fully explicit (weight/distance prompts and level 4 explanations) or partially explicit (non-specific and nut/peg prompts, and level 3 explanations) support. This would not be problematic in itself, except that disproportionate amounts of fully and partially explicit prompts were given to higher performing children. This made it difficult to examine how explicit guidance impacted on the lower performing children, and compare this to the higher group. To test Tolmie *et al*’s. (2005) hypothesis that adult input, when given consistently, impacts differently on children’s progress and understanding depending on whether they are at a more implicit or more explicit representational level, it was imperative for the present study to examine the impact of more standardised input across children. Adult tutors were therefore trained to administer consistent support, as far as possible rather than allowing them free rein over their scaffolding methods.

A further difference from Study 1 involved the categorisation of children as lower and higher performing. In the previous study, the placing of children into categories of lower or higher understanding was established on the basis of their performance during the first problem of the supported session. It was possible therefore, that performance level could have been marginally affected by parental presence. In light of this possibility, a classification test was introduced into the present study. This involved the children working independently on a similar but different task, prior to the main Balance Scale activity. This task was taken from the Balance Beam research conducted by Peters *et al.* (1999), Murphy and Messer (2000), and Pine, Messer and Godfrey (1999), in which children worked with beams of different dimensions and distribution of weight in order to explore their grasp of the properties affecting balance. However, whereas the children in the previous Balance Beam studies were required to physically balance the beams, the present research only permitted the children to predict where the beams would balance if they were placed on the fulcrum. Predictions consisted of the child pointing to one of four lines drawn on each of three symmetrical and three asymmetrical beams, with the lines corresponding to the point where they thought each beam would balance. Children were then asked to give explanations based on their predictions. They did not receive feedback on any predictions, as it was important to gain uncontaminated insight into their reasons for choosing their specific answers. Essentially, the predictions were only a vehicle for exploring their concepts of balance, and explanations alone determined whether they were categorised as having lower or higher levels of understanding. The categorisation criteria were therefore different to those employed in Study 1, where the children were classified on the basis of performance, rather than explanations. However, this present method was considered to be more accurate as it captured more directly the children's initial cognitive grasp of balance prior to any external input.

The previous study also had support constrained to a single session, with all children undertaking the task alone over the following two time-points. Although the appropriation effect observed from this study was similar to that reported by Tolmie *et al.* (2005), it was unclear whether support given across all three sessions might not have produced some variation in outcome. For example, Tolmie *et al.* found that over the course of four sessions, there was a shift in the scaffolding relationship between adult and child, with children first receiving and then appropriating the adult's explanations and providing their own without the adult having to prompt them. As this occurred, adult input with respect to procedural prompts decreased, and explanations shifted to become a commentary on children's own explanations. The effects of this may have been to promote greater benefits for lower understanding children, even if systematic appropriation were beyond them, since it would have provided them with more support over a range of problems allowing them to build up the necessary procedural basis to begin the shift to explicit representations. Higher understanding children, in contrast, might actually benefit from more limited support since this would encourage autonomous use of appropriated explanatory frameworks at an earlier stage. It was therefore decided to contrast the effects of discontinued and continuous support in the present study, particularly with regard to their impact on children at different representational levels.

The participating 7- to 8-year old children were split into two equal groups comprising those who were supported continuously across the three time-points, and those whose support was discontinued after Time 1, with comparable numbers of higher and lower understanding children being assigned to each condition.

Differences between conditions, and between ability grouping were analysed with respect to the number of attempts required to successfully complete the task, and the level of explanation given by the children at each time-point, with explanations being taken as the more central index of children's explicit understanding of the task.

It was anticipated, in line with Tolmie *et. al.*'s (2005) findings and those of Study 1, that children who were of lower understanding in terms of basic balance principles as determined by the classification task, would benefit more, initially at least, from adult input focusing on procedural actions, such as nut/peg prompts, as opposed to higher-level explanations. In contrast, children of higher understanding were predicted to follow the opposite pattern, as they would already hold at least a basic grasp of weight and distance elements of balance, and thus would benefit from higher level weight x distance, and torque rule explanations. It was also predicted that continuous support given across the three time-points would ultimately benefit lower understanding children more, with respect to both procedural actions and explanations, as this would provide them with greater opportunities to gain procedural understanding through adult support, and then build on this to achieve a more explicit grasp. Children with a higher level of understanding were expected to benefit more from discontinued support, as higher level explanations given at the first time-point would be successfully appropriated by those children, and be used across the latter time-points, with subsequent support predicted to be an unnecessary intrusion, and a barrier to autonomous use of appropriated frameworks.

3.3. Method

3.3.1. Design

This study employed a two-way mixed design incorporating both between-subjects conditions (discontinued and continuous support), and repeated-measures factors (time-point of testing on the Balance Scale task). All children worked alone on an initial classification test and received support from an adult tutor on the Balance Scale task at the first time-point. Half of the children were then supported on the Balance Scale task over the following two time-points (continuous support condition), whilst the other half worked alone (discontinued support condition).

The purpose of the classification test was to determine children's understanding of balance prior to undertaking the Balance Scale task. Their understanding was assessed from their explanations of where they believed a series of six balance beams would balance if placed on a fulcrum. This information allowed for categorisation of children into higher or lower levels of initial understanding, and those categories formed an additional between-subjects factor in subsequent analyses.

Balance Scale performance was assessed in terms of the number of attempts required to achieve balance on each of four problems at each time-point, and the level of explanation offered for successful solutions. The nature of adult support on the Balance Scale task was coded in terms of type and frequency of intervention, and of explanation offered. Children's performance was analysed for change across time-points, differences between support conditions and between children with different initial levels of understanding, as well as for the relationship between adult input and child performance within condition and level of understanding.

3.2.2. Participants

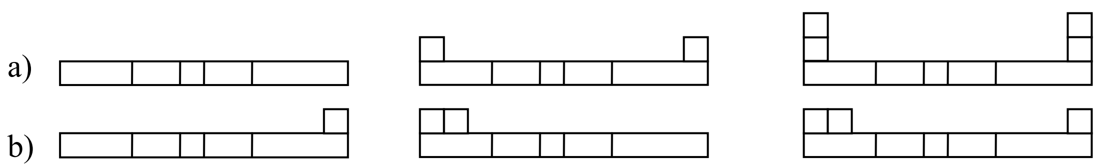
Participants consisted of 58 children from four Primary 3 classes within two primary schools in the West End of Glasgow. There were 36 boys and 22 girls, aged between 7 years, 2 months and 8 years, 5 months, with a mean age of 7 years, 8 months. Of these, 17 boys and 12 girls received support only at Time 1, and 19 boys and 10 girls received support on the Balance Scale across all three time-points. All children had English as their main or only language. Children participated with written consent from parents and the local education authority. The adults providing support comprised two female postgraduate students, with one assisting the researcher at a time. It was necessary to have two assistants to ensure availability on all days that the schools permitted testing to take place. The researcher and those assistants all had clearance from the University ethical committee and Scottish Criminal Record Office for undertaking research with children.

3.2.3. Materials

3.2.3.1. Balance Beams

The balance beams used in the classification test comprised three symmetrical and three asymmetrical wooden beams, 32cm long. Of the symmetrical beams, one consisted of a strip of wood with no blocks, one had a block at each end and one had two blocks mounted on top of one another at each end. The asymmetrical beams comprised one with a block at one end only, one with two blocks side by side at one end only, and one with one block at one end and two blocks side by side at the opposite end. Both symmetrical (a) and asymmetrical (b) beams can be seen in Figure 4. The beams had four lines marked, with each line corresponding to where at least one beam would balance. The symmetrical beams balanced on the third (centre) line (with lines marked from left to right). Of the asymmetrical beams, the one-block beam balanced on the fourth line, the two-block beam balanced on the first line and the final 3-block beam balanced on the second line. A fulcrum (4.6cm x 0.6cm) accompanied the beams.

Figure 4. Symmetrical (a) and asymmetrical (b) beams used in classification test.



3.2.3.2. Balance Scale

The Balance Scale apparatus was the same as that used in Study 1. A description of the Balance Scale equipment can be found on p. 43.

A video camera was again used to record the children's performance on the tasks.

3.2.4. Procedure

After receiving permission from the local education authority and schools involved, parents of Primary 3 children were sent forms through the schools requesting their permission to allow their children to participate in the research. They were informed that the research involved looking at how children formulated problem-solving strategies, and told that their children would be supported on a task by an assistant of the researcher. Children only participated after their parents had granted consent.

The researcher introduced herself to each class prior to testing, so that she would be familiar to the children when they came to be taken out individually. Testing took place in a quiet unused classroom over four sessions. Each child was firstly given the individual classification test. They were asked to sit at a table on which the beams and fulcrum lay. The researcher explained that the purpose of this exercise was to find how much they knew about balancing things. They were informed that they would be shown each beam one at a time, and had to determine which of the four lines each beam would balance on if placed on the fulcrum, although they would not be able balance anything at that time. The presence of the camera was also clarified to them, in terms of the researcher's need to have a record of performance to examine afterwards. When the child was happy with what they were asked to do the camera was switched on and the child was presented with the beams, one at a time and chosen at random from the six. Each beam was held over the fulcrum, but did not touch it. Once they had made a prediction on one beam they were asked to explain their reasons for choosing the particular line, and then the next beam was presented to them. After they had made and explained their predictions on each beam they were thanked and taken back to class. At no point were children given any feedback on their performance.

3.2.4.1. Coding of the classification test

Children's explanations of why they believed each beam would balance on a certain line were scored depending on how far their answers for each beam addressed the salient factors. The criteria for each level of explanation can be seen in Table 6. Weight was given a lower rating to distance, as by 7 years of age, children tend to recognise that weight is an important factor in problems requiring equilibrium (Karmiloff-Smith & Inhelder, 1974). However, recognising the importance of distance in balancing is more difficult for children to comprehend.

Table 6. Coding of children's explanations on the Classification Test

Level of Explanation	Balance Beam
0	No meaningful explanation given
1	Centre of beam is important
2	Weight is important
3	Distance is important
4	Weight and distance are both important

The children were then categorised as lower or higher understanding based on the explanations they gave on this task. If they gave no meaningful explanation for the balance beams, or explained that beams, including those that were asymmetrical, balanced in the middle, they were classed as being of lower understanding, with only implicit grasp of the factors affecting balance. In contrast, those children who spoke of weight and/or distance being important, regardless of whether they had correctly predicted where a beam would balance on the fulcrum, were classed as being of higher understanding in the sense that they had at least some explicit grasp of the factors at work. For this exercise, the children's prediction answers were not taken into account. Approximately equal numbers of children were categorised as having lower and higher understanding (31 and 27 children, respectively), and those at each level were then allocated evenly to discontinued (15 lower and 14 higher level children) and continuous (16 lower and 13 higher level children), support conditions.

After a break of two days, and before working with the children, the two assistants were introduced to the classes. Only one assistant worked with a specific child and on separate days to the other assistant, regardless of support condition. Both assistants were MSc Psychology students attending the same University as the researcher, and both were trained in contingent scaffolding techniques prior to assisting the children, along with the correct way to complete the Balance scale. The training session was organised as follows:

Script of Training Sessions with Assistants

1. The first assistant was asked to meet with the researcher and shown the Balance Scale task. The second assistant was asked to come to the meeting 15 minutes subsequent to the first assistant.

> Researcher:
> Here is the Balance Scale that you will be working on with the children. I'll tell you the rules of the task in the same way that the children will be told. Then I will show you the problems that the children will be given, and you will work through them, one at a time until you have successfully balanced the scale. Firstly, I will put weights on my side (researcher motioned to the left side of the scale), and your job will be to put weights on your side (researcher motioned to the right side of the scale) in such a way that when the rest is removed (researcher pointed to blue rest), the scale will stay in this balanced position. However, you are not allowed to have the same arrangement as me, and you are not allowed to put weights on my side of the scale. You can use as few or as many weights as you think you need to balance the scale. Do you understand everything so far?

2. When the assistant was happy with what she was asked to do, she was shown the first arrangement.

> Researcher:
> If I do this (put two nuts on peg 1), what would you do to make the scale balance?

3. The researcher watched while the assistant tried different configurations, asking occasionally why the scale was not balancing. When the assistant successfully balanced the scale the researcher asked her to explain how it balanced.

4. The remaining five problems were presented to the assistant in the same way as above.

5. After the assistant had successfully completed the final arrangement and explained her methods, she was told that the other assistant would be coming in shortly but she was not to discuss the answers with her.

6. When the second assistant entered the room, the researcher repeated steps 1 to 4 with her.

7. After the assistant had successfully completed all six arrangements and explained her methods, the researcher told both assistants that she was going to explain exactly how to complete the task successfully and teach them to explain their answers in terms of the torque rule.

Researcher:
Ok, so now I'm going to tell you exactly how to complete the task, so that you do not have to use trial-and-error techniques. Have you heard of the torque rule? (even if the assistants had said yes, the researcher would go through it anyway, just to make sure they knew the proper rules). The torque rule is concerned with the relationship between weight and distance, so the weight times distance calculation has to be the same on both sides for the scale to balance. If you think of the pegs as being numbered, this would be number one (researcher pointed to the peg on her side nearest the centre of the scale), two (pointed to the next peg out), three (pointed to the second peg from the end), and four (pointed to the end peg). (She did the same for the other side of the scale). So if I put two weights here (researcher put two weights on peg 1 as for the first arrangement), that would be two weights on peg 1, two times one is two, so you would have to make up two on your side. To do this, you would put one weight on peg two, which would be one times two, which makes two. Do you understand?
For the second problem (researcher put a weight on peg 2 and one on peg 4), there was one weight on peg 2 (pointed to it), and one on peg 4 (pointed to it). Two plus four is six so you have to make six on your side. So you could have two weights on the third peg or a weight on pegs 1, 2 and 3. You could have any combination of weights that add up to six, as long as it's not the same combinations as mine.
For the third problem (researcher put four weights on peg 2), can you tell me what that adds up to? (They would hopefully say eight). Can you tell me some different configurations that would make this one balance? (the researcher listened to the assistants explain the different ways they could make their side add up to eight). So, do you understand now how you can look at my side and balance your side straight away? We'll just go through the final three arrangements to ensure you know exactly what to do.

8. The researcher then presented the final three arrangements as above, and asked the assistants, firstly what number her side made, and then how they could make their side balance in terms of making up the same number.

9. The assistants' roles in the research were then explained to them.

Researcher:
The children are all going to work on this task three times. You will work with all of the children on the Balance Scale at the first time-point. However, half of the children will then work alone on the task for the remainder of the study. The other half will work with you at each of the following two time-points.
Your role will involve only intervening when the child is making mistakes. You should not be too directive with them and not take over control of the scale.

10. The researcher then showed them a video of parents working with high-level children, with some parents offering high-level explanations of the task. Their

attention was drawn to behaviours used by the parent, and the assistants were informed of the general principles of scaffolding.

The researcher did not tell the assistants about the hypotheses of the study, or explain any background theory; they were simply informed that the desired end-goal was children who could solve problems quickly and successfully explain their methods. When the assistants were happy and confident with their task they were ready to enter into schools with the researcher and work with the children.

At the first time-point of testing on the Balance Scale, which took place two days after the classification test, each child was taken out of class individually, as before, and invited to sit beside whichever assistant they were working with. Children were informed that their assistant was there to help them on the task. Children were introduced to the Balance Scale, which was set up in its start position. This consisted of the eight nuts positioned in a line in front of the scale. They were told that the goal of this problem was to make the scale balance when nuts were placed on it. The researcher explained to the children that she would put an arrangement of nuts on "her side" of the scale and they had to make it balance by arranging nuts on "their side". However, the nuts could not be placed either on the researcher's side, or on the child's side in the same arrangement as the researcher had positioned hers, as this would make the task too easy. They were informed that there would be four problems set in total for the task, "to see how you can do different types of problems". The four combinations used at Time 1 and the subsequent two time-points were identical to those used in Study 1 and can be seen in Table 1 on p. 45.

When the child was happy with what they were asked to do the camera was switched on and the researcher set up the first arrangement. The child then attempted to assemble nuts on their side to balance the researcher's arrangement before removing the rest, and the assistant helped when she felt it appropriate. If the scale did not balance the rest was inserted back into the beam and the child tried again. This was repeated until the child's configuration balanced that of the researcher. The only time the researcher intervened during this period was when the child had successfully balanced an arrangement, as a new configuration had to be set up. The torque rule was not explained by the researcher at any point, but immediately after the children had completed each trial, they were asked, "Can you tell me how you made it (the scale) balance"? Another break of two days was given prior to the second time-point, and then again before Time 3. At Times 2 and 3, those in the continuous support condition again worked with the assistant, whereas those in the discontinued support condition now worked on the task alone. For both conditions the same rules applied as before. As before, the children worked until they completed each problem and were then asked to explain their methods. They were then congratulated, thanked and taken back to class.

3.2.4.2. Scoring

The videotapes of each session were transcribed to provide a written record of children's attempts, together with their explanations, and provide a profile of the nature of adult support.

Coding of the Balance Scale task. Attempts on the Balance Scale task were scored in the same way as in Study 1 (see Table 2, p. 47).

On the basis of this coding, two dependent measures were derived for performance on each individual problem across the three time-points: 1) *the number of attempts made*; 2) *the proportion of attempts at either level 6 or 7*, in other words, the extent to which attempts indicated an appreciation of the need to manipulate both weight and distance, albeit without the child necessarily being able to determine their exact relationship. Since a perfect performance would be a single attempt at level 7, fewer attempts and a higher proportion at level 6/7 were indicative of better performance.

A group-level index of the proportion of only single or double attempts taken to balance the scale was also computed, as the sum of all single or double attempts which led to a correct solution within each group of children, divided by the total number of attempts made within that grouping. The proportion of single and double attempts were analysed to find whether those became more commonplace as time went on.

Explanations. Immediately after the child had successfully balanced each arrangement, they were asked to explain their methods, and their answers were transcribed and coded from later videotape analysis. The response given for each problem was coded individually using exactly the same procedure as in Study 1, details of which can be found on p. 48.

<u>Coding of adult input</u>. Again, coding of adult prompts and explanations was the same as in Study 1 (see p. 48). However, this present study required minor adjustments to the adult codes, which included omitting the code for ‘direct control’, as this was not observed here, and including a new code for input which was not observed in the previous study, ‘implicit weight/distance’ prompts. Those were statements referring obliquely to both weight and distance changes that the child could make to their incorrect arrangements (“to balance the scale you could either remove/add on nuts or move them to another part of the scale”). An example of adult support using implicit weight/distance prompts can be seen in Appendix 4.

For each child, a count was made of the number of times each type of assistance and explanation was used across the attempts relating to an individual problem. Scores on those eight variables (i.e. four assistance and four explanation codes) for the Time 1, and where appropriate, Times 2 and 3 problems, formed the raw data for subsequent analysis.

<u>Reliability</u>. The reliability of the coding system was checked through independent examination of seven (approximately 10%) of the Time 1 transcripts. Transcripts were coded with respect to children’s attempts and explanations, and adult support measures and explanations. With respect to children’s attempts, the agreement rate was 100%. Children’s explanations were scored in terms of frequency of each of the five levels (0 to 4) provided. The mean agreement for the four explanation codes was 98.2%. The average agreement rate for adult assistance, which was scored in terms of frequency of each assistance and explanation code type, was 90.9%.

3.3. Results

3.3.1. Overview of analyses

Analyses focused on: 1) the nature of input administered across time to children who received continuous support compared with those who only received support at the first time-point; and, 2) the impact of the two support conditions and children's initial level of understanding on their performance and understanding of the task. An overall profile of children's performance on the Balance Scale task was then examined, with a more detailed breakdown of data exploring their performance and explanations across the four problems at each time-point. More fine-grained analyses focused on the impact that different types of adult support had on children's attempts and understanding at and across the three time-points, within support condition and initial level of understanding.

3.3.2. Profile of Adult Support on the Balance Scale task

It was necessary to firstly investigate the adult input given to all children at Time 1, and that provided to children in the continuous support condition at Times 2 and 3. In particular it was important to ensure parity of input at Time 1, when all children received support.

Initial analyses computed on the adult data at Time 1 investigated how far input in the continuous support condition exhibited proportionately the same distribution of types as that in the discontinued condition. At this point children's level of understanding was not taken into account as it was important to establish that there were no differences with respect to support condition. All children were found to receive very similar amounts of input of all types regardless of whether they were continuously or discontinuously supported.

Independent samples t-tests were computed on the Time 1 data and confirmed that there were no significant differences in the input given to children in the continuous and discontinued support conditions. Independent samples t-tests were used to compute this data as, although the same adults were involved in each case, it was individual child/tutor combinations that provided the unit of analysis, thus the observations could not legitimately be treated as related. To compare the input of the two tutors, further independent samples T-Tests were conducted on the total amount of each support type administered by each of the two adults from Time 1 to Time 3. Those confirmed there were no significant differences in any support measure apart from the number of torque rule explanations given. However, when looking closely at the total mean number of level 4 explanations given by each tutor, plus the standard deviations (0.79 and *0.77*; 0.31 and *0.54*, respectively), it could be seen that both adults gave a very low amount of those explanations, and the significance reflects the difference between values under one.

Subsequent analyses examined how far adult input varied depending on the children's support condition and level of understanding.

The mean frequencies of adult support measures given at Time 1 can be observed in Table 7a, and input measures for Times 2 and 3 can be observed in Table 7b. To help clarify the effects of the adult input, their prompts and explanations have been grouped according to children's support condition and initial level of understanding.

Table 7a. Adult Support Measures at Time 1.

Measure	Time 1							
	Discontinued Support				Continuous Support			
	Lower Understanding		Higher Understanding		Lower Understanding		Higher Understanding	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Non-Specific Prompts	16.47	*8.07*	13.00	*4.49*	18.44	*9.70*	14.77	*7.18*
Implicit Weight /Distance Prompts	3.20	*3.67*	2.50	*3.63*	2.19	*2.48*	1.31	*1.93*
Nut-Peg Prompts	9.33	*5.70*	9.43	*6.67*	8.81	*6.67*	6.38	*5.78*
Weight/Distance Prompts	0.67	*0.72*	0.79	*1.37*	0.75	*0.93*	0.62	*1.39*
Level 1 Explanations	13.20	*6.06*	9.93	*4.43*	14.81	*6.56*	11.08	*6.65*
Level 2 Explanations	0.07	*0.26*	0.14	*0.54*	0.63	*1.78*	0.08	*0.28*
Level 3 Explanations	2.93	*1.91*	1.29	*1.14*	2.87	*2.13*	1.38	*1.56*
Level 4 Explanations	0.53	*0.52*	0.14	*0.36*	0.56	*0.63*	0.33	*0.49*

From Table 7a, it can be seen that the most common methods of support given at Time 1 were non-specific prompts and explanations based on weight, followed by nut/peg prompts. In fact, there was a noticeable difference in the number of non-specific prompts and level 1 explanations given to children depending on their initial level of understanding. Univariate 2-way Anovas (support condition x level of understanding) computed on the eight adult input measures at Time 1 found significant main effects of children's level of understanding with regards to adult explanations given at level 1 ($F(1,54) = 4.91$, $p=.031$), level 3 ($F(1,54) = 11.64$, $p=.001$), and level 4 ($F(1,54) = 5.72$, $p=.020$). From observing the means in Table 7a, this confirms that a significantly higher number of those explanations were given to children who were of lower understanding as opposed to those who were more knowledgeable of the weight/distance properties. Despite the fact that a noticeably higher number of non-specific prompts were given to lower understanding children, this difference was not significant. There were no significant main effects of support condition and no interaction between support condition or level of understanding.

Table 7b shows the input given to children in the continuous support condition only at Times 2 and 3, split into their level of understanding.

Table 7b. Adult Support Measures at Times 2 and 3.

	Time 2				Time 3			
Measure	Lower Understanding		Higher Understanding		Lower Understanding		Higher Understanding	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Non-Specific Prompts	9.19	*5.56*	8.92	*6.06*	11.06	*6.44*	6.08	*4.23*
Implicit Weight /Distance Prompts	3.00	*2.00*	1.54	*1.90*	0.94	*1.48*	0.77	*1.09*
Nut-Peg Prompts	9.75	*6.69*	6.00	*5.29*	8.56	*4.90*	3.92	*3.66*
Weight/Distance Prompts	1.19	*0.98*	0.69	*0.86*	1.13	*1.20*	0.77	*2.20*
Level 1 Explanations	5.69	*3.01*	5.31	*5.25*	9.69	*7.26*	5.92	*6.13*
Level 2 Explanations	0.25	*0.58*	0.15	*0.38*	0.31	*0.70*	0.15	*0.56*
Level 3 Explanations	3.25	*2.96*	1.08	*1.04*	1.69	*1.85*	1.00	*1.29*
Level 4 Explanations	0.13	*0.34*	0.31	*0.86*	0.19	*0.40*	0.00	*0.00*

It can be seen from Table 7b, that the majority of input again centred on non-specific prompts, nut/peg prompts and explanations based on weight, and this was true for both Times 2 and 3. Univariate one-way Anovas were again computed on the eight adult input measures employed at Times 2 and 3 by children's initial level of understanding. At Time 2, there were significant main effects only with regards to adult explanations given at level 3 ($F(1,27) = 6.35$, $p=.018$). At Time 3, there were significant main effects of non-specific prompts and nut/peg prompts ($F(1,27) = 5.75$, $p=.024$) and ($F(1,27) = 8.00$, $p=.009$), respectively. As with Time 1, a significantly higher number of the explanations and prompts highlighted above were provided at both latter time-points with the lower understanding children than those who were of higher understanding.

To investigate how the pattern of support changed *over* the three time-points, two-way mixed Anovas (time-point x level of understanding) were computed. Significant main effects of Time were found for non-specific prompts ($F(2,54) = 17.03$, $p<.001$), level 1 explanations ($F(2,54) = 17.69$, $p<.001$), and implicit weight/distance prompts ($F(2,54) = 4.69$, $p=.019$). Follow-up paired samples t-tests found that the two former input measures decreased significantly in usage from Time 1 to Time 2 ($p<.001$ for both), and were used significantly less frequently at Time 3 than at Time 1. Implicit weight/distance prompts were found to decrease in usage significantly only from Time 2 to Time 3 ($p<.001$)

Significant main effects of understanding level were found for nut/peg prompts ($F(1,27) = 5.65$, $p=.025$) and level 3 explanations ($F(1,27) = 13.90$, $p=.001$). This confirms that significantly more of those prompts and explanations were used with children of lower understanding than those who were of higher understanding.

3.3.3. <u>Profile of children's performance on the Balance Scale task</u>

A detailed breakdown of each child's number of attempts and explanation level on the four problems at each of the three time-points can be observed in Table 8, and the mean frequency of attempts undertaken along with the mean level of explanation across the three time-points can be seen in Table 9. Again, to help clarify the effects of adult input, children are grouped in both tables according to their support condition and initial level of understanding. The presence of systematic trends within the data was examined by means of three-way mixed Anovas on the measures of attempts and mean explanation level (time-point x support condition x level of understanding), along with the relevant correlational analyses.

Table 8. Number of attempts and explanation levels for correct solution for each child on the Balance Scale task, on Problems 1 to 4 (P1 to P4) at Times 1, 2 and 3, ordered by conditions of Discontinued Support, Lower Understanding, (*DS LU*), Discontinued Support, Higher Understanding, (*DS HU*), Continued Support, Lower Understanding,
(*CS LU*) and Continued Support, Higher Understanding, (*CS HU*). Level 4 explanations are shown in bold.

	Time 1								Time 2								Time 3							
	Attempts				Exp level				*Attempts*				Exp level				*Attempts*				Exp level			
	P1	*P2*	*P3*	*P4*	P1	P2	P3	P4	*P1*	*P2*	*P3*	*P4*	P1	P2	P3	P4	*P1*	*P2*	*P3*	*P4*	P1	P2	P3	P4
DS LU																								
1	4	3	4	8	3	2	3	3	4	10	2	10	0	1	0	0	10	3	9	4	3	0	2	0
2	2	5	4	2	**4**	1	3	0	7	12	24	9	3	3	1	3	14	9	8	4	3	1	3	3
3	12	13	1	6	3	3	3	3	5	6	4	9	3	3	3	3	3	8	14	3	1	3	3	1
4	6	9	5	7	0	0	3	1	17	5	1	8	2	0	0	3	19	8	1	1	2	0	0	1
5	4	3	2	5	2	1	1	3	10	4	14	15	1	1	3	1	13	3	3	4	3	3	3	3
6	16	7	11	3	3	1	3	3	16	1	5	10	3	1	1	1	8	1	6	1	1	3	3	3
7	14	3	3	4	3	3	3	3	6	4	12	2	1	1	1	1	18	11	6	2	3	3	3	3
8	7	16	9	15	3	3	3	3	4	3	11	12	3	3	3	3	4	5	3	5	3	3	3	3
9	2	2	5	3	1	3	3	3	11	7	5	3	3	3	3	3	4	1	8	8	3	3	3	3
10	2	7	5	2	1	3	1	3	6	3	3	3	0	1	1	0	2	1	5	3	3	1	3	1
11	11	4	4	1	0	3	3	3	13	5	3	1	**4**	3	3	3	3	3	1	8	**4**	3	3	3
12	9	8	6	5	0	0	3	3	6	5	4	15	3	3	3	3	7	1	13	11	3	3	3	3
13	1	8	3	18	1	1	1	1	17	8	39	5	1	3	3	3	7	5	12	11	3	1	0	1
14	10	27	14	2	2	3	3	3	11	7	3	4	3	3	3	3	21	1	13	1	3	3	3	3
15	6	1	5	2	3	3	3	3	25	4	21	11	3	3	3	3	15	9	1	5	1	3	3	1
Mean	7.1	7.7	5.4	5.5	1.9	2.0	2.6	2.5	10.5	5.6	16.7	7.8	2.2	2.1	2.1	2.2	9.2	4.6	6.9	4.7	2.5	2.2	2.5	2.1
DS HU																								
1	11	3	3	7	3	3	3	3	8	9	3	7	3	3	3	3	3	2	1	12	3	3	3	3
2	6	7	5	1	2	3	0	1	10	10	1	2	**4**	3	3	3	11	5	1	1	3	1	3	3
3	7	10	2	2	3	3	3	3	11	1	9	2	3	3	3	1	2	1	5	3	3	3	3	3
4	8	3	12	4	0	0	1	1	6	4	22	6	1	3	3	1	5	2	6	5	3	1	3	3
5	8	12	11	6	3	3	3	3	10	14	12	5	3	1	3	3	1	3	2	3	3	3	3	3
6	11	5	8	13	1	3	3	3	7	4	1	11	1	3	3	3	1	1	4	5	3	3	3	3
7	6	3	6	21	3	1	3	3	12	6	1	1	3	3	3	3	12	5	7	1	3	3	3	3
8	11	9	8	6	3	3	3	3	4	6	2	2	3	3	3	3	9	1	3	4	1	3	3	3
9	2	4	15	2	1	1	3	3	9	4	4	15	3	1	1	1	5	7	6	2	3	3	1	3
10	14	9	12	2	3	1	1	1	2	4	11	2	1	1	3	3	14	15	8	9	1	1	1	1
11	12	3	2	2	3	3	0	3	3	4	14	6	2	3	3	3	4	8	3	5	3	3	3	3
12	11	4	5	2	3	3	3	3	3	5	7	3	3	3	3	3	6	3	6	2	3	3	3	3
13	8	4	1	4	**4**	**4**	**4**	3	1	1	1	1	**4**	3	**4**	3	1	1	1	1	**4**	**4**	**4**	**4**
14	5	8	1	2	3	3	3	3	1	1	3	4	3	3	3	3	2	7	4	4	3	1	3	3
Mean	8.6	6.0	6.5	5.3	2.5	2.4	2.4	2.6	6.2	5.2	6.5	4.8	2.6	2.6	2.9	2.6	5.4	4.4	4.1	4.1	2.8	2.5	2.8	2.9

CS LU																								
1	10	2	4	2	**4**	3	2	3	10	2	4	2	**4**	3	3	3	4	1	1	6	1	3	3	3
2	5	8	13	15	0	3	0	3	2	1	11	1	1	3	3	3	2	1	6	3	1	1	3	3
3	18	12	2	17	0	3	3	0	26	4	1	4	3	3	3	3	11	2	16	11	3	3	3	3
4	7	5	1	3	3	0	3	3	1	2	4	5	3	3	3	1	1	1	5	2	**4**	**4**	3	1
5	3	4	12	1	3	3	0	2	1	2	3	1	3	0	1	3	2	1	1	3	0	3	0	1
6	4	15	1	16	1	3	3	1	14	4	6	2	3	1	3	1	6	8	6	2	1	3	3	3
7	8	13	2	6	3	0	0	0	8	2	6	5	0	0	3	3	5	2	9	7	3	0	0	3
8	12	23	28	8	1	3	3	2	4	4	11	8	1	1	1	1	17	6	4	8	3	3	3	3
9	1	6	9	8	0	3	0	3	20	3	4	5	0	3	3	1	21	8	4	4	3	1	3	3
10	3	9	2	11	0	0	0	0	4	8	3	4	3	0	1	0	7	2	1	6	3	3	3	3
11	2	1	3	5	0	0	0	0	1	4	2	6	1	0	0	0	1	2	2	7	1	0	0	0
12	12	8	13	1	3	3	3	3	4	8	10	13	3	3	1	3	5	3	22	4	3	3	1	3
13	6	4	3	2	1	1	3	3	5	2	4	4	0	3	3	1	2	3	3	9	3	3	3	3
14	5	8	7	6	1	1	3	3	4	14	4	4	1	1	1	1	12	5	6	5	3	3	3	3
15	7	7	6	7	1	3	1	3	9	1	6	6	3	1	3	3	3	2	4	9	3	3	3	3
16	1	10	13	5	3	3	3	3	14	4	22	3	3	3	3	3	5	5	5	2	3	3	3	1
Mean	6.5	8.4	7.4	7.1	1.5	2	1.7	2.0	7.9	4.1	6.3	4.6	1.6	1.8	2.2	1.9	6.5	3.3	5.9	5.5	2.4	2.4	2.3	2.4
CS HU																								
1	1	8	3	3	3	0	3	3	4	13	7	17	3	3	3	3	2	3	1	8	0	0	0	0
2	1	9	12	5	3	1	3	3	24	1	4	7	3	3	3	3	1	1	1	6	3	3	3	3
3	4	4	6	3	3	3	3	3	3	2	1	2	2	3	3	3	1	1	1	4	3	**4**	1	3
4	7	9	1	1	3	3	3	3	1	1	9	2	3	3	3	3	3	1	2	1	3	3	3	3
5	7	9	5	19	3	0	3	3	3	6	1	4	3	3	**4**	3	3	1	6	3	2	2	3	3
6	1	4	9	2	3	1	**4**	3	1	7	18	4	3	1	3	3	1	3	4	3	0	0	3	0
7	4	19	5	7	3	3	3	2	1	2	6	2	2	3	3	1	1	19	5	4	3	3	3	3
8	5	6	1	10	3	**4**	3	3	7	1	5	6	3	3	3	3	2	1	2	5	3	3	1	3
9	6	16	4	4	**4**	1	3	3	5	20	11	3	2	3	3	3	4	22	9	1	3	1	3	2
10	3	2	5	1	1	0	0	0	2	1	2	4	**4**	0	0	0	2	1	3	1	3	3	3	0
11	18	5	3	5	3	3	3	3	17	9	5	2	3	3	2	3	4	2	3	6	3	3	2	3
12	10	3	2	4	0	0	1	2	1	1	2	14	3	1	0	1	1	1	3	4	3	0	1	3
13	14	12	1	4	3	3	3	3	3	7	1	4	3	3	3	3	2	2	1	5	3	3	3	3
Mean	6.2	8.2	3.6	5.2	2.7	1.7	2.7	2.6	5.5	5.5	5.5	5.5	2.8	2.5	2.5	2.5	2.1	4.5	3.2	3.9	2.5	2.2	2.2	2.2

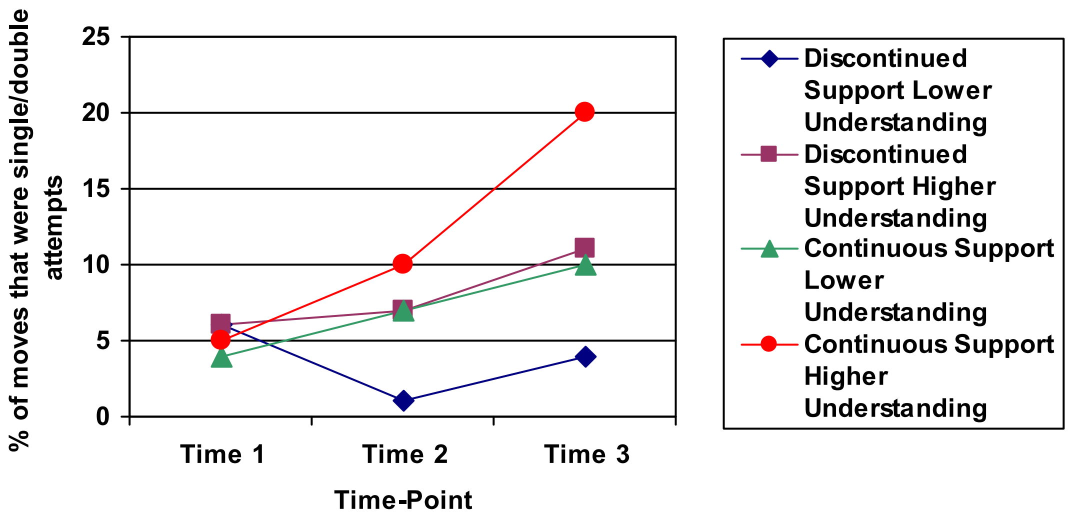
Table 9. Mean number of attempts and level of explanation in all children, split into their support condition and level of understanding.

		Discontinuous Support				Continuous Support			
Measure	Time-Point	Lower Understanding Mean	SD	Higher Understanding Mean	SD	Lower Understanding Mean	SD	Higher Understanding Mean	SD
Attempts	1	25.73	*12.50*	26.43	*8.05*	29.44	*14.89*	24.00	*8.89*
	2	34.00	*15.40*	22.71	*10.19*	22.88	*9.85*	22.00	*12.03*
	3	26.07	*8.49*	17.93	*9.68*	21.19	*10.60*	13.62	*8.88*
Mean Explanation Level	1	2.27	*0.70*	2.46	*0.85*	1.80	*0.92*	2.42	*0.91*
	2	2.15	*1.04*	2.68	*0.55*	1.95	*0.86*	2.58	*0.70*
	3	2.37	*0.79*	2.75	*0.64*	2.39	*0.82*	2.27	*0.93*

a) Attempts. It can be seen from Table 8 and more clearly from the means in Table 9, that whereas children in both discontinued and continuous support conditions who were of higher understanding showed a steady decrease in their attempts, this was not the case in the lower understanding children. Whereas the latter did show the same pattern when they belonged to the continuous support condition, those who received support only at Time 1 showed an increase in attempts, consistent with exploration on the task, at Time 2, but then decreased in their attempts at the final time-point, although only to the level at which they started. The general decrease in attempts across the time-points resulted in a overall main effect of Time ($F(2,108) = 8.54$, $p=.001$), with follow-up paired samples t-tests confirming that activity did decrease significantly between Times 2 and 3 ($p<.01$) and from Time 1 to Time 3 ($p<.001$). There was also a significant main effect of level of understanding on the number of attempts undertaken ($F(1,54) = 6.57$, $p=.013$), showing that children of higher understanding did perform significantly less attempts overall than the lower level group. In fact, by Time 3 the higher level children who were continuously supported showed the greatest improvement in performance (mean = 13.62, compared with 26.07, 17.93, 21.19 for children in the other three conditions). However, despite those noticeable differences, there were no interaction effects for Time, understanding level or support condition, reflecting the fairly large standard deviations. The interaction between Time, support condition and level of understanding was marginal, however, as $p<.1$.

To investigate children's performance in terms of their success in balancing the scale using the least number of attempts, the proportion of single or double attempts taken to balance the scale across the four problems was calculated within children's support condition and level of understanding at each time-point (see Table 8 for a detailed breakdown of this data). To find the proportion of single or double attempts made to successfully balance the scale over the four problems, the sum of all single or double attempts within each group of children (CSLU, CSDU, DSLU, DSHU), were taken and divided by the total number of attempts made within each grouping. The results can be observed in Figure 5.

Figure 5. % of attempts at each time-point that were single or double attempts only.



It can be seen from Figure 5 that, at Time 1, all children were performing similarly in terms of the number of single or double attempts made to successfully balance the scale. Closer examination of Figure 5 shows that the lower understanding, continuously supported children achieved balance in those minimal moves slightly less than children belonging to the other three groups (4% compared to 5, 6 and 6%).

At Time 2, however, this pattern had changed, as the lower understanding, continuously supported children were now balancing the scale in proportionately more single/double attempts than the lower understanding group now working alone (7% compared to only 1%, respectively). Interestingly, those children who were still receiving support and were of lower understanding were making proportionately the same number of single or double moves to balance the scale as the higher understanding children who were now working alone. The most successful group at this second time-point, in terms of their ability to balance the scale in one or two moves, were those who were of higher understanding and still receiving support. 10%

of the total number of moves they made to balance the scale was either achieved in a single or double attempt.

At Time 3, this latter group were very much outperforming the others in their ability to balance the scale in one or two moves as 20% of their total Time 3 attempts were all single or double attempts. Again, the lower understanding, supported children were performing proportionately the same number of single/double moves to balance the scale as higher understanding children working alone (10% and 11%, respectively). The children who made the least number of single/double attempts to balance the scale overall were those who were of lower understanding and had their support discontinued after the first time-point, as their ability to balance the scale in one or two attempts only rose from 1% at Time 2, to 4% of their total number of moves required at Time 3.

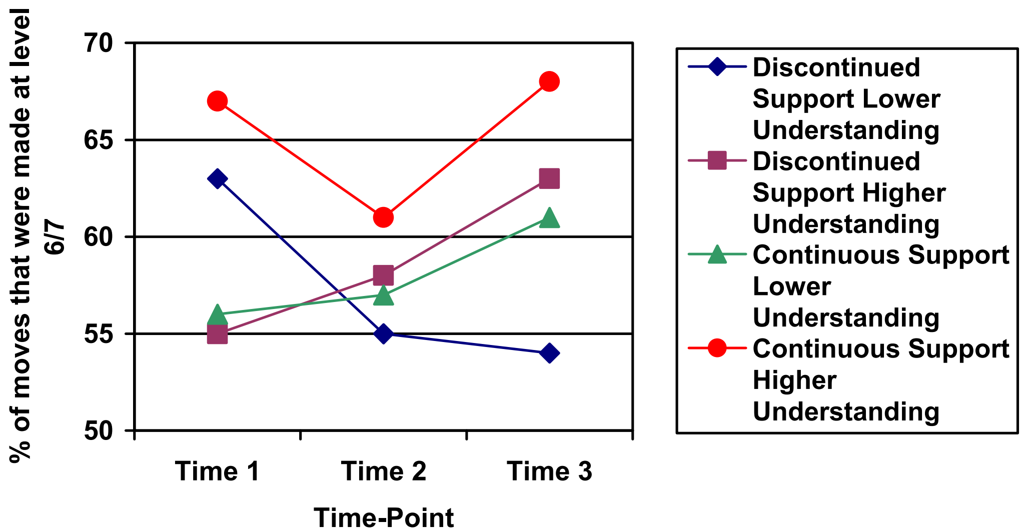
As a way of examining those differences further with respect to how individual children differed in their ability to complete a problem in a single or double attempt, the number of single/double attempts were subjected to individual-level analyses. A three-way mixed Anova (time-point x support condition x level of understanding) confirmed that the differences in the number of single or double attempts taken by individual children to balance the scale, led to a significant main effect of time-point ($F(2,108) = 7.13$, $p=.001$), with follow up paired samples t-tests revealing that the differences were significant between Times 1 and 3 ($p=.001$) and Times 2 and 3 ($p=.007$). This confirmed that the scale was successfully balanced in one or two attempts significantly more in proportion to the total number of moves made to achieve balance at Time 3 than at Times 1 or 2. There was also a main effect of level of understanding ($F(1,54) = 6.72$, $p=.012$), confirming that the higher understanding children did balance the scale in a single or double attempt significantly more than those of lower understanding. The final significant main effect was found with respect to support condition ($F(1,54) = 4.48$, $p=.039$, and Figure 5 shows that, as a whole, children who received continuous support balanced the scale in a single or double attempt significantly more than those who received discontinued support .

There was also a significant interaction between time-point and level of understanding ($F(2,108) = 3.72$, $p=.028$), confirming that, at the later two time-points, higher level children did balance the scale in only one or two moves significantly more often than children with lower understanding.

Along with finding how successful children were at balancing the scale in a minimal number of moves (i.e. in one or two attempts), it was necessary to find how *close* children were to balancing the scale prior to actually achieving balance. Children who were working within the parameters which indicated an appreciation of the need to manipulate both weight and distance, albeit without necessarily being able to determine their exact relationship, were coded as working at level 6. Attempts that actually balanced the scale were coded at level 7 (see Table 2, p. 47). A maximum of four attempts at any one time-point could have been coded at level 7, so level 6 and 7 attempts were taken together for analyses to examine how many moves, in proportion to the overall number of attempts taken to balance the scale, were either just off balance together with those that were actually successful.

To find the proportion of attempts made at level 6/7, the number of attempts made at those levels on the four problems were added together for each time-point, and divided by the total number of attempts made at the corresponding time-point (see the data for those values in Table 8). The results can be observed in Figure 6.

Figure 6. % of total attempts at each time-point that were made at levels 6 and 7.

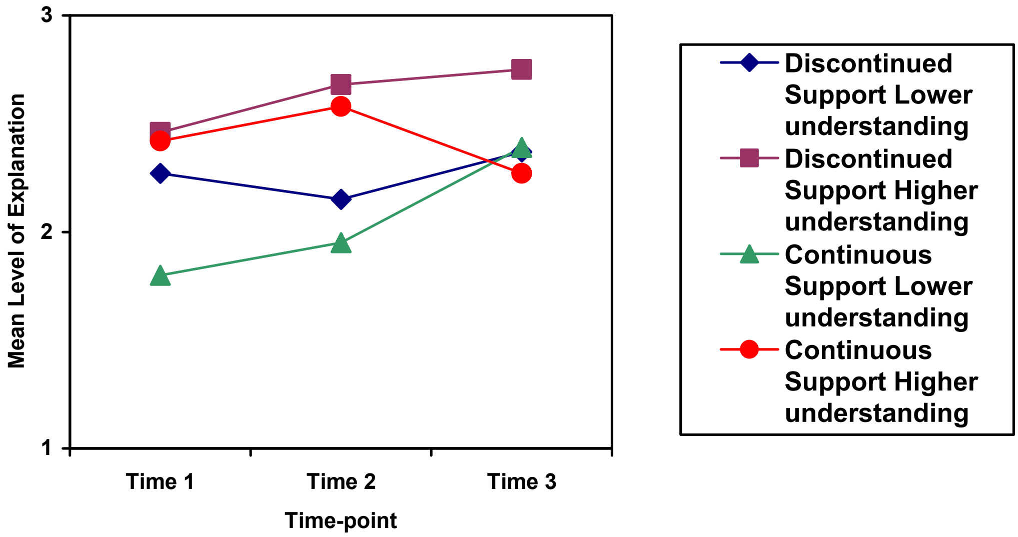


It can be seen from Figure 6 that the children who were continuously supported and of higher understanding performed consistently better than the other 3 groups in their proportionate number of moves made at levels 6/7 (67% compared to 63, 56 and 55%). Children of lower understanding whose support was discontinued after Time 1, did perform a fairly high proportion of levels 6/7 moves at this time-point. However, when support had ceased, this number fell considerably from 63% to 55% and then slightly to 54% at the final time-point. They performed the least proportionate number of level 6/7 moves at the second and third time-points when compared to the other 3 groups. With respect to children whose support was discontinued after Time 1, and were of higher understanding, they performed proportionately the least number of moves at levels 6/7 at Time 1, just slightly less than those of lower understanding whose support was continued throughout the study. At Time 2, however, both groups of children were performing very similarly (58% and 57%, respectively), and this was also true for Time 3 (63% and 61%). This data is very similar to that for the proportionate number of single/double attempts, as the two groups mentioned above also performed very similarly in the number of times they balanced the scale in only one or two moves. In fact, across Times 2 and 3 this data does, to a degree, mirror that for the single/double attempts, as the groups performed in the same order of success, in both cases.

A three-way mixed Anova (time-point x support condition x level of understanding) confirmed that those differences, with respect to the proportionate number of level 6/7 moves made by the four groups of children, led to a significant main effect of time-point ($F(2,108) = 8.03$, $p=.001$). Follow-up paired samples t-tests revealed that those differences lay between Times 1 and 2 ($p=.008$) and Times 1 and 3 ($p<.001$). There was also a main effect of understanding ($F(1,54) = 5.15$, $p=.027$) confirming that the higher understanding children were generally making significantly more moves at level 6/7 than those of lower understanding. There were no interaction effects between time-point, support condition and level of understanding.

b) Explanations. When looking back to Tables 8 and 9, it can be seen that the patterns of explanations were very different to those of attempts for the four groups of children. The mean explanation levels for children, split into their support condition and level of understanding at each of the three time-points, can be seen in Figure 7.

Figure 7. Children's mean level of explanation across time-point by level of understanding.



Children of higher understanding who were only supported at Time 1 gave the most sophisticated explanations over the three time-points, with this difference appearing particularly prominent at Time 3 (Mean explanation = 2.75 compared to 2.37, 2.39 and 2.27). From Table 8 it can be seen that across the 3 time-points this group of children consistently gave the most torque rule explanations (level 4), and the least explanations at level 0 (none present at the final two time-points). This confirms that every child in this group gave at least some form of relevant explanation during the second and final time-points. Comparing those children to their peer understanding group who were supported across the three time-points, the latter group gave a much smaller number of torque rule explanations, and a number of level 0 explanations at the final two time-points. Furthermore, this group appeared to peak in their mean explanation level at Time 2 (Mean = 2.58), and then fell slightly in their explanations at the final time-point (2.27), to a level closer to the two lower understanding children in the continuous and discontinued support conditions (2.39 and 2.37, respectively).

The group who appeared to make the most progress in their explanations was those of lower understanding who were supported throughout the study. At Times 1 and 2 they gave the lowest mean explanation level (1.80 and 1.95, respectively). However, there was a substantial increase in their mean explanation level at Time 3, as by this final time-point they were performing on a par with the supported higher understanding children, and lower understanding children now working alone.

A three-way mixed Anova (time-point x support condition x level of understanding) conducted on all children established that there were no main effects with respect to time-point, but there was a main effect of understanding on the mean level of explanation ($F(1,54) = 4.82$, $p=.032$) confirming that, in general, children of higher understanding gave a more sophisticated explanation than those of lower understanding. There were no significant interactions between time-point, support condition or level of understanding.

c) Relationship between children's attempts and explanations. To establish the relationship between children's performance on and understanding of the Balance Scale and their pattern of change over the three time-points, bivariate correlations were computed on attempts and explanations at each of and across Times 1 to 3. Those correlations will be reported firstly in the absence of adult influence, and the impact of adult support on children's performance and understanding will be reported later on. Analyses were conducted separately for each of the four groups of children. Results will focus firstly on the lower and higher understanding children whose support was discontinued, and then on lower and higher children in the continuous support condition. All correlations are one-tailed.

Although the following analyses reflect the trends of relationships between variables, it should be noted that they do not directly infer causation of one variable over another. Instead, interpretations of the correlational findings below are merely suggestions based on the direction (positive or negative) of the correlation coefficients.

For children of lower understanding who received discontinued support, their concurrent attempts and explanations were unrelated at all three time-points ($p>.1$), suggesting their actions were not being led by their understanding during any session. However, their attempts at Times 2 and 3 were positively related ($r = .45$, $p=.047$), as were their Times 2 and 3 explanation levels ($r = .45$, $p=.048$) indicating that their performance and understanding were improving gradually as time went on, although neither performance nor understanding were directing the other, even over time.

The pattern for higher understanding children whose support was discontinued was very different to that shown by those of lower understanding. Although attempts and mean explanation level were unrelated to one another at Time 1 ($p>.1$), the understanding gained from Time 1 predicted an improvement in performance and understanding both at Time 2 ($r = -.52$, $p=.028$, and $r = .58$, $p=.015$, respectively) and Time 3 ($r = -.53$, $p=.026$, and $r = .62$, $p=.009$, respectively). At Time 2, children's attempts were being guided by their understanding ($r = -.62$, $p=.009$), with understanding at Time 2 predicting a further increase in that at Time 3 ($r = .54$, $p=.022$). By this final time-point, the relationship between performance and understanding was very highly negatively related ($r = -.87$, $p<.001$).

This pattern of attempts and explanations becoming increasingly negatively related was identical to that for the higher understanding children in Study 1. This may suggest therefore, that children who have initial understanding about balancing a scale may benefit from support which is given only at an initial session, whereas those who do not have any prior understanding of balance do not benefit from support given at one session only. Certainly, the higher understanding children did not appear to be driven by their understanding of the task immediately, although by the second time-point, as they were undertaking the task independently, the understanding gained initially did direct their performance and lead to further understanding as time went on.

For children who were continuously supported, those of lower understanding showed a relatively similar pattern to the lower level children in the discontinued support condition, although there were also some noticeable differences. The main similarities were that concurrent attempts and mean explanation level were unrelated at every time-point, although the relationship did become positively stronger over time ($r = .16$; .32, and .40, for Times 1, 2, and 3, respectively), and the relationship was marginal at this final time-point ($p<.1$). This suggests a possible transfer from experience to understanding, as suggested for the lower understanding children in Study 1. As children's attempts here improved over time, their relationship at successive time-points became stronger ($r = .45$, $p=.040$, and $r = .73$, $p=.001$ from Times 1 to 2, and Times 2 to 3, respectively). There was also a strong association between attempts at Time 1 and Time 3 ($r = .62$, $p=.006$).

The relationship between attempts and explanations at successive time-points also became stronger over time ($r = .06$, $p>.1$, and $r = .41$, $p<.1$ from Times 1 to 2, and Times 2 to 3, respectively), as the relationship between explanations at successive time-points became weaker ($r = .67$, $p=.002$, and $r = .37$, $p<.1$ from Times 1 to 2, and Times 2 to 3, respectively). This is consistent with an improvement in the children's explanations being driven, at least in part, by their experience of solving problems.

Continuously supported children of higher understanding did not show nearly the same gains in their performance or understanding at each or across the three time-points, as those higher level children whose support was discontinued. One of the main differences between the two support conditions was that here, the relationship between attempts and mean explanations was positive and not negative as for the children in the other support condition. Furthermore, the significant associations between concurrent attempts and explanations at Times 2 and 3 seen in the higher discontinuous, were also lost here, although Time 3 was marginal ($r = .40$, $p<.1$).

Whereas the lower level continuously supported children showed consistently high carry-over between time-points in attempts, there was strikingly little seen here, with significance only between those at Times 1 and 3 (r = .51, p=.037). In terms of mean explanations, there was a shift from Times 1 to 2 (r = .85, p<.001), as seen in the lower level children in this condition, and a positive influence from Time 1 performance to Time 3 understanding (r = .50, p=.042). However, this influence shifted to being negative between performance at Time 2 to understanding at Time 3 (r = -.50, p=.042).

The influence of the Time 1 attempts on Time 3 understanding was rather suggestive of a return to the start-point, which is what the mean explanation levels actually exhibited.

It can be seen, therefore, that whereas the lower understanding children who were continuously supported appeared to use their experience of solving the balance problems in order to improve their understanding over time, those lower level children whose support was discontinued did not seem to have the ability to do this. The opposite pattern seemed to apply for higher understanding children, as when support was given continuously, those children did not appear to be driven by their prior understanding of balance, or their performance at early sessions. In contrast, when support was discontinued, the higher level children did appear to use their understanding gained at the initial, supported time-point, to direct their performance and lead to further understanding as they worked on the task, subsequently alone.

The extent to which adult input had an effect on those findings was then analysed.

d) Relationship between adult support and children's attempts and explanations.

To establish the effects that adult support had on children's performance and understanding on the Balance Scale task at each time-point and over time, bivariate correlations were computed between the 8 adult strategies and children's attempts and explanations. Again, analyses were conducted separately for the four groups of children and results for each group will be reported in the same order as before. It should be noted that a number of the correlation coefficients are based on data that have a very small frequency of occurrence (for example, explanations given at level 2), and so in these instances, the results should be interpreted with some caution.

Discontinuous Support condition

Lower Understanding children (n = 15)

Table 10a shows the relationships between adult input and children's attempts and explanations at Time 1, and Table 10b shows effects of adult input at Time 1 on children's attempts and explanations at Times 2 and 3.

Table 10a. Relationship between Time 1 adult input and children's attempts and explanations (all correlations are 1-tailed).

	Non-Spec prompts	Implicit w/d prompts	Nut/ Peg prompts	w/d prompts	Level 1 ex	Level 2 ex	Level 3 ex	Level 4 ex
Attempts	**r=.54 p=.018**	**r=.58 p=.012**	**r=.81 p<.001**	**r=.46 p=.041**	**r=.95 p<.001**	**r=.47 p=.038**	r=.22	**r=-.63 p=.006**
Mean Ex	r=.38	r=-.11	r=.13	r=-.23	r=.17	r=.29	r=.16	r=-.22
Non-Spec prompts	/	r=.23	r=.34	r=.00	**r=.64 p=.005**	**r=.53 p=.021**	**r=.68 p=.002**	r=-.41
Implicit w/d prompts		/	**r=.64 p=.005**	**r=.78 p<.001**	**r=.56 p=.015**	r=-.10	r=.27	r=-.32
Nut/Peg prompts			/	**r=.50 p=.030**	**r=.82 p<.001**	r=.23	r=-.11	**r=-.50 p=.028**
w/d prompts				/	r=.42 p=.058	r=-.26	r=-.02	r=-.26
Level 1 ex					/	**r=.58 p=.011**	r=.27	**r=-.58 p=.011**
Level 2 ex						/	r=.30	r=-.29
Level 3 ex							/	r=-.18
Level 4 ex								/

It can be seen from Table 10a, that the majority of support measures were associated with an increased number of attempts, in particular nut/peg prompts ($r=.81$, $p<.001$), and level 1 explanations ($r=.95$, $p<.001$). Despite the significant associations between adult support and children's attempts, however, their input appeared have no immediate effect on children's understanding, as there were no significant correlations between children's mean explanations and adult support measures. The one exception to the pattern of positive association with attempts was level 4 explanations, which were found to be negatively associated with children's attempts ($r=-.63$, $p=.006$). This might suggest that, in line with the findings from Study 1, higher level input given by the adults constrained the number of attempts children required to balance the scale. However, the general infrequency of level 4 explanations, the relatively high level of attempts among this grouping (see Table 8), and the absence of any negative relationship between attempts and weight/distance prompts indicates that this is unlikely. The more plausible explanation is that if children showed more aptitude by requiring fewer attempts to balance the scale, they received higher level explanations from the adult, and that adult input was in general reactive. Under this interpretation, the positive associations with the other forms of input simply reflect a tendency for input to go up more or less across the board the more attempts children made, with only level 4 explanations being used in more strategic fashion.

Consistent with this, adult prompts were all found to be interrelated, with the exception of non-specific prompts, and even the relationship between these and the other prompts was generally positive. This suggests those prompts tended to form part of an overall 'package' of support. In terms of adult explanations, Level 1 explanations were positively correlated with those given at Level 2 ($r=.58$, $p=.011$), but negatively correlated with explanations given at level 4 ($r=-.58$, $p=.011$), suggesting that lower level explanations were given together, but adults tended to either administer higher or lower level explanations, rather than both types together. Level 1 explanations were also highly related to all prompts, apart from weight/distance prompts to which they were marginally related. Prompts were all negatively related to level 4 explanations, including those that were non-significant. This tends to confirm the presence of a core package of prompts and level 1 explanations, and to a lesser extent level 2 and level 3 explanations, plus an alternative strand of input focused on level 4 explanations.

In sum, then, support apparently had little immediate impact on children's performance. The child generated much activity, the adult input in general (their support package) increased, but when the child generated less activity it was the adult torque rule explanations that increased.

Table 10b. Relationships between adult input at Time 1 and children's attempts and explanations at Times 2 and 3 (all correlations are 1-tailed).

	Time 1 Non-Spec prompts	*Time 1* Implicit w/d prompts	*Time 1* Nut/Peg prompts	*Time 1* w/d prompts	*Time 1* Level 1 ex	*Time 1* Level 2 ex	*Time 1* Level 3 ex	*Time 1* Level 4 ex
Time 2 Attempts	**r = -.50 p=.030**	r = .03	r = -.27	r = .03	r = -.19	r = -.07	r = -.04	r = -.08
Time 2 Mean ex	r = .27	**r = .56 p=.014**	r = .27	r = .12	r = .30	r = .23	r = .38	r = -.06
Time 3 Attempts	r = -.32	r = .38	r = .33	**r = .56 p=.015**	r = .13	r = -.30	r = -.33	r = -.16
Time 3 Mean ex	r = .12	r = .09	r = .34	r = -.24	r = .07	r = .22	r = -.11	r = -.21

Greater differentiation was apparent in the longer term effects of the adults' input, however. From Table 10b it can be seen that the number of non-specific prompts given at Time 1 was negatively associated with the number of attempts taken to complete the task at Time 2 (r = -.50, p=.030), whilst implicit weight/distance prompts were positively related to the mean level of explanation given at Time 2 (r = .56, p=.014). The implications of those significant correlations is that procedural support at Time 1 in the form of non-specific and implicit weight/distance prompts (the latter essentially amounting to implicit recommendations to alter the key factors at work) was helpful in terms of improving children's attempts and explanations, respectively, at Time 2 – and, as noted above, these were then correlated with attempts and explanations at Time 3. Despite these support strategies being beneficial to children's Time 2 performance and understanding, however, they had no direct impact on children's attempts and mean explanations at Time 3, suggesting an effect that was 'light touch' in character. In contrast, weight/distance prompts given at Time 1 were positively associated with Time 3 attempts (r = .56, p=.015), indicating that more explicit assistance led to confusion rather than more focused activity. Level 4 explanations, despite apparently being used in strategic fashion, had no significant impact on performance or understanding at Times 2 and 3.

Overall, then, adult input appeared to be largely reactive to children's performance, and its benefits were restricted. Implicit guidance, along with letting the child direct their own activity, produced gradual improvement in performance and understanding, although not coordination between the two. More explicit guidance led to increased confusion, as had been predicted.

Higher Understanding children (n = 14)

Table 11a shows the relationships between adult input and children's attempts and explanations at Time 1, and Table 11b shows effects of adult input at Time 1 on children's attempts and explanations at Times 2 and 3.

Table 11a. Relationship between Time 1 adult input and children's attempts and explanations (all correlations are 1-tailed).

	Non-Spec prompts	Implicit w/d prompts	Nut/Peg prompts	w/d prompts	Level 1 ex	Level 2 ex	Level 3 ex	Level 4 ex
Attempts	r = .42	r = .37	**r=.68 p=.004**	r = -.03	**r=.62 p=.009**	r = -.16	r = .24	**r=.56 p=.019**
Mean Ex	**r=-.55 p=.021**	r = -.11	r = -.39	r = .19	r = .17	r = .18	r = -.35	r = -.23
Non-Spec prompts	/	r = .04	r = .20	r = -.34	r=.45 p=.054	r = -.19	r = .02	r = -.05
Implicit w/d prompts		/	**r=.59 p=.013**	r = .10	r = .31	r = -.04	**r = .60 p=.012**	**r = .53 p=.027**
Nut/Peg Prompts			/	r = .13	r = .20	r = .03	**r=.66 p=.005**	**r=.83 p<.001**
w/d prompts				/	**r = -.49 p=.039**	r = .05	r = -.11	r = .22
Level 1 ex					/	r = .14	r = .20	r = .06
Level 2 ex						/	r = .18	r = -.11
Level 3 ex							/	r = .45 p=.052
Level 4 ex								/

From Table 11a, it can be seen that, in contrast to Study 1, but in line with the pattern observed for the lower understanding children in this condition, almost all adult input here was associated with an *increase* in attempts at Time 1, once more suggesting the adults were offering support in reaction to the children's actions. There was, again, little sign of any positive impact on explanations. This pattern was less true for weight/distance prompts, though, which were unrelated to attempts, and weakly positively related to explanations. Though the effect is a noisy one, the implication is that these prompts may have been used in a more strategic fashion, possibly with some impact on outcomes, though the association with explanations may once more reflect reaction rather than effect. In line with these signs of strategic use, weight/distance prompts were unrelated to other prompts, negatively related to level 1 explanations, and weakly related to level 4 explanations. They therefore seemed to form a distinct strand of input. Implicit weight/distance and nut/peg prompts were related to each other (r = .59, p=.013), and to level 3 and level 4 explanations, forming a second strand of input. Non-specific prompts were not related to any other prompts, but were marginally related to level 1 explanations, forming a third strand.
The implications of this are that whilst weight/distance prompts may not have been used significantly more often with this group of children than with the lower understanding group, they were apparently used in more strategic fashion, perhaps in response to signs of better understanding, and sometimes accompanied by level 4 explanations to flesh things out more explicitly, as in Study 1. Level 4 explanations were, however, also used in conjunction with nut/peg and implicit weight/distance prompts, and level 3 explanations, apparently in response to moderate or poor performance, given the positive associations of these to attempts. Non-significant prompts and level 1 explanations also appear to have been used when performance was poorer.

Table 11b. Relationships between adult input at Time 1 and children's attempts and explanations at Times 2 and 3 (all correlations are 1-tailed).

	Time 1 Non-Spec prompts	*Time 1* Implicit w/d prompts	*Time 1* Nut/Peg prompts	*Time 1* w/d prompts	*Time 1* Level 1 ex	*Time 1* Level 2 ex	*Time 1* Level 3 ex	*Time 1* Level 4 ex
Time 2 Attempts	**r = .46 p=.050**	r = .08	r = .11	r = -.35	r = .30	r = -.13	r = .20	r = .13

Time 2 Mean ex	**r = -.54 p=.024**	r = -.25	r = -.42	r = .16	r = -.27	r = .17	**r = -.46 p=.050**	r = -.14
Time 3 Attempts	r = .10	r = .24	**r = .73 p=.001**	r = .12	r = -.02	r = -.03	**r = .54 p=.023**	**r = .77 p=.001**
Time 3 Mean ex	r = -.36	**r = -.55 p=.021**	r = .01	r = -.15	r = .02	r = .11	r = -.42	**r = -.49 p=.036**

It can be seen from Table 11b, that the majority of prompts and explanations given at Time 1 were also associated with an increase in attempts at Time 2, with this being particularly so for non-specific prompts (r = .46, p=.050) and level 1 explanations, one of the initial strands of input. The impact on attempts of the elements of the second identified strand of input carried over to Time 3, especially with regard to nut/peg prompts (r = .73, p=.001) and explanations at levels 3 (r = .54, p=.023) and 4 (r = .77. p=.001). Non-specific prompts and explanations at level 3 also had a negative effect on children's mean explanation levels at Time 2 (r = -.54, p=.024 and r = -.46, p=.050, respectively). Implicit weight/distance prompts and level 4 explanations at Time 1 impacted negatively on children's mean explanation level at Time 3 (r = -.55, p=.021, and r = -.49, p=.036, respectively). Weight/distance prompts, however, were weakly associated with reduced attempts and better explanations at Time 2 – in the latter case, as they had been at Time 1 – at the point when, as noted earlier, understanding appeared to take over in fuelling attempts and subsequent progress.

For this group of children, therefore, the bulk of adult input was again given reactively to children's performance, but with weight/distance prompts and to a lesser extent level 4 explanations being used in more strategic fashion than the other support strategies. Though the effects were not strong, strategic use of explicit guidance with these children apparently led to reduced attempts and improved understanding, which drove performance at Times 2 and 3. However, this was only the case when guidance was tied to operationalising solutions: more implicit guidance and abstract explanations were both counterproductive.

Continuous Support condition

Lower Understanding children (n = 16)

Table 12a shows the relationships between adult input and children's attempts and explanations at Time 1, and Table 12b shows the relationships between Time 1 adult input and children's attempts and explanations at Times 2 and 3.

It can be seen from Table 12a that there was once more a general positive association between adult input and children's attempts, though this varied in strength. The significant correlations between children's attempts and non-specific prompts (r=.86, p<.001), nut/peg prompts (r = .76, p<.001), and level 1 explanations (r = .89, p<.001) were all similar to the patterns noted for lower level children in the discontinued support condition. However, there were differences between the two conditions, including the absence here of any negative relationships between attempts and level 4 explanations, and between the prompts plus level 1 explanations and level 4 explanations. Similarly, the lack of significant positive correlations between children's mean explanations and adult input was broken here by level 2 explanations (r = .43, p=.050). Finally, there was a lack of tight associations between the prompts.

Table 12a. Relationship between Time 1 adult input and children's attempts and explanations (all correlations are 1-tailed).

	Non-Spec prompts	Implicit w/d prompts	Nut/Peg prompts	w/d prompts	Level 1 ex	Level 2 ex	Level 3 ex	Level 4 ex
Attempts	**r=.86 p<.001**	r = .25	**r=.76 p<.001**	r = .26	**r=.89 p<.001**	r = -.04	r = .39	r = .28
Mean Ex	r = .29	r = .40	r = .23	r = -.26	r = .17	**r=.43 p=.050**	r = .05	r = -.36
Non-Spec prompts	/	r = .32	**r=.57 p=.011**	r = .21	**r=.79 p<.001**	r = .20	**r=.59 p=.008**	r = .17
Implicit w/d Prompts		/	r = .32	r = -.09	**r = .50 p=.024**	r = .21	r = -.03	r = -.03
Nut/Peg prompts			/	r = .23	**r=.82 p<.001**	r = -.14	r = -.02	r = .21
w/d prompts				/	r = .23	r = -.18	r = .35	r = .48
Level 1					/	r = -.06	r = .27	r = .21

ex								
Level 2 ex						/	r = .41	r = .14
Level 3 ex							/	r = .16
Level 4 ex								/

Thus, overall there was less sense of a defined core ‘package’ with children in this condition, even though adults were not yet aware of the fact they would be working with them again. Looking back to children’s explanations on the balance beam tests, it may be that those differences are due to the fact that, although children were randomly assigned to support conditions subsequent to the classification task, a larger proportion of lower understanding children assigned to the continuous condition apparently had absolutely no grasp of the task at all (i.e. gave no meaningful explanation, as opposed to centre explanations), compared to those whose support ceased subsequent to Time 1. Although the differences in explanations between those children were not large, there may have been enough of a difference to affect the results here, with more uniformly poor performance attenuating the correlations between scale of input and performance level. Certainly, this group of children made more attempts on average at Time 1 than any of the others (see Table 9), and even though the standard deviation of this mean was also higher, as can be seen from Table 9, there were fewer children here who made only a moderate number of attempts than was the case among the lower understanding children in the discontinued condition.

This said, there were some signs of strategic usage along the lines of that noted for the discontinued condition with children at this level of understanding. In particular, level 2 explanations (rather than level 4, as previously) were at least unassociated with attempts as well as being positively associated with children’s explanations, and were used here more frequently than with any other condition/level of understanding combination (see Table 7a). Similarly, implicit weight/distance prompts, associated with subsequent improvements in understanding in the discontinued condition, were only weakly associated with attempts at Time 1 here, and were marginally positively correlated with mean explanation level ($r = .40$, $p = .064$). Both may have been used strategically, therefore, where there were signs of better understanding.

Importantly, both were also associated with greater numbers of attempts (the apparent driver of change) and better understanding at Time 2 (r = .54, p=.015, and r = .33, n.s, respectively for implicit weight/distance prompts; r = .47, p=.034 and r = .46, p=.038, respectively for level 2 explanations; see Table 12b), and thence with more attempts and better understanding at Time 3, as noted earlier. In weaker form, these relationships persisted for implicit weight/distance prompts through to Time 3. Similar kinds of relationship to Time 2 and Time 3 performance were also apparent for Time 1 non-specific prompts, nut/peg prompts and level 1 explanations – but only for attempts. In contrast, whilst the effects were weaker, more explicit support in the form of weight/distance prompts and level 4 explanations had *negative* associations with subsequent attempts and explanations. Overall, the data are consistent with more implicit or simpler forms of support having benefits, especially by promoting exploration, whilst more fully explicit forms were largely counterproductive, as predicted.

Table 12b. Relationship between Time 1 adult input and children's attempts and explanations at Times 2 and 3 (all correlations are 1-tailed).

	Time 1 Non-Spec prompts	*Time 1* Implicit w/d prompts	*Time 1* Nut/Peg prompts	*Time 1* w/d prompts	*Time 1* Level 1 ex	*Time 1* Level 2 ex	*Time 1* Level 3 ex	*Time 1* Level 4 ex
Time 2 Attempts	r=.41 p=.057	**r=.54 p=.015**	**r=.46 p=.036**	r= -.30	**r=.59 p=.008**	**r=.47 p=.034**	r= .21	r= .10
Time 2 Mean Ex	r= .14	r= .33	r= .17	r= .07	r= .18	**r=.46 p=.038**	r= .32	r= -.20
Time 3 Attempts	**r= .45 p=.039**	r= .41 p=.058	**r= .59 p=.008**	r= -.18	**r= .74 p=.001**	r= -.20	r= -.01	r= .00
Time 3 Mean Ex	r= .28	r= .20	r= .28	r= -.17	r= .29	r= .03	r= .24	**r= -.45 p=.039**

Table 12c shows the relationships between adult input and children's attempts and explanations at Time 2, and Table 12d shows the relationships between Time 2 adult input and children's attempts and explanations at Time 3.

Table 12c. Relationship between Time 2 adult input and children's attempts and explanations (all correlations are 1-tailed).

	Non-Spec prompts	Implicit w/d prompts	Nut/Peg prompts	w/d prompts	Level 1 ex	Level 2 ex	Level 3 ex	Level 4 ex
Attempts	**r=.74 p<.001**	**r=.43 p=.048**	**r=.69 p=.002**	**r=.58 p=.009**	**r=.51 p=.022**	r=-.08	r= .27	r= .14
Mean Ex	r= .37	r= -.36	r= .13	r= -.31	r=.02	r= .13	**r=-.48 p=.031**	r= -.15
Non-Spec prompts	/	r= .27	**r=.61 p=.006**	**r=.49 p=.026**	**r=.73 p=.001**	r= -.27	r= .22	r= .41 p=.058
Implicit w/d prompts		/	**r=.49 p=.026**	r= .20	**r=.49 p=.028**	r= -.29	r= .36	r= .29
Nut/Peg prompts			/	**r=.55 p=.014**	r= .42 p=.052	r= -.07	r= .20	r= .13
w/d prompts				/	r= .32	r= .03	**r=.51 p=.021**	r= .32
Level 1 ex					/	r= -.30	r= .30	r= .30
Level 2 ex						/	r= -.23	r= -.17
Level 3 ex							/	r= .10
Level 4 ex								/

It can be seen from Table 12c, that adult input at Time 2 was more coordinated, and more consistently reactive, with all four forms of prompt being interrelated, and associated with level 1 explanations, and all of these being positively associated with attempts. Weight/distance prompts were more strongly associated with level 3 explanations than with level 1, however, and both of these showed slight increases here. Level 2 explanations, meanwhile, dropped (see Table 7b), and the positive association between level 2 explanations and children's mean explanations disappeared. Weight/distance prompts and level 3 explanations were both negatively related to children's Time 2 mean explanation levels, though more weakly in the case of the first ($r = -.31$, $p = .125$, and $r = -.48$, $p=.031$, respectively), possibly signalling a reactive response to poorer understanding. Both were associated with greater numbers of attempts at Time 3, though, and, more weakly, with better explanations (see Table 9). Time 2 nut/peg prompts were also positively associated with Time 3 attempts. On the other hand, Time 2 implicit weight/distance prompts were negatively related to mean explanation levels at both this point and at Time 3, in contrast to the positive relationship to these of Time 1 implicit weight/distance prompts. In general, then, the picture that emerges is one of the adult shifting to using more sophisticated and explicit forms of support at this stage than they employed at Time 1, particularly as a contingent response to poorer understanding, with this having beneficial effects on children's later performance. There was some carry-over of the effects of implicit support too, though, since non-specific prompts exhibited much the same pattern of effects at Time 3 as weight/distance prompts.

Table 12d. Relationship between Time 2 adult input and children's attempts and explanations at Time 3 (all correlations are 1-tailed).

	Time 2 Non-Spec prompts	*Time 2* Implicit w/d prompts	*Time 2* Nut/Peg prompts	*Time 2* w/d prompts	*Time 2* Level 1 ex	*Time 2* Level 2 ex	*Time 2* Level 3 ex	*Time 2* Level 4 ex
Time 3 Attempts	**r= .51 p=.023**	r= .36	**r= .54 p=.015**	**r= .61 p=.006**	r= .29	r= -.11	**r= .49 p=.027**	r= .33
Time 3 Explan	r= .22	r= -.39	r= -.02	r= .32	r= -.13	r= .27	r= .18	r= -.19

Table 12e shows the relationships between adult input and children's attempts and explanations at Time 3.

Table 12e. Relationship between Time 3 adult input and children's attempts and explanations (all correlations are 1-tailed).

	Non-Spec prompts	Implicit w/d prompts	Nut/Peg prompts	w/d prompts	Level 1 ex	Level 2 ex	Level 3 ex	Level 4 ex
Attempts	**r=.84 p<.001**	r= -.17	**r=.82 p<.001**	**r=.72 p=.001**	**r=.87 p<.001**	r= -.13	r= .27	r= .38
Mean Ex	r= .29	**r=-.68 p=.002**	r= .22	r= .10	r= .26	r= .18	r= -.40	r= .27
Non-Spec prompts	/	r= .08	**r=.66 p=.003**	**r=.63 p=.005**	**r=.74 p<.001**	r= .03	r= .10	**r=.46 p=.038**
Implicit w/d prompts		/	r= .09	r= -.26	r= -.05	r= .08	r= .28	r= -.09
Nut/Peg			/	**r=.56**	**r=.60**	r= -.23	r= .18	r= .21

prompts				**p=.011**	**p=.007**			
w/d prompts				/	**r=.58 p=.010**	r= -.21	r= .14	r= .36
Level 1 ex					/	r= -.24	r= .37	r= .36
Level 2 ex						/	r= -.18	r= -.22
Level 3 ex							/	r= -.27
Level 4 ex								/

The pattern of correlations at the final time-point was very similar to that of Time 2, except that implicit weight/distance prompts, which dropped substantially in frequency here (see Table 7b), were no longer related to other prompts or explanations, or positively related to children's attempts. This suggests that their use as part of the 'reactive package' had been discounted. They were significantly negatively related to children's mean explanations, however (r = -.68, p=.002), which suggests they were in fact only used where understanding was notably poorer. The implication from this was that more generally they were now too implicit to be helpful. The remaining prompts were now more strongly associated with level 1 explanations, and the relationship of weight/distance prompts to level 3 explanations apparent at the previous time-point was now absent. Non-specific prompts, however, were associated with level 4 explanations, which had a weak positive association with children's understanding. The implication, perhaps, is that whilst adults persisted with more explicit operational support (see again Table 7b), they felt less need now to back this up with explicit *explanation*, except where performance was sufficiently good to not require such support, and instead merited attempts to spell out the full torque rule principle.

Thus, for this group of children, the general pattern that seems to emerge is that early strategic use of implicit or simpler guidance, such as references to distance on its own, led to greater subsequent exploration, which drove understanding. In contrast, if explicit guidance was given too early, this only produced later confusion. However, when this explicit guidance was introduced at Times 2 and 3, it had more positive effects, where a continuation with implicit guidance had negative consequences. Any advantage continuous guidance possessed over discontinued appeared to stem from this opportunity to shift emphasis as performance improved, and attempts decreased.

Higher Understanding children (n = 13)

Tables 13a to 13e show the relationships between adult input and children's attempts and explanations for the higher understanding children in the same order as for the lower.

Table 13a. Relationship between Time 1 adult input and children's attempts and explanations (all correlations are 1-tailed).

	Non-Spec prompts	Implicit w/d prompts	Nut/Peg prompts	w/d prompts	Level 1 ex	Level 2 ex	Level 3 ex	Level 4 ex
Attempts	**r= .49 p =.044**	r= -.03	r= .43	r= .33	**r= .62 p=.012**	r= .24	r= -.07	r=-.18
Mean Ex	r= .13	r= -.40	r= .09	r= .06	r= .06	r= .31	r= .19	**r= -.54 p=.036**
Non-Spec prompts	/	**r= .64 p=.009**	**r= .57 p=.020**	r= .11	**r= .70 p=.004**	**r= .64 p= .01**	**r= .52 p=.036**	r= .12
Implicit w/d prompts		/	r= .31	r= -.01	r= .39	**r= .73 p=.002**	r= .46 p=.059	r= .25
Nut/Peg prompts			/	**r= .75 p=.002**	**r= .75 p=.002**	r= .08	**r= .58 p=.020**	**r= .49 p=.043**
w/d prompts				/	r= .46 p=.059	r= -.13	r= .31	r= .44
Level 1 ex					/	r= .40	r= .30	r= .23
Level 2 ex						/	r= -.07	r= -.19
Level 3 ex							/	r= .61
Level 4 ex								/

As can be seen in Table 13a, the pattern of relationships at Time 1 for children in this grouping was somewhat different to that identified for the higher understanding children in the discontinued support condition. Nut/peg prompts were still associated with level 3 and level 4 explanations, but the link with the fourth element of this strand, implicit weight/distance prompts, was weaker, and those prompts were now more related to level 2 explanations. Non-specific prompts were still associated with level 1 explanations, but now also with level 2 and level 3. Weight/distance prompts were now more strongly related to level 4 explanations, but also to level 1, and were strongly associated with nut/peg prompts too. In general, then, there was a stronger sense of a core package of input than observed in the discontinued condition.

Broadly speaking, though, adult input appeared to be reactive to greater numbers of attempts and poorer levels of explanation in similar ways to those seen with children at this level in the discontinued condition. Although not all were significant, most adult input measures were positively correlated with children's attempts, and level 4 explanations were negatively associated with children's understanding (r = -.54, p=.036), suggesting that they were deployed in an effort to improve poorer levels of explanation. There was little sign of weight/distance prompts being used strategically here, but both these and more particularly nut/peg prompts were negatively correlated with Time 2 attempts and positively correlated with Time 3 explanations (see Table 13b), suggesting similar effects of explicit operational guidance (albeit of a less specific kind) to those seen among the higher discontinued children. As there, more implicit guidance in the form of implicit weight/distance prompts, and more abstract explanation in the form of level 3 and level 4 explanations were both negatively related to Time 2 explanations, though these effects no longer persisted to Time 3.

Table 13b. Relationship between Time 1 adult input and children's attempts and explanations at Times 2 and 3 (all correlations are 1-tailed).

	Time 1 Non-Spec prompts	*Time 1* Implicit w/d prompts	*Time 1* Nut/Peg prompts	*Time1* w/d prompts	*Time 1* Level 1 ex	*Time 1* Level 2 ex	*Time 1* Level 3 ex	*Time 1* Level 4 ex
Time 2 Attempts	r= -.01	r= -.13	**r= -.55 p=.026**	r= -.29	r= -.33	r= .28	r= -.33	r= -.45
Time 2 Explan	r= -.07	**r= -.53 p=.031**	r= -.20	r= -.23	r= .02	r= .08	**r= -.72 p=.003**	**r= -.70 p=.001**
Time 3 Attempts	r= .40	r= -.15	r= .32	r= .45	r= .37	r= .05	r= .33	r= .01
Time 3 Mean Expla	**r= .56 p=.022**	r= .18	**r= .52 p=.035**	r= .15	**r= .49 p=.046**	r= .16	r= .21	r= .08

Table 13c. Relationship between Time 2 adult input and children's attempts and explanations (all correlations are 1-tailed).

	Non-Spec prompts	Implicit w/d prompts	Nut/Peg prompts	w/d prompts	Level 1 ex	Level 2 ex	Level 3 ex	Level 4 ex
Attempts	**r= .73 p=.002**	r= .08	**r= .72 p=.003**	**r= .57 p=.022**	r= .30	r= .00	r= -.22	r= .30
Mean Expla	r= .40	r= -.02	r= .20	r= -.24	r= .14	r= -.05	r= -.47 p=.052	r= .10
Non-Spec prompts	/	r= .09	r= .36	r= .46	**r= .48 p=.048**	r= -.40	r= -.26	r= .42
Implicit		/	r= .20	r= .21	**r= .74**	r= .23	r= .10	r= .15

w/d					**p=.002**			
Nut/Peg prompts			/	r= .28	r= .23	r= .29	r= .12	**r= .53 p=.030**
w/d				/	r= .34	r= -.10	r= .12	r= .03
Level 1 ex					/	r= -.20	r= -.08	r= .50
Level 2 ex						/	r= .18	r= -.16
Level 3 ex							/	r= .16
Level 4 ex								/

It can be seen from Table 13c that at Time 2 there was a notable absence of significant associations between prompts and explanations, suggesting that there was greater differentiation of input here. Two strands seem to be apparent. First, nut/peg prompts were significantly related to level 4 explanations (r = .53, p=.030). Non-specific and implicit weight/distance prompts, on the other hand, were more associated with explanations given at level 1 (r = .48, p=.048, and r=.74, p=.002, respectively), although not with each other. Strikingly, however, neither strand seemed to be used in any very strategic fashion, with both being positively related to attempts and explanations in much the same way, suggesting that whether children did better or worse, they received much the same response. The only input that seemed to be used in more strategic fashion was weight/distance prompts and level 3 explanations, which were both negatively related to children's explanations, albeit weakly. Both were infrequent, however, and isolated from other input, bar a tenuous link between weight/distance prompts and non-specific prompts. The reasons for this lack of strategic input are not entirely clear, but perhaps lie in the relative dissociation between attempts and explanations noted earlier, in spite of general levels of both being quite good, leaving tutors bemused as to whether support was needed or not, especially in terms of understanding. The net effect seems to have been further confusion. Non-specific prompts were negatively associated with children's explanations at Time 3, and implicit weight/distance prompts were positively associated with attempts (see Table 13d), as might be expected for children at this level of understanding. However, nut/peg prompts, weight/distance prompts and level 4 explanations also all showed one or other of these patterns too.

Table 13d. Relationship between Time 2 adult input and children's attempts and explanations at Time 3 (all correlations are 1-tailed).

	Time 2 Non-Spec prompts	*Time 2* Implicit w/d prompts	*Time 2* Nut/Peg prompts	*Time 2* w/d prompts	*Time 2* Level 1 ex	*Time 2* Level 2 ex	*Time 2* Level 3 ex	*Time 2* Level 4 ex
Time 3 Attempts	r= .30	r= .46 p=.058	**r= .56 p=.022**	r= .02	r= .43	r= .42	r= .29	**r= .66 p=.007**
Time 3 Explan	**r= -.73 p=.002**	r= -.15	r= -.08	**r= -.67 p=.006**	r= -.35	r= .28	r= .17	r= .04

Table 13e. Relationship between Time 3 adult input and children's attempts and explanations (all correlations are 1-tailed).

	Non-Spec prompts	Implicit w/d prompts	Nut/Peg prompts	w/d prompts	Level 1 ex	Level 2 ex	Level 3 ex	Level 4 ex
Attempts	**r= .91 p<.001**	**r= .55 p=.026**	**r= .95 p<.001**	**r= .53 p=.032**	**r= .96 p<.001**	r= .013	r= -.14	n/a
Mean Ex	r= .18	r= -.41	r= -.05	r= .27	r= .03	**r= -.73 p=.002**	r= -.29	n/a
Non-Spec prompts	/	r= .24	**r= .81 p<.001**	r= .36	**r= .89 p<.001**	r= -.22	r= -.09	n/a
Implicit w/d prompts		/	**r= .64 p=.009**	**r= .60 p=.015**	**r= .53 p=.031**	**r= .61 p=.013**	r= -.06	n/a
Nut/Peg prompts			/	**r= .67 p=.006**	**r= .92 p<.001**	r= .01	r= .02	n/a
w/d prompts				/	**r= .59 p=.017**	r= -.11	r= .06	n/a
Level 1 ex					/	r= .05	r= .00	n/a
Level 2 ex						/	r= .00	n/a
Level 3 ex							/	n/a
Level 4 ex								/

From Table 13e, it can be seen that at Time 3, support was once again positively related to children's attempts. The four types of prompts became tightly intercorrelated once more at this point, indicating little differentiation in deployment. They were also all significantly related to level 1 explanations, although not to any other explanation level, with the exception of implicit weight/distance prompts which were related to explanations given at level 2 (r = .61, p=.013). Perhaps most importantly, though, this lack of differentiation came at a point where most types of prompt declined in frequency, presumably as a result of the continued drop in attempts, without these being replaced by any effort to focus on developing children's explicit grasp of the principles at work (see Table 7b). Indeed, level 4 explanations had ceased to be used at this final time-point for this group of children, and level 3 remained infrequent. Only level 2 explanations appeared to be used strategically, given their negative correlation to children's explanations, but they were rare, and in any case limited by definition to dealing solely with distance.

For higher understanding children, continuous support did not seem to be at all beneficial in terms of explicit grasp of the principles at work, as highlighted earlier with regard to the lack of negative associations between attempts and explanations, and the drop in mean explanation level at Time 3, despite the substantial fall in attempts. With regard to the impact of support on performance and understanding, at Time 1 operationally explicit support was beneficial to subsequent attempts and understanding, whilst support that was implicit or over-abstract had negative effects, in much the same way as seen among the higher understanding children in the discontinued condition. Subsequently, however, children apparently failed to engage with the support given to improve their understanding. This was in part, perhaps, because of the seeming lack of strategic deployment of explanation by the tutors – but this itself was arguably because the lack of coordination between children's explanations and attempts left it unclear as to when explicit explanations should be deployed. That lack of coordination was possibly due to the continued presence of the adult, which denied the children the necessary autonomy required to progress, but it might equally have been because it made them lazy, and allowed them to rely on the adult to provide the explanations for their increasingly correct strategies.

3.4. Discussion

Based on the findings of Study 1, it was predicted firstly, that children of lower understanding would benefit from implicit, procedural support whereas more explicit explanations would facilitate children of higher understanding, despite the use of an unfamiliar adult tutor. It was also predicted that the lower understanding children would benefit from continuous support employed throughout the three sessions, as this would facilitate the development of procedural strategies over time, ultimately providing the basis for a shift to the acquisition of more explicit representations. In contrast, discontinued support was hypothesised to be more beneficial to children of higher understanding, as it would encourage appropriation of a framework to support their autonomous actions.

With regard to the first prediction, despite the tutors being trained prior to the study to ensure consistency in their support, and the lack of differences found in the overall profile of support between conditions at Time 1 (indicating tutors were generally consistent in their approach to scaffolding), there *were* differences in the support offered to children with lower and higher understanding.

With respect to the *types* of input employed by the adults, there was no evidence here of the direct control measures observed with lower understanding children in Study 1, and the children in Wood and Middleton's (1975) study. However, the adults here were, unlike those in these earlier studies, trained in their scaffolding techniques and were unknown to the children. This training, and possibly the lack of relationship between tutor and child, apparently served to constrain any tendency for the adults to take over the task. This may also have led to some of the explicit support observed in Study 1, especially the use of torque rule explanations, being sacrificed due to the adults desire to administer a steady level of support with all children as they knew that those of lower understanding would have found difficulty with grasping the torque rule.

Despite this, however, the lower understanding children received both more support in general than those of higher understanding, and there was a tendency for this support to be proportionately more implicit, with some bias towards non-specific and implicit weight/distance prompts, and more particularly level 1 explanations based on weight, with this being in line with the broad thrust of the differences seen in Study 1. The following example illustrates this type of support being given to a child of lower understanding, who is trying to balance the first problem (two nuts on the first peg):

> *(Child places one nut on the third peg).*
> *Adult: "So it's (Balance Scale) gone down, so that side (researcher's) is too light and that side (child's) is too heavy. So what else could we try?"*
> *(Child places another two nuts on the third peg so there are now three nuts on this peg).*
> *Adult: "If it's too heavy with one, is it not going to be too heavy with three on it? Does more not make it heavier?"*
> *(Child now places one nut each on the second and third pegs).*
> *Adult: "Too heavy, so we need to change it by moving where they are or taking something off."*

Importantly, whereas the increased amount of support offered to the lower understanding children could be construed as a function of their increased number of attempts, the differences in the *focus* of this support are not so easily interpreted in this way. As the children and tutors were previously unknown to each other, the persistence of similar shifts in the pattern of support to those observed in Study 1, depending on the children's level of understanding, strongly suggests that these differences were not a function of past history or expectation, which may have played some role for parents. Instead, it would appear that they must have been a response to some aspect of the child's performance. The consistent positive correlations across support conditions between number of attempts and non-specific prompts and weight explanations, indicates that the key element here was probably the lower understanding children's continuing tendency towards unproductive activity.

The issue of whether lower understanding children benefited more from implicit procedural scaffolding than explicit prompts and explanations must be addressed alongside the impact of support condition, due to the additional evidence provided by the effects of these. With respect to the lower understanding children, it was only those who were continuously supported who showed an overall decrease in the number of attempts taken to balance the scale over the three time-points. Those whose support was discontinued showed an increase in attempts at Time 2 before dropping again at Time 3 to the same level they were at initially. Differences with regard to support condition among the lower understanding children were also apparent when it came to the pattern of change in their explanations, if not the actual point reached at Time 3. Those whose support was discontinued showed a late modest increase in explanation level, following on the increased attempts at Time 2. The correlations between concurrent attempts and explanations in this group were positive at Time 1, but shifted to a negative association at Time 3, as would be the case if understanding were beginning to drive performance, but the relationship was not significant.

When this finding was compared to lower level children who were supported throughout the three sessions, it can be seen that those children showed a consistent and accelerating increase in explanation level over time, as attempts decreased. Rather than the two indices becoming negatively related, however, the relationship was positive throughout and became stronger, with explanation at each time-point increasingly disassociated from its level at the preceding time-point. This suggests that increases in explanations were consistently performance-driven. Therefore, the implication is, as predicted, that the lower understanding children did perform better in the continuous support condition, as they showed a stable pattern of improved attempts and a consistent relationship between attempts and gains in understanding. The gains in the discontinued condition were more haphazard, even if they did eventually begin to generate productive insights. This perhaps supports the premise that adult input on a task is only readily facilitative when children already have an initial familiarity with it, and feel comfortable with what is required of them (Rogoff, 1987). In order for support to be beneficial, there has to be an element of 'shared thinking' (Freund, 1990) between both adult and child. As the children in this group did not yet have any understanding of the main properties of balance, it would have been harder to establish shared thinking between child and adult during the first time-point. Without further continuous support, the child would have struggled more to complete and understand the task when undertaking it subsequently.

The finding that lower understanding children who were continuously supported improved primarily through gradual procedural gains, with knock-on effects on understanding, is therefore consistent with the benefits of tutoring for children at this level having the expected procedural focus. The relationship of change to tutor input bears this out up to a point, but also qualifies that picture.

Certainly, at Time 1, tutor use of implicit or simple procedural guidance, comprising implicit weight/distance prompts and explanations based on distance alone, was associated with greater subsequent exploration, which drove understanding, as noted above. Partially explicit procedural support in the form of nut/peg prompts had less effect, however, whilst early fully explicit guidance comprising weight/distance prompts and torque rule explanations were counterproductive. Similar effects were present in the discontinued condition. However, in the continuous support condition, the introduction at Time 2 of more explicit guidance incorporating weight/distance prompts and explanations in response to poorer understanding at that point had more positive subsequent effects, whilst continuation with implicit guidance had a negative impact.

Thus, the advantage of receiving continuous support over that which was discontinued would seem to stem primarily from the adults' opportunity to shift emphasis as children's performance gradually improved and their attempts decreased. The implication of this is that the initial contingency exhibited by the adults in adjusting their input to children's level of understanding appeared to remain in effect and they produced further adjustment, given the opportunity. In terms of the initial hypotheses, then, the findings show that purely implicit procedural support was not beneficial in any sustained fashion long-term. Ultimately, however, the ability to maintain moment to moment, and for the most part procedural scaffolding, did have important advantages for this lower understanding group. In this sense the prediction that procedural support would be more beneficial for them was upheld, in line with the expectations derived on the basis of theorising about interactions between existing representational level (Karmiloff-Smith, 1992) and adult input.

This lends further support to Rogoff's (1987) theory, as, although this group of children may have approached the task at Time 1 with difficulty, continuous guidance from the adult allowed them to develop familiarity with the task, which in turn, encouraged them to become more comfortable undertaking it as time progressed, even though this had to be done in the presence of the adult.

For children of higher understanding, predictions derived from theorising about the interaction between representational level and adult input were also broadly borne out. Adult support took a more explicit form for this group of children, and the general pattern of performance and change in performance was much as predicted. That is, in both continuous and discontinued support conditions, this group of children generally made fewer attempts to begin with than those of lower understanding, and these fell off further to Time 3, especially in the continuous condition. Similarly, with regard to explanations, the categorisation made on the basis of Balance Beam testing was sustained, with the higher understanding children exhibiting higher explanation levels, which also generally increased over time. In the discontinued support condition especially, children's attempts and explanation levels became increasingly strongly and negatively correlated, indicating substantial integration of explicit understanding and performance, with the former acting as the driving force. This contrasts with the pattern for the lower understanding children, where performance was the driving influence on change.

The higher understanding children who were continuously supported did not show this pattern but largely in ways that were consistent with the predictions made about the effects of type of support. For example, these children, despite consistently improving in their attempts over the three time-points only showed an increase in explanation level at Time 2, with this explicit understanding declining again at the final time-point. Interestingly, this mirrors the pattern exhibited in *performance* by the lower understanding children in the support condition that had been predicted to be less effective.

In addition, in contrast to those in the discontinued support condition, the higher level children who were continuously supported failed to show any evidence of understanding driving performance, as shown by the positive correlations between those two indices at each time-point, and the gradual decline of values as time went on. Given the sharp reduction in attempts at Time 3, along with their inconsistent progress and lack of influence of explicit understanding, it could be suggested that for this group of children gains were essentially performance-driven only, with explicit grasp apparently reducing to a secondary concern, perhaps as a result of loss of interest and importance of the task to the children.

Therefore, these data are not only consistent with the initial prediction in terms of the higher understanding children showing more coherent gains when support was discontinued after Time 1, but they also indicate that, as anticipated, continuous support was less effective precisely because it apparently served to undermine any effort on the part of children to appropriate or develop any explicit conceptual framework to resource their own action. The reasons behind this effect are less clear, although the tendency was for input to become more residual and *implicit* over time (at least as regards explanation) for the higher understanding children, as the number of attempts they required to solve the problems decreased, just as support became proportionately more explicit for children of lower understanding as they failed to improve in their attempts to the same degree. The impact of this may have been to reduce the visibility of the explicit reasoning that children could capitalise on to improve their own understanding – though where it was present it seemed in fact to be counterproductive – whilst in addition sending the message that such reasoning was unimportant.

It is possible, therefore, that the outcomes for higher understanding children who were continuously supported might have been somewhat different if the adult tutors had maintained more in the way of fuller explicit support. At the same time, though, it is clear that fairly optimal effects could be obtained for these children by withdrawing support entirely after Time 1, and trying to adjust continuous support would in this sense only be redundant.

This said, the precise effects at work even for those children whose support was discontinued are less obvious than they were in Study 1. Implicit and abstract explicit support at Time 1 had definite negative effects on higher understanding children's subsequent performance and understanding, and fully explicit operational support in the form of weight/distance prompts was associated with progress in both attempts and explanations, as predicted. However, the latter effects were weak, and there was less sign here of the progress made by those children resting on direct appropriation of such operationalisations and the representations related to them. This may be because the adult tutors employed in the present study made rather less use of explicit forms of support than the parents with fully explicit styles did in Study 1. Whatever the source of the differences from Study 1, though, the differences between the pattern of gains exhibited by higher understanding children in the discontinued and continuous support conditions confirmed that support does have an impact. Furthermore, the general pattern of gains in the discontinued condition was very similar to that seen among children who received such support in Study 1, and there appeared to be no sign of any alternative to the appropriation of explicit representations as a mechanism explaining those gains. Finally the lagged nature of the observed effects is consistent with its operation. It would seem simply that the effects observed here were weaker and less apparent than those captured previously, but that they were nevertheless of the same type.

There are other points of correspondence with, and filling out of the information provided by, Study 1 beyond the relationship between representational level and effects of adult input. In particular, as was seen previously, contingency appeared to operate most effectively at the more strategic level rather than the micro level argued for by Wood (Wood and Middleton, 1975; Wood, 1986). Tutors made early decisions to adopt a more or less implicit style of input depending on children's performance, and whilst further adjustment to this occurred, it was over the course of different sessions that it was evident. Indeed, there was apparently a considerable level of consistency exhibited by tutors beyond the adjustments made for support condition and understanding level. However, such contingency was not always effective, as seen from the shift towards more implicit support in the continuous condition for higher understanding children which definitely appeared to be counterproductive. This was the exception, though, as the general tailoring of input to higher and lower understanding children at different stages does seem to have been broadly appropriate.

This does not mean that it is always possible to rely on tutors making naturally appropriate adjustments, however. As Wood (1986) argued, tutors in general need to be trained to act appropriately, as they were here, at least up to a point. Moreover, there were further adjustments that could usefully have been made, particularly with regard to the use of fully explicit support for higher understanding children. Despite training, the tutors employed here only used nut/peg or weight/distance prompts and torque rule explanations in fairly intermittent ways, whereas the message from Study 1 was that more consistent support of this kind would have been likely to have been more productive.

The bigger contingent adjustment, however, is a more strategic one, and might not always be in a tutor's power to apply perfectly. The present data confirmed the prediction of the RR-based tutoring model that lower understanding learners need continuous support to progress optimally, so that they can build up implicit representations first, and then move on to the acquisition of an explicit framework based on these. On the other hand, those of higher understanding benefit most from a single explicit intervention, as they are already at a level at which they understand the basic properties of the task and so continuous input only hinders their desire to self-regulate their knowledge (Baker and Brown, 1984) via the appropriation of explicit formulations. Early identification of an individual's present understanding, and strategic selection of a session plan is therefore crucial. The implications of this for teaching are profound.

Overall, a consistent picture emerges across Studies 1 and 2, but there remain areas of uncertainty. In particular, whilst Study 1 captured a clear pattern of appropriation on the part of some children, that pattern was less evident here though the lagging of effects is consistent with the operation of this or something like it. However, across both studies children who received support in general advanced, even if the mechanisms by which they did so remained more hidden. A further effort to track how change occurs is desirable, but attempts to do this are constrained as long as children's thinking can remain internal simply because they are working on their own. Examining the impact of support on the activity of *pairs* of children, however, might help resolve this difficulty, since the effort after collaboration is likely to compel them to externalise their thinking, at least to the extent that they are capable of making this explicit. It would also address an additional question of no little educational importance: how does the conceptual and linguistic input of teachers resource learners' subsequent interactions? Study 3 attempts to address those issues.

Chapter 4

STUDY 3

4.1. Introduction

Studies 1 and 2 provide confirmatory evidence of tutor support operating in a differential fashion, depending on the supported child's initial level of understanding. Children who already possessed some limited explicit understanding of the principles at work in the task being dealt with appeared to benefit most from one-off support which focused on further explication of those principles, embedded in terms that they could readily appropriate and use for themselves. Those who lacked explicit understanding at the outset benefited most, in contrast, from more continuous support which focused on prompting moves in the direction of immediate solutions to problems, and only gradually introduced more explicit formulations of the principles at work. These patterns of effective support were consistent with Vygotskian accounts of the induction of learners into the use of signs to mediate activity via tutoring within the zone of proximal development; and also with Wood's account of the use of varying levels of control in the process of scaffolding. However, they went beyond both in terms of precision by tying the impact of tutor sign use specifically to the child's own current representational level (the RR-based tutoring model), and by establishing evidence of an apparently natural tendency on the part of tutors to gravitate towards the *general* support mode that was most appropriate to the learner with whom they were working.

There are limitations in the work reported thus far, however. In particular, the process of appropriation of tutor descriptions and explanations among children with a higher level of understanding proved not to be consistently observable. It was more apparent in Study 1 than in Study 2, where it could only be inferred from other indicators; for the most part, and even in Study 1, it was not evidenced in entirely consistent fashion across different children. Similarly, the evidence for a *lack* of appropriation, at least initially, on the part of children with a lower level of understanding is essentially negative: there was little sign of more explicit reasoning or higher level explanation being used by these children, and no evidence that what usage there was could be traced back directly to tutor input. With regard to both points, it could be argued that the methodology employed by Studies 1 and 2 imposed an unhelpful constraint by only requiring children to provide explanations of solutions on completion of these, and only generating codable data on their understanding at these final points. The net effect may have been to obscure the occurrence of appropriation in its full-blown form among higher understanding children, and in early forms among lower understanding children.

One way to deal with this limitation would be to require children to use talk-aloud protocols as they work on problems both during and following tutor support. However, providing commentaries of this kind is an artificial process, and the risk is that difficulties on the part of children in switching to this mode of working may again serve to obscure shifts in explicit representation. Setting supported children to work collaboratively in pairs, on the other hand, would have the advantage of providing a context in which thinking naturally tends to be made explicit, potentially allowing appropriation and shifts in representation to be tracked over time with a relatively high degree of sensitivity without forcing verbal statements to be made. At first sight, such a method may seem to create difficulties of its own in as much as there would appear to be some danger of individual change in representation becoming contaminated by the effects of collaboration. However, past research on collaborative learning provides some reassurance on this point.

There are two overlapping accounts of the effects of collaborative learning. One is the Piagetian account, in which discovery of different viewpoints in others (which will normally be the case in any random grouping) creates internal disequilibrium, resolution of which leads, via subsequent reflection, to conceptual change. The other is the social constructionist account (Doise & Mugny, 1978) in which conflict between viewpoints creates motivation to negotiate resolution during task. Howe & Tolmie (1998), however, argued that those accounts were not, in fact, competing theories, but descriptions of different processes that occur under different circumstances. Opinion differs as to what those circumstances are, but Tolmie (in press) argued that the evidence suggests the key factor is the representational level of the collaborating peers. When this representational level among peers is low and implicit, despite differences in thinking possibly being apparent, the explanations offered for different stances are limited, and hard for learners to connect to their own representations, with the result that progress lags substantially behind the experience of conflict (see e.g. Tolmie, Howe, Mackenzie & Greer, 1993). On the other hand, where the initial representations of learners are more explicit, on-task coordination of different perspectives is more readily achieved, for much the same reason as appropriation occurs when learners are at this level (Howe, Tolmie, Anderson & Mackenzie, 1992; Williams & Tolmie, 2000).

The message of this work for the use of peer collaboration within the present research seems clear. Firstly, collaborative work, especially in problem-solving contexts, is a good mechanism for uncovering thinking. Differences in ideas or representations are apparent, even when representational level is similar (e.g. Howe, Tolmie & Rodgers, 1992; Tolmie *et al.*, 1993), and such differences lead to disagreements, and disagreements to attempts at explanation (Howe, Tolmie, Greer & Mackenzie, 1995; Howe, Tolmie, Thurston, Topping, Christie, Livingston, Jessiman & Donaldson, in press). Secondly, the danger of collaboration leading to undetected contamination is low, as, if learners are at lower representational levels, then the effects of their exchanges are likely to be substantially delayed. For example, in research undertaken by Howe *et al.* (1992) and Tolmie *et al.* (1993), it was found that effects took around ten weeks to appear.

If the collaborating children are at a higher level, however, effects may well appear during the experimental sessions, but the presence of these should take the form of readily detectable mutual secondary appropriations. This was found in research undertaken by Richard Anderson and his colleagues, in which they identified a ‘snowball hypothesis’ (Anderson, Nguyen-Jaheil, McNurlen, Archodidou, Kim, Reznitskaya, Tillmanns and Gilbert, 2001). Their findings suggested, in line with Piaget’s (1985) theory of cognitive conflict, that when a child initiated a theory of how to progress with a task or invited another child to express a view by asking their opinion, this promoted the other children within the group to communicate their views. This then led to a gradual increase in discussion among the group members of different concepts, or ‘argument stratagems’, with each child taking on board what another had said, and using those stratagems to develop and expand on their own knowledge. Thus, there was a ‘snowball’ effect of one concept, or argument stratagem that was originally generated by one child in the group, but then spread to the other group members, who then used this stratagem to appropriate their own versions of the original theory, or develop new theories based on the original concept. This led to the children developing a higher level of knowledge and understanding of the concepts in use during discussions, allowing them to use and expand on those stratagems in their own ways.

Thus, as the foregoing made apparent, this past research leads to clear differential predictions of outcomes depending on initial representational level, in terms of the presence or absence of such secondary appropriations. This, of course, carries considerable educational implications (building on those identified by Study 2) with regard to the manner in which teacher input may or may not resource subsequent interactions between learners.

Previous research does signal one important issue for the present work, however. Despite its educational significance, few studies have actually examined the conjunction of tutor support and peer collaboration, and almost none have considered the issue of learner appropriation of tutor descriptions and explanations in this context. Tolmie *et al.* (2005) do report such research in their second study, in which the impact of tutors working with single children was compared to that of tutors working with groups of three children. This found that children in the tutor-group condition progressed more in terms of generalisable understanding than those in the tutor-child condition, but that no direct signs of appropriation were apparent in either. The lack of appropriation was attributed to the children involved being at a relatively implicit representational level, and indeed this was the start point for the present focus on the effects of representational level. In contrast, the superior performance of children in the tutor-group condition was attributed to the impact of disagreement and reflection, which was feasible in this research since the intervention sessions took place over a four-week period.

However, it is worth noting that this research employed only a very broad brush-stroke coding system, which identified instances of explanations being provided, for example, but not what the content of these was. Given the very specific nature of the appropriations predicted by the RR-based tutoring model, the absence of this level of detail may have served to increase measurement noise considerably, correspondingly reducing the capacity of the research to detect effects of this kind. This did not necessarily mean that they were present in that case, but since the goal of the present research is to uncover such effects if they are present – both in primary and secondary form – it suggests a strong need to adopt a fine-grained coding system that deals with relatively specific content. The coding system for explanations used in Studies 1 and 2 only went part way towards this, since the precise formulation of, say, a weight and distance explanation, might vary considerably. For example, this type of explanation could range from a basic weight/distance description based on number and position: "there's one nut on the second peg and two on the third peg", to one which is much more detailed, such as, "you put less nuts at the end of the scale as it's heavier at the end". Appropriation of one form does not necessarily lead directly to some others. Therefore, there was a need for the present research to extend the earlier approach to record the incidence of more specific forms of description and explanation.

Regarding the use of the initial classification and Balance Scale tasks, Study 3 took the same format to Study 2. Unlike Study 2, however, Study 3 involved children working on the Balance Scale task in pairs, rather than individually as they had done previously. A three-way mixed design was employed, incorporating support condition (support versus no support given at Time 1), time-point of testing, and pair-type (based on the children's initial understanding of balance). The no support condition acted as a control to allow the specific effects of support to be disentangled. However, support was given only at Time 1 despite the Study 2 findings because firstly, the focus here was on tracking appropriation which was expected to occur more among children with higher understanding who benefited from a single intervention; and secondly, because this allowed examination of the ways in which tutor support resourced *subsequent* discussion between dyads. There were three time-points of testing, with an interval of only two to three days between each time-point as before to prevent the impact of delayed internal reflection intruding on data.

With respect to the between-subjects factor of pair-type, children were identified as being lower or higher understanding based on the classification test, as was the case in Study 2. Children were also put into pairs on this basis. There was three pair types used: Low-Low, High-High and Mixed (one child of lower and the other of higher understanding). All children worked in the same single-sex pairs throughout the study to maintain a stable individual representational context, and avoid intrusion of other social effects into interaction. All supported pairs worked with the same tutor to avoid the issue of potential cross-tutor variation in input. Each dyad's performance was examined in terms of the number of attempts it took them to achieve balance on the four problems, and explanations offered for those. Explanations were analysed on an individual child's basis, as within the dyads, children may have given very different reasons as to why they believed the scale balanced. Furthermore, both tutor and children were coded using a fine-grained, content-based system, in order to identify appropriations from tutor and each member of the dyad.

Therefore the predictions for Study 3 were that, firstly, supported children would progress more than those who were unsupported regardless of their level of understanding, in terms of both reduction in number of attempts to reach a solution of problems on the Balance Scale and levels of explanation offered for successful solutions. Secondly, supported children at a lower level of understanding would progress less than those at a higher level given the one-off nature of support. Thirdly, progress among higher level supported children will be directly related to incidence of primary (from tutor) and secondary (from the partner, where appropriate) appropriation. And, finally, both forms of appropriation would be more apparent among High-High pairs than Low-Low or Mixed.

4.2. Method

4.2.1. <u>Design</u>

This study employed a three-way mixed design incorporating both between-subjects conditions (support condition and pair-type), and repeated-measures conditions (time-point of testing on the Balance Scale task). Prior to the first time-point of Balance Scale testing, all children worked alone on the Balance Beam classification test, which was used to determine whether or not they had any initial explicit understanding of the factors affecting balance. On the basis of their performance, they were then assigned to same-sex pairs to work on the Balance Scale task in the same manner as in Studies 1 and 2. Pairs consisted of children who were both either of lower understanding (Low-Low), higher understanding (High-High), or one of lower and one of higher understanding (Mixed). Approximately half of the dyads of each type received support at the first time-point of the Balance Scale task. Children stayed in the same dyads for the duration of the study, and all dyads worked in the absence of support during the second and third time-points.

As in Studies 1 and 2, Balance Scale performance was assessed in terms of indices relating to the number of attempts taken to achieve balance, and the level of explanation offered by dyad members after solving each problem. Descriptions and explanations of strategies to solve the problems and of the principles at work provided by children within pairs and by the adult assisting, where relevant, were coded according to a more fine-grained system based on the presence of specific content features. The nature of support on the Balance Scale task was also scored in terms of type and frequency of intervention, and of explanation offered. Children's performance was analysed for change over time-point of testing; differences between support conditions and pair types (Low-Low, High-High or Mixed balance understanding) in the profile of change observed; and the relationship between children's interactions with one another across the three time-points, and, where appropriate, with the adult input given at the first time-point.

4.2.2. <u>Participants</u>

Participants were 106 children from Primary 3 classes within three primary schools in South Lanarkshire, Scotland. There were 56 boys and 50 girls, aged between 7 years, 1 month and 8 years, 1 month, with a mean age of 7 years, 7 months. Of these, 55 children, 31 girls and 24 boys, were classified as having lower understanding and 51 children, 19 girls and 32 boys, were classified as having higher understanding. For the purpose of the Balance Scale task, children were assigned to same-sex dyads as follows: 20 lower understanding only (Low-Low), 18 higher understanding only (High-High) and 15 mixed understanding (Mixed). Numbers were not exactly equal across dyad types, due to the constraint imposed by the distribution of gender and understanding across school classes, and the need to assign children to pairs from within classes, to control for familiarity. Of these, 28 dyads, (11 Low-Low, 10 High-High, and 7 Mixed) received support at Time 1, and 25 dyads (9 Low-Low, 8 High-High, and 8 Mixed) received no support. Children worked within the same dyads across all three time-points. All children had English as their main or only language. Children participated with written consent from parents and the local education authority. The adult providing support was a female post-graduate student. The researcher and assistant both had clearance from the university ethical committee and Scottish Criminal Record Office for undertaking research with children.

4.2.3. <u>Materials</u>

4.2.3.1. <u>Balance Beams</u>

The Balance Beams used in the classification test were the same as those used in Study 2, as described and illustrated on p. 73.

4.2.3.2. <u>Balance Scale</u>

The Balance Scale apparatus was the same as that used in the previous two studies, and is described on p. 43 and illustrated on p. 44.

A tape recorder was required for the classification test to record the children's answers and explanations, and a video camera was used to record their performance on the Balance Scale tasks.

4.2.4. Procedure

After receiving permission from the local education authority and the schools involved, parents of Primary 3 children were sent forms through the school requesting their permission to allow their children to participate in the research. They were informed that the research involved looking at how children work together to formulate problem solving strategies, and that some would be working in the presence of adult support. Children only participated after their parents had given written consent.

Testing took place over four sessions in a separate unused room within the child's school. For the first session, each child was taken out of class to the separate room and given the individual classification test, using the Balance Beam apparatus. The procedure for carrying out this test was identical to that for Study 2, as was that used to assign children to the category of higher or lower understanding. These are described and illustrated on p. 73. Children were then assigned to dyads on the basis of gender and level of understanding, as described above.

Two days after completing the classification task, each class was introduced to the assistant who would be working with supported children on the Balance Scale task at Time 1. The assistant was an MSc Psychology student attending the same university as the researcher, who had been trained in contingent scaffolding techniques and the correct way to complete the Balance Scale prior to this point. The script used to structure the training sessions with the assistants in Study 2 was also used for the present assistant, and can be seen on p. 76.

Each dyad was then taken out of class in turn and introduced to the Balance Scale, which was set up in its start position. This consisted of the eight nuts positioned in a line in front of the scale. Children in the support condition were invited to sit beside the assistant, who was seated at one end of the desk to allow the children to sit together beside her. They were then told that the goal of this problem was to make the scale balance when nuts were placed on it. The researcher explained to the children that she would put an arrangement of nuts on “her side” of the scale and they had to make it balance by arranging nuts on “their side”. However, the nuts could not be placed either on the researcher’s side, or on the child’s side in the same arrangement as the researcher had positioned hers, as this would make the task too easy. They were informed that there would be four combinations set in total for the task “to see how you can do different types of problems”. The four combinations used at Time 1 and the subsequent two time-points were identical to those used in Studies 1 and 2 and can be seen in Table 1 on p. 45.

Children were told that they were to work together to complete the task, and they were encouraged to discuss their ideas and strategies with each other. They were informed that they were not in competition with one another on the task, but were to work as a team.

When the children were happy with what they were asked to do the camera was switched on and the researcher set up the first arrangement. Each dyad then attempted to assemble nuts on their side to balance that of the researcher before removing the rest, and the assistant helped when she felt it to be appropriate. If the scale did not balance the rest was re-inserted and the dyad tried again. This was repeated until the children’s configuration balanced that of the researcher. The only time the researcher intervened during this period was when the dyad had successfully balanced an arrangement, as a new configuration had to be set up. The torque rule was not explained by the researcher at any point, but immediately after the children had completed each problem, they were asked individually, “Can you tell me how you made it (the scale) balance”?

For the pairs who were not supported at Time 1, the procedure of taking them out of class and introducing them to the Balance Scale was the same as for those who were supported. The two children were invited to sit beside one another at one side of the desk, and the researcher explained the process of working through the task as she did for the supported children.

Another break of two days was given prior to the second time-point, and then again before Time 3. At Times 2 and 3, all dyads worked on the task alone, and the same rules applied as before. As in Studies 1 and 2, one new problem was introduced at Time 2, and a further one was brought in at Time 3. As before, the children worked until they completed the problem and were then asked individually to explain their methods. They were then congratulated, thanked and taken back to class.

4.2.4.1. Scoring of Balance Scale task

The objectives of scoring were: 1) to quantify various aspects of children's performance on each task at each time-point; and 2) to provide a profile of the nature of adult support. The scoring process involved transcribing children and the adult's moves and dialogue from videotape, and then coding this transcript.

Coding of the Balance Scale task. Attempts and explanations of solutions on the Balance Scale task were scored in the same way as in Studies 1 and 2, with the exception that there were two separate databases used for analyses; one which calculated values for each individual (i.e. each child would have the same value for attempts as their partner, but different mean explanations); and the other calculated values for each dyad which appeared together in one cell. Explanation levels were scored individually and as a mean across dyad members to allow the relationship between joint attempts and joint understanding to be computed.

On the basis of this coding, a group-level index of the proportion of only single or double attempts taken to balance the scale was also computed, as the sum of all single or double attempts which led to a correct solution within each group of children, divided by the total number of attempts made within that grouping. The proportion of single and double attempts were analysed to find whether those became more commonplace as time went on.

The coding system for dialogue was applied to both the adult and children, for each time-point and condition. This system consisted of 13 codes, ordered in level of sophistication. They were based on an expansion of the prompt and explanation codes used in Study 2, except for non-specific prompts, which carried little informational value. Dialogue was firstly coded using the Study 2 system (see p. 79) and then sub-types of each code were defined according to differences in the exact framing employed. Other regular explicit expressions used that were not covered by the Study 2 system were added to form the final version. The basic objective was to code for argument stratagems in the sense employed by Kim, Anderson, Nguyen-Jaheil & Archodidou (2007). Suggestions regarding moves and non-specific prompts were ignored in this system, as the focus was solely on statements that to a greater or lesser extent make explicit reference to the principles at work, and which are therefore capable of promoting representational change. The earlier distinction between prompts and explanations is to some degree blurred, except in so far as prompts tend to be less explicit than explanations. Codes are ordered in terms of degree of explication and coordination.

The 13 codes are shown, with examples, in Table 14. The dialogue used was scored separately for adult and child input, although there was a lack of differentiation in terms of the child input. An example of the dialogue used between adult and dyad and within dyads, can be seen in Appendix 5.

Table 14. Dialogue codes used throughout Balance Scale task by adult and children.

Code	Definition
0	Notes that information is implied by rate of fall e.g. "it was close"
1	Implicit weight/distance prompt – number signalled e.g. "do you think we need to use less?"
2	Implicit weight/distance prompt – distance signalled e.g. "you can use any of these pegs"
3	Non-specific Implicit weight/distance prompt – number and distance signalled e.g. "is it something to do with weight and distance/right, we had two on that one?"
4	Nut/peg prompt – reference to relative position e.g. "they're on the first one"
5	Nut/peg prompt – reference to number and relative position e.g. "where are Sharon's two?"
6	Nut/peg prompt – Disjunction between number and weight e.g. "there's two there and two here, so why is it (why is this side) still too heavy?"
7	Weight exp – reference is specifically in terms of weight e.g. "this side's (still) too heavy/this side's heavier again/what side was heavier?"
8	Number exp – Explanation in terms of comparison of number e.g. "they've got the same amount/one is lighter than two/ we took another one off and it didn't fall 'cos that one's got less than this one"
9	Distance exp – reference to/comparison of position e.g. "maybe it was because they're too close"
10	Number and Position exp – description of number and position e.g. "we put one there and there's two there and we put one on the second one/

	there's no middle one there, but we've put them on that middle one/ if you put more there it would fall down"
11	Number and Position exp – description in terms of the relationship between number and position e.g. "you put less at the end 'cos it's heavier at the end/ you can't put too much on that one to balance 'cos it'll be too heavy there's two here and only one here, so do you think it's 'cos it's further along it makes it balance?"
12	Torque rule exp – explicit equivalence of weight achieved via manipulation of distance e.g. "this one's probably the same weight as those two 'cos it's on different ones/ that one's on the first one and that's on the second – that would balance 'cos it would have the weight of two/ these have the same weight as those two, 'cos they're on the third and those are on the second and fourth"

The dependent measure derived was the frequency of each code for each problem at each of the three time-points.

Reliability. A check on the reliability of the coding of post-solution explanations and the intervening dialogue was made by obtaining independent coding of approximately 10% of the transcripts. As the reliability of the coding for attempts and explanations was established in Study 2 there was no need to repeat it here, given that the coding was the same. For the dialogue codes, agreement was 81.6%.

4.3. Results

4.3.1. Overview of analyses

Analyses firstly focused on: 1) an overall profile of children's performance on the balance scale task, with respect to the impact that support condition and pair type may have had on children's performance and understanding of the task, examined through their attempts and mean explanation level; and, 2) the nature of adult input administered across time to dyads who received support at Time 1, broken down by pair type, in order to establish whether there was evidence of contingent deployment of different elements of support. More fine-grained analyses then focused on variations in children's use of different forms of dialogue around the task, and the relationship of such usage to their performance, to adult input (primary appropriation), and to the dialogue of dyad partners (secondary appropriation), where appropriate.

Preliminary analysis was conducted on the children's age in months by pair type and support condition, to ensure that these did not differ significantly in this respect. A univariate Anova confirmed that this was the case.

4.3.2. Profile of children's performance on the Balance Scale task

As all children worked on the Balance Scale with a partner, attempts to balance the scale were generated by conjoint rather than individual activity. Therefore, analyses on the number of attempts taken to balance the scale used pairs as the unit of analysis, since individual contributions could not be readily disentangled. This was not the case for their level of explanations, however, as after successfully balancing the scale both children within the pair were asked to give an explanation as to how the scale was balancing. Children were asked for their explanations separately to ascertain the extent to which each understood the weight/distance properties of balance. As a result, analyses on the mean level of explanation across problems used the individual child as the unit of analysis.

The number of attempts taken by dyads in the supported and unsupported conditions to balance the Scale for the four problems at the three time-points can be seen in

Tables 15a and 15b, respectively. Children have been grouped by pair type within condition to clarify the nature of variation across and within each.

Table 15a. Number of attempts to achieve balance for each supported pair of children on the Balance Scale task, on Problems 1 to 4 (P1 to P4) at Times 1, 2 and 3. Table is split into children's pair type of Support, Low-Low understanding (*S LL*); Support, High-High Understanding (*S HH*), and Support, Mixed Understanding (*S M*). Where single or double attempts have been successful in balancing the scale, this has been shown in bold.

Supported Children	Time 1 *Attempts*				Time 2 *Attempts*				Time 3 *Attempts*			
	P1	*P2*	*P3*	*P4*	*P1*	*P2*	*P3*	*P4*	*P1*	*P2*	*P3*	*P4*
S LL (n = 11)												
1	9	**1**	5	5	13	**2**	3	4	7	**1**	**1**	5
2	10	11	3	**1**	10	10	**2**	17	9	14	**2**	5
3	13	4	7	5	10	**2**	5	18	**2**	21	6	5
4	**2**	3	5	**2**	**2**	16	10	8	9	12	7	**2**
5	8	6	13	**1**	12	**2**	**1**	3	6	5	**2**	3
6	8	5	12	12	27	23	9	**1**	6	16	**1**	7
7	7	3	9	**2**	12	5	**1**	4	6	25	8	6
8	18	8	9	**1**	5	5	10	/	13	11	4	4
9	11	3	6	3	4	4	3	3	8	**1**	**2**	5
10	17	23	**1**	4	10	3	3	**2**	14	14	8	7
11	9	14	**2**	4	26	13	5	34	6	8	**1**	6
Mean	10.2	7.4	6.5	3.6	11.9	7.7	4.7	9.4	7.8	11.6	3.8	5.0
S M (n = 7)												
1	5	8	**2**	9	7	11	**2**	9	13	9	**1**	4
2	10	18	5	7	14	7	**2**	**1**	12	6	11	10
3	3	7	**2**	11	21	8	7	4	22	3	5	3
4	4	3	**1**	6	12	**2**	3	20	13	18	**2**	4
5	**2**	15	4	**2**	5	4	3	4	**2**	**1**	**2**	5
6	4	14	9	25	26	6	5	5	13	**2**	8	4
7	3	4	4	**2**	16	**2**	**2**	10	11	3	**1**	3
Mean	4.4	9.9	3.9	8.9	14.4	5.7	3.4	7.6	12.3	6.0	4.3	4.7
S HH (n = 10)												
1	8	5	4	6	6	**2**	4	11	14	**2**	**1**	9
2	4	16	5	**1**	3	**2**	**2**	**2**	**1**	**1**	**2**	**2**
3	12	**2**	11	**2**	12	8	9	14	12	18	4	11
4	7	**1**	6	6	**1**	**1**	8	7	**1**	3	3	**2**
5	4	**1**	10	5	12	**1**	**1**	14	48	**1**	**2**	9
6	7	6	5	4	26	13	6	5	14	8	14	**2**
7	15	4	4	12	20	5	4	28	3	14	**1**	**2**
8	8	10	4	6	15	12	11	9	7	3	3	1
9	20	6	**1**	8	17	17	**2**	3	17	7	5	7
10	17	6	12	3	**1**	17	**1**	7	**2**	6	**1**	6
Mean	10.2	5.7	6.2	5.3	11.3	7.8	4.8	10.0	11.9	6.3	3.6	5.1

Table 15b. Number of attempts to achieve balance for each unsupported pair of children on the Balance Scale task, on Problems 1 to 4 (P1 to P4) at Times 1, 2 and 3. Table is split into children's pair type No Support, Low-Low understanding (*NS LL*); No Support, High-High Understanding (*NS HH*), and No Support, Mixed Understanding (*NS M*). Where single or double attempts have been successful in balancing the scale, this has been shown in bold.

Non-Supported Children	Time 1				Time 2				Time 3			
	Attempts				*Attempts*				*Attempts*			
	P1	*P2*	*P3*	*P4*	*P1*	*P2*	*P3*	*P4*	*P1*	*P2*	*P3*	*P4*
NS LL (n = 9)												
1	15	9	18	3	6	16	**2**	27	12	3	7	5
2	24	23	5	9	**2**	9	**1**	31	1	12	4	5
3	10	**2**	18	4	5	6	7	18	16	**1**	9	5
4	**2**	12	9	11	11	**1**	4	4	8	4	**2**	4
5	23	33	5	4	10	5	8	4	25	10	**2**	**2**
6	12	5	18	17	9	4	31	**2**	8	10	**2**	3
7	18	7	4	4	8	5	14	3	**1**	4	11	3
8	22	13	11	26	17	**2**	**2**	17	6	4	**1**	4
9	18	15	3	10	15	17	9	5	28	5	11	**2**
Mean	16.0	13.2	10.1	9.8	9.2	7.2	8.7	12.3	11.7	5.9	5.4	3.7
NS M (n = 8)												
1	**1**	23	8	16	21	**1**	**1**	14	8	**2**	**1**	**2**
2	21	6	14	10	11	7	3	20	5	**2**	8	**2**
3	**2**	13	20	**1**	5	3	3	19	**1**	6	**2**	6
4	16	15	13	3	**1**	**2**	6	16	**1**	**1**	5	23
5	17	10	6	13	8	3	6	9	10	7	18	4
6	6	12	4	3	8	**1**	6	5	9	**1**	8	5
7	18	18	12	20	3	5	5	29	4	6	7	4
8	37	5	5	20	21	6	7	3	12	34	5	**2**
Mean	14.8	12.8	10.3	10.8	9.8	3.5	4.6	14.4	6.3	7.4	6.8	6.0
NS HH (n = 8)												
1	9	21	8	5	3	**1**	10	13	3	**2**	5	9
2	18	3	**1**	4	16	8	**2**	3	3	7	**1**	4
3	37	6	6	10	**2**	19	4	12	13	**2**	22	8
4	9	7	3	16	10	29	27	21	5	7	5	**1**
5	**2**	12	5	15	6	6	**1**	10	6	5	**1**	3
6	**2**	**2**	9	5	12	8	**1**	4	10	**2**	12	**2**
7	**1**	11	**2**	**2**	**1**	**2**	11	7	4	**1**	9	4
8	**1**	7	**1**	6	14	3	5	4	11	8	4	9
Mean	9.9	8.6	4.4	7.9	8.0	9.5	7.6	9.3	6.9	4.3	7.4	5.0

It can be seen from Tables 15a and 15b that with regards to performance on specific problems across the time-points, the highest number of attempts taken to balance the scale at each of the three time-points occurred generally during the first problem in a set, possibly as children were trying to settle into the task. Of the supported children, although the Mixed group took the least number of attempts to complete the task on the first problem at Time 1, the opposite was true for their performance on this problem at Times 2 and 3. The Low-Low children who were unsupported tended to take the longest time to complete the first problem with the exception of Time 2. Overall, the smallest number of attempts was conducted on the third problem.

High-High supported pairs completed the task in a single or double move more often than any other group, whereas the unsupported Low-Low pairs achieved balance in a single or double move the least number of times of all the groups. The High-High children who were unsupported at Time 1 also achieved balance in a single or double move on more occasions than the other two groups in this condition. This finding serves to confirm the general validity of the classification of children as High and Low in their understanding.

The mean total of attempts for each dyad at each time-point, and mean individual explanation level, broken down by support condition and pair-type, can be seen in Table 16. The values for attempts can also be seen in Figure 8, and for explanation levels in Figure 9, again with children grouped according to their support condition and pair type.

Table 16. Mean number of attempts and mean explanation level given by each dyad, split into support condition and pair-type.

		Support given at Time 1						No Support given at Time 1					
Measure	Time-Point	Low-Low Mean	*SD*	Mixed Mean	*SD*	High-High Mean	*SD*	Low-Low Mean	*SD*	Mixed Mean	*SD*	High-High Mean	*SD*
Attempts	1	27.55	*9.22*	27.00	*14.14*	27.20	*6.48*	48.56	*13.84*	48.50	*14.59*	30.75	*15.25*
	2	32.91	*20.06*	31.14	*9.28*	34.00	*15.54*	37.44	*10.20*	32.25	*8.14*	34.25	*21.86*
	3	28.27	*10.54*	27.29	*10.40*	26.90	*17.46*	26.67	*10.31*	26.38	*13.72*	23.50	*10.46*
Mean Explanation Level	1	2.20	*0.47*	2.57	*0.27*	2.45	*0.37*	2.01	*0.74*	2.11	*0.74*	2.53	*0.42*
	2	2.25	*0.81*	2.59	*0.50*	2.50	*0.46*	1.90	*0.98*	2.20	*0.53*	2.53	*0.46*
	3	2.20	*0.68*	2.66	*0.24*	2.45	*0.71*	1.97	*0.88*	2.16	*0.95*	2.41	*0.56*

Figure 8. Total attempts across time-point by support condition and pair type.

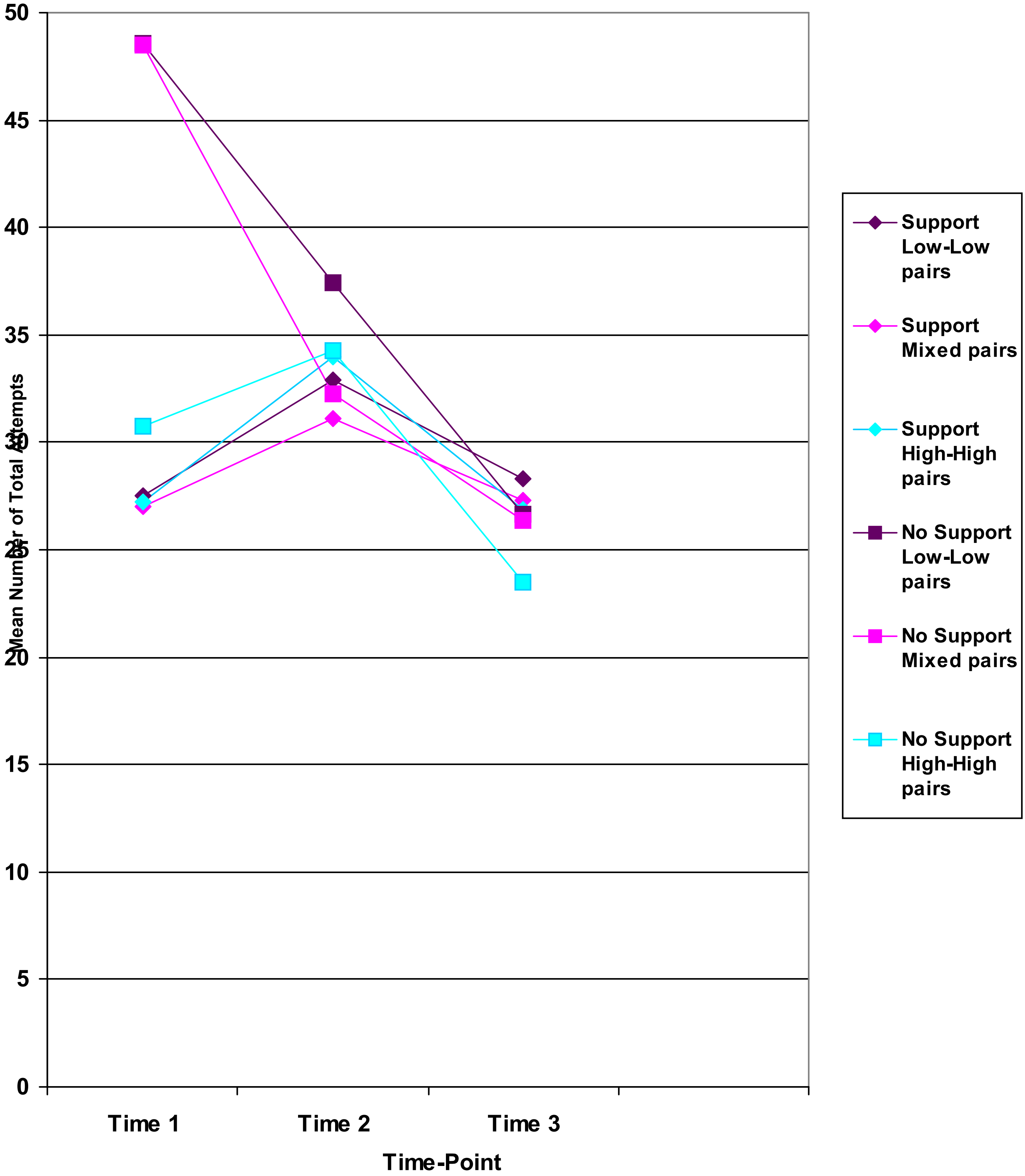
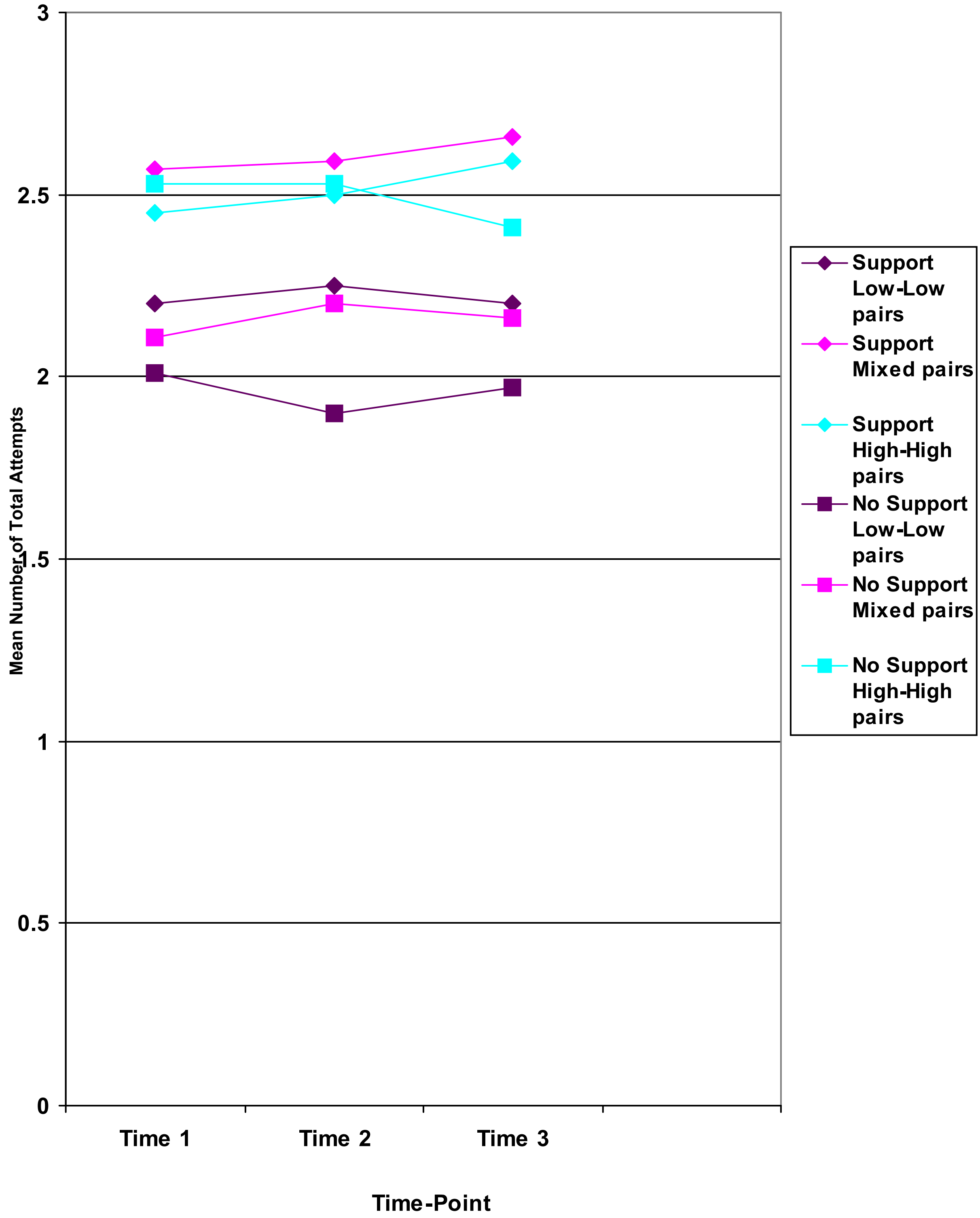


Figure 9. Mean explanation level across time-point by support condition and pair type.



a) Attempts. It can be seen from Table 16 and Figure 8 that the supported children generally required less attempts overall to balance the scale than those who were unsupported. At the first time-point, the supported children, along with those of higher understanding who were unsupported, were all performing similarly. At Time 2, those children all increased in the number of attempts made, before decreasing in attempts again at the final time-point. In contrast, the unsupported children who were of lower and mixed understanding, made the most attempts to achieve balance at Time 1, but then dropped steadily in their number of attempts until they were performing roughly the same as children in the other conditions at the final time-point. By Time 3 it was the High-High dyads in the unsupported condition that were making the least number of attempts to achieve balance of all the groups. However, any differences here were obviously very marginal.

A 3-way mixed Anova (support condition, dyad type and time-point) confirmed a main effect of Time ($F(2,94) = 7.01$, $p=.001$), and follow-up paired T-Tests showed that the differences lay between Times 2 and 3 ($p=.006$), and Times 1 and 3 ($p=.002$). This confirms that the dyads made significantly fewer attempts to complete the task at Time 3 than they had at Times 1 and 2. There was also a main effect of support condition ($F(1,47) = 4.15$, $p=.047$). From the mean values in Table 16 it can be seen that those who were supported made fewer attempts overall than those who were unsupported. Finally, there was a significant interaction between time-point and support condition, and an independent samples T-Test showed that this difference lay at Time 1 ($p<.001$). This confirmed that those who were supported at Time 1 made significantly fewer attempts to complete the task than those who were unsupported. This difference had disappeared by Time 2, however. There were no effects of pair type, despite the differences between High-High and other pairs at Time 1 in the unsupported condition. The results indicate that adult support had an impact at Time 1, but only for those of mixed or lower understanding. In general, with the exceptions noted above, the performance profiles were strikingly similar regardless of condition or pair type.

b) Explanations. From the mean values in Table 16 and Figure 9, especially, it can be seen that Low-Low children belonging to the supported condition were giving very similar explanations to the Low-Low and Mixed children in the unsupported condition across the three time-points. In contrast the unsupported High-High children were giving very similar explanations to the supported High-High and Mixed children. A 3-way mixed Anova (support condition, dyad type and time-point) confirmed there was a main effect of pair type ($F(2,100) = 3.79$, $p=.026$). Follow-up T-Tests confirmed that the differences lay between the Low-Low and High-High pairs ($p =$

.005). There were no other significant main effects or interactions, with the exception of a marginal main effect of support condition (F(1,100) = 3.35, p=.070). The implication from those findings is that support had little impact overall on children's mean explanation, except perhaps for the Mixed group, this being the only pair type where the profile of explanations differed much between the two support conditions. In fact, from Figure 9 it can be seen that there really was little or no progress in explanations over time for any of the six dyad groups.

c) Relationship between attempts and explanations. Whilst support may have had little sustained impact on performance, in terms of attempts and explanations, it might have affected the relationship between these elements by making it more explicit. Therefore, to explore this, bivariate one-tailed correlations were calculated using individual explanation values and total attempts for the dyad that children were in, separate results being computed according to support condition and pair type.

Supported children

<u>Low-Low children (N = 22)</u>

Table 17a shows the relationship between the supported Low-Low children's attempts and individual mean explanations across the three time-points.

Table 17a. Relationship between Attempts and Mean Explanation level across Times 1, 2 and 3 for the supported Low-Low children.

	Time 1 Attempts	Time 1 Mean Ex	Time 2 Attempts	Time 2 Mean Ex	Time 3 Attempts	Time 3 Mean Ex
Time 1 Attempts	/	r = .22 n.s	r = .07 n.s	**r = .41 p=.029**	r = .31 n.s	**r = .45 p=.017**
Time 1 Mean Ex		/	**r = -.43 p=.022**	**r = .59 p=.002**	r = -.11 n.s	**r = .57 p=.003**
Time 2 Attempts			/	**r = -.47 p=.013**	r = -.06 n.s	**r = -.36 p=.050**
Time 2 Mean Ex				/	r = -.14 n.s	**r = .64 p=.001**
Time 3 Attempts					/	r = -.10 n.s
Time 3 Mean Ex						/

There were no significant correlations between attempts and explanation at either Time 1 or Time 3, although there was some sign of coordination at Time 2, with higher explanation levels being associated with fewer attempts (r = -.47, p=.013). There seems to be a pattern of carry-over among this group of children who initially gave higher explanations, however, as their understanding at Time 1 was also associated with fewer attempts at Time 2 (r = -.43, p=.022) and higher explanations at Times 2 (r = .59, p=.002) and 3 (r = .57, p=.003). The association between Time 2 attempts and explanations can therefore be interpreted as an indirect function of that between Time 1 explanations and Time 2 attempts. Consistent with this carry-over pattern, fewer attempts made at Time 2, and higher explanations given at this time-point were associated with higher explanations at Time 3 (r = -.36, p=.050 and r = .64, p=.001, respectively). In contrast, those who made more attempts at Time 1 showed better understanding at Times 2 and 3 (r = .41, p=.029 and r = .45, p=.017, respectively). The lack of correlation between Time 1 attempts and explanations suggests this was a separate group of children who progressed via experience, as seen before. These children may have done worse under adult support, which in Studies 1 and 2 acted typically to suppress attempts.

Mixed (Low-High) children (N = 14)

Table 17b shows the relationship between the supported Mixed children's attempts and individual mean explanations across the three time-points.

Table 17b. Relationship between Attempts and Mean Explanation level across Times 1, 2 and 3 for the supported Mixed children.

	Time 1 Attempts	Time 1 Mean Ex	Time 2 Attempts	Time 2 Mean Ex	Time 3 Attempts	Time 3 Mean Ex
Time 1 Attempts	/	r = -.02 n.s	r = .19 n.s	r = -.15 n.s	r = .22 n.s	r = -.30 n.s
Time 1 Mean Ex		/	r = .38 n.s	**r = .61 p=.010**	r = -.06 n.s	r = .39 n.s
Time 2 Attempts			/	**r = .49 p=.037**	**r = .51 p=.032**	r = .13 n.s
Time 2 Mean Ex				/	r = -.10 n.s	r = .06 n.s
Time 3 Attempts					/	r = -.13 n.s
Time 3 Mean Ex						/

The supported Mixed pairs showed vestiges of the patterns of progress for Low-Low dyads. In line with the latter group, there were no significant concurrent correlations between attempts and explanations at either Time 1 or Time 3, but there was a carry-over in explanations from Time 1 to Time 2 (r = .61, p=.010), and a relationship between Times 1 and 3 explanations, which was positive although marginal. There were also signs that some at least of the Mixed group were learning from experience, albeit at a later point. Time 2 attempts positively correlated with Time 2 explanations (r = .49, p=.037) and Time 3 attempts (r = .51, p=.032).

High-High children (N = 20)

Table 17c shows the relationship between the supported High-High children's attempts and individual mean explanations across the three time-points.

Table 17c. Relationship between Attempts and Mean Explanation level across Times 1, 2 and 3 for the supported High-High children.

	Time 1 Attempts	Time 1 Mean Ex	Time 2 Attempts	Time 2 Mean Ex	Time 3 Attempts	Time 3 Mean Ex
Time 1 Attempts	/	r = .19 n.s	r = .35 p=.068	r = .08 n.s	r = -.25 n.s	**r = .45 p=.022**
Time 1 Mean Ex		/	r = .26 n.s	r = .29 n.s	r = .14 n.s	r = .10 n.s
Time 2 Attempts			/	r = -.07 n.s	r = .32 n.s	r = .00 n.s
Time 2 Mean Ex				/	r = .04 n.s	**r = .60 p=.003**
Time 3 Attempts					/	r = -.14 n.s
Time 3 Mean Ex						/

There were no concurrent significant associations with the High-High supported children.
The correlations do suggest some vestiges of the carry-over of higher explanations seen in the Low-Low group, but only from Time 2 to Time 3 (r = .60, p=.003). These were not associated with attempts though, despite the high variability between dyads in this respect (see Table 16). There were also vestiges of the learning from experience seen in the Low-Low pairs, with Time 1 attempts positively associated with Time 3 explanations (r = .45, p=.022). In general then, the patterns of progress are not hugely different between the Low-Low, Mixed and High-High understanding groups, which is consistent with the lack of differences in Means.

Non-supported children

Low-Low children (N = 18)

Table 18a shows the relationship between the unsupported Low-Low children's attempts and individual mean explanations across the three time-points.

Table 18a. Relationship between Attempts and Mean Explanation level across Times 1, 2 and 3 for the unsupported Low-Low children.

	Time 1 Attempts	Time 1 Mean Ex	Time 2 Attempts	Time 2 Mean Ex	Time 3 Attempts	Time 3 Mean Ex
Time 1 Attempts	/	r = -.14 n.s	r = .28 n.s	r = .19 n.s	r = -.06 n.s	r = -.25 n.s
Time 1 Mean Ex		/	**r = -.66 p=.001**	**r = .75 p<.001**	r = -.37 n.s	**r = .65 p=.002**
Time 2 Attempts			/	**r = -.49 p=.019**	r = .21 n.s	**r = -.56 p=.008**
Time 2 Mean Ex				/	**r = -.42 p=.041**	**r = .71 p<.001**
Time 3 Attempts					/	**r = -.58 p=.006**
Time 3 Mean Ex						/

The associations for unsupported Low-Low children were very similar to this group who were supported at Time 1. For example, there was no coordination of attempts and explanations at Time 1, with this not being evident until the second time-point ($r = -.49$, $p=.019$), where it could again be seen as a function of the carry-over of explanations, since more sophisticated explanations at Time 1 were associated with fewer attempts and higher explanation levels at Time 2 ($r = -.66$, $p=.001$, and $r = .75$, $p<.001$, respectively). In contrast to the findings for the Low-Low supported children, the unsupported children's Time 3 attempts were negatively related to their explanations at this final time-point ($r = -.58$, $p=.006$), but this could also be seen as a carry-over effect. Explanations at Time 2 were significantly related to Time 3 understanding ($r = .71$, $p<.001$) and Time 3 attempts ($r = -.42$, $p=.041$).

There are no signs here of learning from experience, however, with no positive association between earlier attempts and later explanations despite the lack of support.

Mixed (Low-High) children (N = 16)

Table 18b shows the relationship between the unsupported Mixed children's attempts and individual mean explanations across the three time-points.

Table 18b. Relationship between Attempts and Mean Explanation level across Times 1, 2 and 3 for the unsupported Mixed children.

	Time 1 Attempts	Time 1 Mean Ex	Time 2 Attempts	Time 2 Mean Ex	Time 3 Attempts	Time 3 Mean Ex
Time 1 Attempts	/	r = -.10 n.s	**r = .78 p<.001**	r = -.28 n.s	r = .41 p=.059	r = -.20 n.s
Time 1 Mean Ex		/	r = -.17 n.s	**r = .80 p<.001**	r = -.21 n.s	**r = .60 p=.008**
Time 2 Attempts			/	**r = -.44 p=.046**	r = -.14 n.s	**r = -.55 p=.014**
Time 2 Mean Ex				/	r = -.04 n.s	**r = .87 p<.001**
Time 3 Attempts					/	r = .20 n.s
Time 3 Mean Ex						/

The pattern for the Mixed unsupported children was less like that for the supported Mixed and more like that for the unsupported Low-Low group, who actually had the most similar performance profiles to them, in terms of explanation levels and attempts. The carry-over in explanations was strong across all time-points (r = .80, p<.001 for Times 1 and 2; r = .87, p<.001 for Times 2 and 3; and r = .60, p=.008 for Times 1 and 3), and this again impinged on attempts, although the only concurrent association was at Time 2, where the effect was weak (r = -.44, p=.046). However, the higher the attempts at Time 2, the lower the explanation given at Time 3 (r = -.55, p=.014). This, along with the other non-significant correlations, suggests that, in line with the lower unsupported dyad types, there was once again no sign of learning from experience.

High-High children (N = 16)

Table 18c shows the relationship between the unsupported High-High children's attempts and individual mean explanations across the three time-points.

Table 18c. Relationship between Attempts and Mean Explanation level across Times 1, 2 and 3 for the unsupported High-High children.

	Time 1 Attempts	Time 1 Mean Ex	Time 2 Attempts	Time 2 Mean Ex	Time 3 Attempts	Time 3 Mean Ex
Time 1 Attempts	/	r = .09 n.s	r = .28 n.s	r = -.11 n.s	r = .41 p=.058	r = -.26 n.s
Time 1 Mean Ex		/	r = -.32 n.s	r = .41 p=.060	r = .36 n.s	**r = .50 p=.024**
Time 2 Attempts			/	r = -.24 n.s	r = -.05 n.s	r = -.27 n.s
Time 2 Mean Ex				/	r = .37 n.s	**r = .57 p=.010**
Time 3 Attempts					/	**r = .54 p=.016**
Time 3 Mean Ex						/

Correlations for the unsupported High-High children were again very similar to this group who were supported at Time 1. The carry-over in explanations was more consistent across the three time-points than for the supported High-High group, as although there was only significance between Times 2 and 3 (r = .57, p=.010), and Times 1 and 3 (r = .50, p=.024), the association between Time 1 and 2 was marginal (r = .41, p=.060). As with the other unsupported groups there was no sign of learning from experience, though, except perhaps at Time 3, where there was a positive correlation between attempts and explanations (r = .54, p=.016).

In summary, therefore, dyad types within conditions exhibited broadly similar patterns of progress. Those similarities extended across conditions too, except that the unsupported dyads showed much less sign of learning from experience. This suggests that if adult support had an impact it was primarily in terms of somehow resourcing this kind of process.

4.3.3. <u>Profile of Adult Input</u>

To find how the adult may have impacted on any differences between the supported and unsupported children, analyses now focused on the adult's use (type and frequency) of the 13 codes with the three types of dyads.

Table 19. Mean number of times the adult used each of the 13 interaction codes with supported dyads, split into children's dyad type at Time 1.

		Adult to supported pairs					
Code	Description	Low-Low (N=11)		Mixed (N=7)		High-High (N=10)	
		M	*SD*	M	*SD*	M	*SD*
0	Information implied by rate of fall	0.00	*0.00*	0.14	*0.38*	0.20	*0.42*
1	Implicit w/d prompt – number	0.55	*0.93*	0.86	*0.69*	0.80	*0.92*
2	Implicit w/d prompt – distance	0.55	*0.69*	0.29	*0.49*	0.00	*0.00*
3	Implicit w/d prompt – number & distance	1.00	*1.43*	0.86	*0.69*	0.70	*0.95*
4	Nut/peg prompt – position	0.18	*0.41*	0.00	*0.00*	0.40	*0.97*
5	Nut/peg prompt – number & position	0.36	*0.51*	0.00	*0.00*	0.70	*1.25*
6	Nut/peg prompt – number/weight disjunction	1.55	*1.29*	1.86	*1.68*	1.90	*1.45*
7	Explanation – reference to weight	16.18	*8.65*	12.29	*9.36*	13.90	*5.36*
8	Explanation – number comparison	0.45	*0.52*	0.14	*0.38*	0.60	*1.08*
9	Explanation – reference to distance	0.18	*0.41*	0.14	*0.38*	0.30	*0.48*
10	Explanation – Number & position description	0.36	*0.51*	0.29	*0.49*	0.70	*0.68*
11	Explanation – relationship between Number & position	3.82	*2.71*	0.71	*0.76*	2.60	*2.17*
12	Torque rule explanation	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
	Total Mean Utterances	25.18	*12.49*	17.57	*11.84*	22.80	*8.88*

From Table 19 it can be seen that the adult generated the most dialogue with the lower understanding pairs, and the least support was given to those of mixed understanding. The most common code used was code 7 (reference to outcomes/solutions is specifically in terms of weight), and the adult did not use any torque rule explanations (code 12). There was quite a discrepancy in the extent to which code 11 (explanation in terms of the relationship between number and position of nuts on the Balance

Scale) was employed, as it was used over five times as often with the lower understanding pairs as with the mixed pairs.

These fluctuations proved not to be significant, however. A series of one-way Anovas were computed on the 13 codes to find whether there were differences in the number of times the codes were used depending on the children's pair type. There was initially a significant difference among the pair types in the use of code 11 (p=.025). However, as so many Anovas were computed, a Bonferroni correction for significance was made. Due to the Bonferroni adjustment required (p now <=.004), there were no significant differences in the use of codes with the three pair types. The lack of any significant effects of dialogue used with the different dyad types suggests that there was a high degree of convergence in adult input across dyads.

4.3.4. <u>Profile of dialogue used by three pair types</u>

Analyses now examined the type and frequency of dialogue that was used by each pair of supported and unsupported children, to explore the ways in which they were developing and extending their understanding of the task through discussing the different strategies that could be attempted, and why specific attempts had not worked, or would potentially not work if attempted. Furthermore, it was also important to investigate whether dialogue differed significantly depending on the children's initial understanding of the properties of balance, type of dyad they belonged to, and whether support was given or not.

The mean number of times each of the 13 interaction codes were used by children within support condition and dyad type, at Times 1, 2, and 3, along with means and standard deviations, can be observed in Tables 20a, 20b and 20c, respectively. By splitting pairs into their support condition and dyad type, the potential impact of the adult on the supported children's dialogue use at each time-point, could be observed.

It can be seen from Table 20a that at Time 1, children who were supported generated a much higher level of dialogue overall than those children who were unsupported, with this being particularly noticeable with regard to the usage of code 10, which was used much more by the supported Mixed dyads than any other group. In fact, in both supported and unsupported conditions, the most dialogue was generated overall by the Mixed pairs, who received least adult input when supported, followed by the High-High pairs. The unsupported Low-Low dyads generated the least amount of dialogue of all the conditions. The standard deviations were similar across both support conditions and dyad type, suggesting that the variation in the amount of dialogue generated was fairly consistent across the board.

Table 20a. Mean number of times each of the 13 interaction codes were used at **Time 1** by Supported and non-supported dyads, split into dyad type and support condition.

		Supported Children						Unsupported Children					
Code	Description	Low-Low (N=11)		Mixed (N=7)		High-High (N= 10)		Low-Low (N=9)		Mixed (N=8)		High-High (N=8)	
		M	*SD*	M	*SD*	M	*SD*	M	SD	M	SD	M	SD
0	Information implied by rate of fall	0.00	*0.00*	0.14	*0.38*	0.10	*0.32*	0.22	0.67	0.00	0.00	0.13	0.35
1	Implicit w/d prompt – number	0.18	*0.41*	0.00	*0.00*	0.20	*0.42*	0.33	0.71	0.00	0.00	0.25	0.71
2	Implicit w/d prompt – distance	0.00	*0.00*	0.00	*0.00*	0.20	*0.42*	0.44	1.33	0.00	0.00	0.00	0.00
3	Implicit w/d prompt – number & distance	0.09	*0.30*	0.29	*0.49*	0.00	*0.00*	0.00	0.00	0.00	0.00	0.00	0.00
4	Nut/peg prompt – position	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.22	0.67	0.00	0.00	0.00	0.00
5	Nut/peg prompt – number & position	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	0.00	0.00	0.00	0.13	0.35
6	Nut/peg prompt – number/weight disjunction	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.11	0.33	0.13	0.35	0.00	0.00
7	Explanation – reference to weight	6.73	*6.08*	9.29	*6.05*	7.00	*4.42*	4.22	3.87	8.50	6.99	6.00	5.76
8	Explanation – number comparison	0.91	*1.14*	1.57	*1.27*	1.50	*1.51*	1.89	1.54	1.25	0.71	1.13	1.81
9	Explanation – reference to distance	2.45	*3.45*	0.86	*0.90*	1.20	*1.23*	1.11	1.17	1.38	1.19	0.38	0.52
10	Explanation – Number & position description	4.27	*2.10*	6.43	*2.37*	4.90	*3.14*	3.44	1.81	3.38	1.30	3.50	1.41
11	Explanation – relationship between Number & position	2.00	*1.73*	1.86	*1.57*	3.20	*1.62*	0.11	0.33	1.38	1.30	3.38	2.39
12	Torque rule explanation	0.00	*0.00*	0.43	*1.13*	0.60	*1.27*	0.11	0.33	0.13	0.35	0.63	0.74
	Total Mean Utterances	16.64	*6.44*	20.86	*7.24*	18.90	*8.41*	12.22	*4.74*	16.13	*6.98*	15.50	*5.98*

Interestingly, despite the absence of any torque rule explanations (code 12) given by the adult (see Table 19), it can be seen from Table 20a that a very small number of the High-High and Mixed understanding pairs gave at least one torque level explanation during the session although there was no marked difference between conditions in this respect. This suggests that on-task they had enough explicit representation of weight and distance to be able to fight towards tying these together explicitly. However, the very small means indicate they had not yet internalised this type of explanation, but instead, some form of co-construction was happening.

Table 20b. Mean number of times each of the 13 interaction codes were used at **Time 2** by Supported and non-supported dyads, split into dyad type and support condition.

Code	Description	Supported Children: Low-Low (N=11) M	SD	Mixed (N=7) M	SD	High-High (N= 10) M	SD	Unsupported Children: Low-Low (N=9) M	SD	Mixed (N=8) M	SD	High-High (N=8) M	SD
0	Information implied by rate of fall	0.09	*0.30*	0.00	*0.00*	0.00	*0.00*	0.11	*0.33*	0.00	*0.00*	0.13	*0.35*
1	Implicit w/d prompt – number	0.27	*0.91*	0.00	*0.00*	0.20	*0.63*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
2	Implicit w/d prompt – distance	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
3	Implicit w/d prompt – number & distance	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
4	Nut/peg prompt – position	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
5	Nut/peg prompt – number & position	0.09	*0.30*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
6	Nut/peg prompt – number/weight disjunction	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.11	*0.33*	0.00	*0.00*	0.00	*0.00*
7	Explanation – reference to weight	4.91	*5.21*	9.86	*10.30*	4.70	*6.18*	4.22	*2.39*	4.50	*3.34*	3.75	*2.44*
8	Explanation – number comparison	0.82	*1.54*	0.29	*0.49*	0.80	*1.55*	0.78	*1.64*	0.75	*0.71*	0.75	*1.39*
9	Explanation – reference to distance	1.27	*1.90*	0.14	*0.38*	0.50	*0.71*	0.67	*0.87*	0.75	*1.39*	0.63	*0.92*
10	Explanation – Number & position description	3.91	*2.51*	4.57	*2.15*	3.00	*2.00*	2.89	*2.47*	3.89	*1.55*	4.89	*1.81*
11	Explanation – relationship between Number & position	0.91	*1.04*	2.14	*1.68*	3.50	*1.78*	1.56	*2.46*	1.63	*2.00*	1.87	*2.10*
12	Torque rule explanation	0.18	*0.60*	0.00	*0.00*	0.40	*0.52*	0.00	*0.00*	0.25	*0.71*	0.00	*0.00*
	Total Mean Utterances	12.45	*5.45*	17.00	*10.77*	13.10	*6.32*	10.33	*2.65*	11.75	*4.10*	12.00	*4.41*

From the mean values in Tables 20b and 20c, it can be seen that at Times 2 and 3, those children who had previously been supported were still generating more dialogue within their dyads than those who worked unsupported in their pairs at Time 1. However, it was the supported Mixed dyads who consistently generated the most dialogue, especially with regard to code 10, with means for the supported Low-Low and High-High groups gradually falling back to the level exhibited by their unsupported equivalent at Time 3.

Table 20c. Mean number of times each of the 13 interaction codes were used at **Time 3** by Supported and non-supported dyads, split into dyad type and support condition.

		Supported Children						Unsupported Children					
Code	Description	Low-Low (N=11)		Mixed (N=7)		High-High (N= 10)		Low-Low (N=9)		Mixed (N=8)		High-High (N=8)	
		M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*
0	Information implied by rate of fall	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
1	Implicit w/d prompt – number	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
2	Implicit w/d prompt – distance	0.00	*0.00*	0.14	*0.38*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
3	Implicit w/d prompt – number & distance	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
4	Nut/peg prompt – position	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
5	Nut/peg prompt – number & position	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
6	Nut/peg prompt – number/weight disjunction	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
7	Explanation – reference to weight	2.73	*1.95*	5.86	*4.25*	2.70	*2.11*	2.00	*2.00*	2.75	*2.44*	2.38	*1.41*
8	Explanation – number comparison	1.00	*1.41*	0.57	*0.98*	1.00	*2.21*	1.22	*1.92*	1.25	*1.28*	0.75	*1.39*
9	Explanation – reference to distance	1.00	*1.18*	0.14	*0.38*	0.20	*0.42*	0.67	*0.71*	0.50	*1.07*	0.75	*1.04*
10	Explanation – Number & position description	4.09	*2.43*	5.43	*2.88*	4.40	*2.46*	3.56	*3.05*	3.87	*1.96*	4.13	*0.99*
11	Explanation – relationship between Number & position	0.64	*1.43*	1.29	*1.60*	1.60	*1.71*	0.89	*1.36*	2.25	*2.77*	2.25	*2.55*
12	Torque rule explanation	0.18	*0.41*	0.14	*0.38*	0.10	*0.32*	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*
	Total Mean Utterances	9.64	*2.98*	13.57	*3.95*	10.00	*1.94*	8.33	*3.32*	10.63	*5.26*	10.25	*4.13*

Mixed 3-way ANOVAs (time-point x support condition x pair type) computed on the total number of coded utterances generated by children at Times 1, 2 and 3 found significant main effects of time-point ($F(2, 94) = 26.67$, $p<.001$), and Support

Condition (F(1, 47) = 5.50, p=.023). Follow-up t-tests confirmed that the total dialogue generated decreased significantly from Time 1 to Time 3 (p ranged from <.001 to .002), confirming that children were generally saying significantly less as the time went on. This suggests they were beginning to internalise the strategies required to balance the scale, and so were not having to verbally think out or discuss with their partner what they were doing. Supported children also produced a significantly higher number of utterances than those who had received no support at Time 1, suggesting the adult's support was effective in encouraging the dyads to discuss their strategies and ideas with one another. There were no significant effects of pair type and no significant interactions. The lack of interactions here may have been due to the high levels of variation in the pattern exhibited by the supported Mixed pairs. The small number of Mixed pairs tested (N = 7), may also have impacted on the results.

Mixed 3-way ANOVAs (time-point x support condition x pair type) were also conducted on each of the 13 codes to find whether there were any significant effects on specific dialogue types. There was a main effect of time-point found with code 7 (F(2, 94) = 14.03, p<.001), and follow-up t-tests confirmed that this type of dialogue (reference specifically in terms of weight), decreased significantly from Time 1 to Time 3 (p ranged from <.001 to .044). There was also a main effect of time-point found with code 8 (explanation in terms of comparison of number), which decreased in usage significantly from Time 1 to Time 2 (F(2, 94) = 5.95, p=.005). A main effect of time-point was found with code 9 (F(2, 94) = 3.79, p=.034), and this type of dialogue (reference specifically in terms of position), decreased significantly from Time 1 to Time 2 (p=.049) and from Time 1 to Time 3 (p=.009). There was also a main effect of pair type (F(1, 47) = 3.24, p=.048) for this type of dialogue. From Table 20 it can be seen that references to position were generated mostly by the supported Low-Low pairs.

A significant interaction between time-point and support condition was found with code 10 (F(2, 94) = 3.71, p=.034), and follow-up t-tests showed that this type of dialogue (explanation in terms of number and position) was used significantly more at Time 1 by children who were supported.

Finally, there was a main effect of pair type with respect to code 11 (F(1, 47) = 6.51, p=.003). From Table 20 it can be seen that this more sophisticated type of dialogue (explanation is in terms of the relationship between number and position) was used mostly by High-High dyads. There was also a significant interaction between time-point, support condition and pair type (F(1, 47) = 5.50, p=.003). Interaction plots showed that this type of dialogue was used least of all by Low-Low dyads whilst High-High dyads consistently generated this type of dialogue more frequently than the other two pair types regardless of support condition and time-point. The position of the supported Mixed dyads altered over time, however, going from lowest usage at Time 1 out of the supported dyads to something close to parity with the High-High dyads at Time 3.

Therefore, from those findings it could be inferred that, firstly, separate explanations of weight or distance were abandoned in favour of integration of these; and secondly, this happened more in the supported dyads and unsupported High-High pairs, with the supported Mixed dyads showing a more pronounced shift towards doing this.

To find whether there was a relationship between Mean explanation and the use of codes 7 to 12 (those focused on explanations) by dyads, bivariate one-tailed correlations were calculated on individual explanation values and the total use of each code 7 to 12 within dyads, split into support condition and pair type.

Supported children

<u>Low-Low children (N = 22)</u>

Tables 21a, 21b and 21c show the relationship between the supported Low-Low children's individual mean explanations and their dyadic use of codes 7 to 12, at Time 1, Time 2 and Time 3, respectively.

Table 21a. Relationship between explanation level and use of codes 7 to 12 at Time 1.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = .07 n.s	**r = -.46 p=.016**	r = .02 n.s	r = .28 n.s	**r = .56 p=.004**	/

Table 21b. Relationship between explanation level and use of codes 7 to 12 at Time 2.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = -.01 n.s	r = -.26 n.s	r = -.044 n.s	**r = .59 p=.002**	**r = .46 p=.017**	r = -.05 n.s

Table 21c. Relationship between explanation level and use of codes 7 to 12 at Time 3.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = .29 n.s	**r = -.66 p<.001**	r = .30 n.s	**r = .45 p=.017**	**r = .38 p=.042**	r = -.05 n.s

It can be seen from the above Tables that for the supported Low-Low dyads at Time 1 the individual mean explanation given was negatively correlated with dyad code 8 (explanation in terms of comparison of number) (r = -.46, p=.016), but positively correlated with dyad code 11 (explanation in terms of the relationship between number and position) (r = .56, p=.56, p=.004). This suggests that the more often children used less sophisticated codes on-task, the lower the individual explanation given at the end. More sophisticated dyad codes, namely the relationship between number and position, used throughout the task predicted a higher explanation level given at the end when balance was achieved. This latter pattern was also true at Time 2, as both high-level dyad Codes 10 (description of number and position given) and 11 were associated with higher mean explanation levels (r = .59, p=.002 and r = .46, p=.017, respectively). At Time 3, all previous dyad codes that were significantly correlated at Times 1 and 2 (codes 8, 10 and 11) were now associated with mean explanation level (r = -.66, p<.001; r = .45, p=.017 and r = .46, p=.042, respectively).

<u>Mixed children (N = 14)</u>

Tables 22a, 22b and 22c show the relationship between the supported Mixed children's individual mean explanations and their dyadic use of codes 7 to 12, at Time 1, Time 2 and Time 3, respectively.

Table 22a. Relationship between explanation level and use of codes 7 to 12 at Time 1.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = .17 n.s	r = -.36 n.s	r = -.22 n.s	r = .30 n.s	r = .27 n.s	r = .14 n.s

Table 22b. Relationship between explanation level and use of codes 7 to 12 at Time 2.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = .15 n.s	r = -.41 n.s	r = .39 n.s	**r = .55 p=.021**	r = .03 n.s	/

Table 22c. Relationship between explanation level and use of codes 7 to 12 at Time 3.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = -.20 n.s	r = -.22 n.s	r = -.25 n.s	r = .30 n.s	r = -.14 n.s	r = -.14 n.s

Tables 22a to 22c show that for the supported Mixed children, there was not really any relationship between their dyad utterances produced during the task, and explanations given at the end. The only significant association was seen at Time 2, with dyad code 10 (r = .55, p=.021). The lack of significant correlations here suggest, with the exception of Time 2, that children were not generally using their dialogue generated on-task to help them describe how the scale balanced at the end, but were using it more as a process of exploration to guide them through the task.

<u>High-High (N = 20)</u>

Tables 23a, 23b and 23c show the relationship between the supported High-High children's individual mean explanations and their dyadic use of codes 7 to 12, at Time 1, Time 2 and Time 3, respectively.

Table 23a. Relationship between explanation level and use of codes 7 to 12 at Time 1.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual	r = .17	**r = -.46**	r = -.27	**r = .45**	r = -.14	r = -.28

Mean Ex	n.s	**p=.020**	n.s	**p=.023**	n.s	n.s

Table 23b. Relationship between explanation level and use of codes 7 to 12 at Time 2.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = -.30 n.s	**r = -.50 p=.013**	r = -.20 n.s	r = .36 p=.059	r = .28 n.s	r = -.05 n.s

Table 23c. Relationship between explanation level and use of codes 7 to 12 at Time 3.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = -.16 n.s	**r = -.74 p<.001**	r = .03 n.s	**r = .47 p=.018**	**r = .43 p=.030**	r = .25 n.s

Tables 23a to 23c show that the supported High-High dyads were showing the same pattern of correlations to the Low-Low group over the three time-points, with respect to individual explanations negatively associating with lower dialogue codes (namely code 8) and positively associating with higher dialogue codes (Codes 10 and 11). However, this negative relationship with dyad code 8 was present throughout each time-point, becoming stronger as time went on (r = -.46, p=.020 at Time 1; r = -.50, p=.013 at Time 2 and r = -.74, p<.001 at Time 3). This suggests that by Time 3, lower dialogue codes were very scarcely generated when sophisticated explanations were given at the end of the task. On the other hand, more sophisticated utterances generated on-task predicted a higher individual explanation at the end.

Unsupported children

Low-Low children (N = 18)

Tables 24a, 24b and 24c show the relationship between the unsupported Low-Low children's individual mean explanations and their dyadic use of codes 7 to 12, at Time 1, Time 2 and Time 3, respectively.

Table 24a. Relationship between explanation level and use of codes 7 to 12 at Time 1.

	Dyad	Dyad	Dyad	Dyad	Dyad	Dyad

	Code 7	Code 8	Code 9	Code 10	Code 11	Code 12
Individual Mean Ex	r = -.15 n.s	r = -.34 n.s	r = .14 n.s	**r = .79 p<.001**	r = .27 n.s	r = .27 n.s

Table 24b. Relationship between explanation level and use of codes 7 to 12 at Time 2.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = -.05 n.s	r = -.39 p=.056	r = .06 n.s	**r = .60 p=.004**	r = .26 n.s	/

Table 24c. Relationship between explanation level and use of codes 7 to 12 at Time 3.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	**r = .42 p=.041**	**r = -.44 p=.033**	r = -.38 n.s	**r = .77 p<.001**	r = .29 n.s	/

It can be seen from Tables 24a to 24c that the pattern of correlations for the unsupported Low-Low children was very different to that for the supported group. At Times 1 and 2, for example, it was only dyad code 10 that was associated with individual explanations given at the end of the task (r = .79, p<.001 and r = .60, p=.004). At Time 3, whereas dyad code 8 was negatively associated with individual explanations given at the end of the task (-.44, p=.033), the relationship was positive for dyad Codes 7 and 10 (r = .42. p=.041 and r = .77, p<.001, respectively). The fact that the least sophisticated dyad code 7 (reference was specifically in terms of weight) was positively associated with explanations suggests that, when children generated dialogue pertaining to the heaviness of their nuts on the Balance Scale throughout the task, this somehow helped them to generate higher explanations to describe how the scale balanced at the end.

Mixed children (N = 16)

Tables 25a, 25b and 25c show the relationship between the unsupported Mixed children's individual mean explanations and their dyadic use of codes 7 to 12, at Time 1, Time 2 and Time 3, respectively.

Table 25a. Relationship between explanation level and use of codes 7 to 12 at Time 1.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = .11 n.s	r = .21 n.s	r = -.11 n.s	**r = .60 p=.007**	r = .26 n.s	r = .24 n.s

Table 25b. Relationship between explanation level and use of codes 7 to 12 at Time 2.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = -.16 n.s	**r = -.46 p=.037**	r = -.01 n.s	r = .24 n.s	r = .29 n.s	r = .23 n.s

Table 25c. Relationship between explanation level and use of codes 7 to 12 at Time 3.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	**r = .51 p=.023**	**r = -.47 p=.034**	r = 36 n.s	**r = .78 p<.001**	**r = .47 p=.033**	/

For the unsupported Mixed dyads, at Time 1 it was only dyad code 10 that predicted a higher individual explanation being given at the end of the task (r = .79, p<.001), whereas at Time 2, there was only significance between dyad code 8 and individual explanations, with this association again being negative for this code (r = -.46, p=.037). At Time 3, there was a very strong relationship between dyad codes and individual explanations given at the end of the task, as significant correlations were seen for dyad code 7 (r = .51, p=.023), code 8 (r = -.47, p=.034), code 10 (r = .78, p<.001), and code 11 (r = .47, p=.033). The direction of correlations was the same as those observed previously (i.e. positive for codes 7, 10 and 11, and negative for code 8). It could be seen therefore, that the unsupported Mixed dyads looked much like all the others, especially the Low-Low unsupported, in contrast to the supported Mixed dyads, who produced a different pattern.

High-High (N = 16)

Tables 26a, 26b and 26c show the relationship between the unsupported High-High children's individual mean explanations and their dyadic use of codes 7 to 12, at Time 1, Time 2 and Time 3, respectively.

Table 26a. Relationship between explanation level and use of codes 7 to 12 at Time 1.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = .24 n.s	**r = -.45 p=.039**	r = .26 n.s	r = .22 n.s	r = .33 n.s	r = .24 n.s

Table 26b. Relationship between explanation level and use of codes 7 to 12 at Time 2.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = -.30 n.s	**r = -.50 p=.013**	r = -.20 n.s	r = .36 p=.059	r = .28 n.s	r = -.05 n.s

Table 26c. Relationship between explanation level and use of codes 7 to 12 at Time 3.

	Dyad Code 7	Dyad Code 8	Dyad Code 9	Dyad Code 10	Dyad Code 11	Dyad Code 12
Individual Mean Ex	r = -.06 n.s	r = -.28 n.s	**r = -.53 p=.017**	r = .42 p=.053	r = .36 n.s	r = .25 n.s

The unsupported High-High dyads showed a similar pattern in their correlations to those who were supported, and indeed to all other conditions. At Times 1 and 2 it was only dyad code 8 that was related to individual explanations, with this relationship again being negative (r = -.45, p=.039, and r = -.50, p=.013, for Times 1 and 2 respectively). At Time 3, however, it was only dyad code 9 that was correlated with individual explanations, with this relationship being negative (r = -53, p=.017). This implies that, for this group of children, it was the less sophisticated dialogue generated on-task that impacted most on individual explanations given at the end.

It can be concluded from the above findings, therefore, that the supported Mixed children were showing a different pattern to the other groups, as all other conditions showed a negative influence of dyad code 8 on individual explanations (where significant), whereas the relationship with dyad codes 11 and 12 was positive, and this pattern generally got stronger over time. However, with regard to the supported Mixed children, there was much less relationship between dialogue and individual explanations. As this group generated more dialogue than the other conditions (see Table 20a), it could be suggested that they were generating dialogue more as an exploration process to guide them through the task, but this was not being reflected in their individual explanations at the end.

4.3.5. <u>Appropriation of adult input to subsequent problems undertaken by dyads</u>

It can be seen from the data that adult input did have an impact, generating greater explicit discussion, especially (it would appear) in the Mixed dyads. It was therefore important to examine the relationship between adult input and dyad dialogue in order to determine how this influence worked, and whether it was via the kind of appropriation envisaged. To do this, it was necessary to examine how far utterances used by the adult on each problem at Time 1 were used by the dyads, to a related extent, during subsequent problems at Time 1 and then at Times 2 and 3. Correlations were therefore computed between the frequency of use of each code (e.g. 0, 1, 2, etc) by the adult during the first problem and the total number of usages of the corresponding codes by the dyads across the second, third and fourth problems at Time 1, the four problems at Time 2 and the four problems at Time 3.

Similarly, correlations were computed between adult usage on Problem 2 and dyad usage across Time 1 Problems 3 and 4 and Times 2 and 3. The same pattern was then followed for Problems 3 and 4. In this way, the precise impact of adult input at different points during the first session could be treated. Separate correlations were computed for each dyad type within the supported condition, given the fluctuations in their own dialogues noted above.

The results of the correlations between the adult and Low-Low pairs can be seen in Table 27a, correlations between the adult and High-High pairs can be seen in Table 27b, and correlations between the adult and Mixed pairs can be seen in Table 27c.

Table 27a. Correlations between Codes 0 to 12 used by the adult during Problems 1, 2, 3, and 4 at Time 1, and the corresponding Codes used by Low-Low dyads on subsequent problems.

	Adult Time 1 Problem 1	Adult Time 1 Problem 2	Adult Time 1 Problem 3	Adult Time 1 Problem 4
Code 0 – rate of fall information	/	/	/	/
Code 1–implicit w/d prompt - Number				
Dyad Time 1 Problems 2-4	r = -.16	-	-	-
Dyad Time 1 Problems 3-4	-	/	-	-
Dyad Time 1 Problem 4	-	-	/	-
Dyad Time 2 Problems 1-4	r = .19	/	r = -.10	/
Dyad Time 3 Problems 1-4	/	/	/	/
Code 2–implicit w/d prompt -Distance	/	/	/	/
Code 3–implicit w/d prompt-No.&Dis				
Dyad Time 1 Problems 2-4	r = .31	-	-	-
Dyad Time 1 Problems 3-4	-	/	-	-
Dyad Time 1 Problem 4	-	-	/	-
Dyad Time 2 Problems 1-4	/	/	/	/
Dyad Time 3 Problems 1-4	/	/	/	/
Code 4 – nut/peg prompt - Position	/	/	/	/
Code 5 – nut/peg prompt - No.&Pos				
Dyad Time 1 Problems 2-4	/	-	-	-
Dyad Time 1 Problems 3-4	-	/	-	-
Dyad Time 1 Problem 4	-	-	/	-
Dyad Time 2 Problems 1-4	r = .42	/	/	r = -.10
Dyad Time 3 Problems 1-4	/	/	/	/
Code 6 – nut/peg prompt No./weight	/	/	/	/
Code 7 – weight explanation				
Dyad Time 1 Problems 2-4	r = -.16	-	-	-
Dyad Time 1 Problems 3-4	-	r = -.45	-	-
Dyad Time 1 Problem 4	-	-	r = -.21	-
Dyad Time 2 Problems 1-4	/	r = -.48	r = -.14	r = -.15
Dyad Time 3 Problems 1-4	/	r = -.47	r = -.12	r = -.13
Code 8 – comparison of number				
Dyad Time 1 Problems 2-4	r = .24	-	-	-
Dyad Time 1 Problems 3-4	-	r = -.18	-	-
Dyad Time 1 Problem 4	-	-	r = .31	-
Dyad Time 2 Problems 1-4	r = .22	r = -.18	r = .04	r = -.18
Dyad Time 3 Problems 1-4	r = .35	r = .00	r = .47	r = -.24
Code 9 – distance explanation				
Dyad Time 1 Problems 2-4	r = -.16	-	-	-
Dyad Time 1 Problems 3-4	-	r = -.32	-	-
Dyad Time 1 Problem 4	-	-	/	-
Dyad Time 2 Problems 1-4	r = .45	r = -.22	/	/
Dyad Time 3 Problems 1-4	r = -.42	r = .00	/	/
Code 10 –description of no.&pos				
Dyad Time 1 Problems 2-4	/	-	-	-
Dyad Time 1 Problems 3-4	-	/	-	-
Dyad Time 1 Problem 4	-	-	r = -.39	-
Dyad Time 2 Problems 1-4	/	/	r = -.40	r = .41
Dyad Time 3 Problems 1-4	/	/	r = -.38	r = .12
Code 11 –relationship between no.&pos				
Dyad Time 1 Problems 2-4	r = -.22	-	-	-
Dyad Time 1 Problems 3-4	-	**r = -.66 p=.013**	-	-
Dyad Time 1 Problem 4	-	-	r = -.10	-
Dyad Time 2 Problems 1-4	r = .09	r = -.03	r = .47	r = .49

Dyad Time 3 Problems 1-4	r = .15	r = .26	r = .16	r = .32
Code 12 – torque rule explanation	/	/	/	/

N.B. Where (/) appears in the Tables, this indicates that the specific code was not used by either the adult or child during the problem(s) and so a correlation could not be computed. Where (-) appears in the Table, this indicates that analyses were not conducted between the column and row items (e.g. a (-) would appear between Adult problem 1 and Dyad Problems 3 and 4).

It can be seen from Table 27a showing the associations between the adult and Low-Low pairs, that the only significant correlation was a negative one between the adult's use of code 11 (explanation in terms of the relationship between number and position of nuts on the Balance Scale) on the second problem, and the dyad's use of this code during the final two problems ($r = -.66$, $p=.013$). The fact that the correlation was negative implies that the adult's use of this sophisticated code suppressed the dyad's use of it subsequently.

Although the correlations were non-significant, it can also be seen that across all four problems at Time 1, the trend was that the more often the adult used code 7 (reference to Balance Scale is specifically in terms of weight), the less likely the dyads were to use this code subsequently.

Overall, then, the pattern for the Low-Low pairs was much as it was for lower understanding children working individually in the discontinued condition in Study 2. Where explicit formulation of the problem was provided by the adult, even at a rudimentary level, this tended on the whole to have a negative effect, perhaps by creating confusion.

With respect to the High-High dyads, it can be seen from Table 27b that there were a larger number of associations between the adult's utterances and dyad's subsequent use of them. For example, the less sophisticated codes were negatively associated with later use of them, as was seen with the Low-Low dyads, whereas more sophisticated codes were positively associated with their later use. In particular, it was the adult's use of those codes during earlier problems that appeared to be influential. Finally, the effects of the use of more sophisticated codes, especially, code 11, were both immediate and prolonged. The pattern is strongly consistent with the process of appropriation of more sophisticated explicit explanations of the principles at work seen in Studies 1 and 2.

Table 27b. Correlations between Codes 0 to 12 used by the adult during Problems 1, 2, 3, and 4 at Time 1, and the corresponding Codes used by High-High dyads on subsequent problems.

	Adult Problem 1	Adult Problem 2	Adult Problem 3	Adult Problem 4
Code 0 – rate of fall information	/	/	/	/
Code 1 – implicit w/d prompt-Number				
Dyad Time 1 Problems 2-4	r = .37	-	-	-
Dyad Time 1 Problems 3-4	-	/	-	-
Dyad Time 1 Problem 4	-	-	r = -.11	-
Dyad Time 2 Problems 1-4	r = .25	/	r = -.11	/
Dyad Time 3 Problems 1-4	/	/	/	/
Codes 2 to 6	/	/	/	/
Code 7 – weight explanation				
Dyad Time 1 Problems 2-4	r = .43	-	-	-
Dyad Time 1 Problems 3-4	-	**r = -.60 p=.033**	-	-
Dyad Time 1 Problem 4	-	-	r = .23	-
Dyad Time 2 Problems 1-4	r = -.10	r = -.09	r = .20	r = .40
Dyad Time 3 Problems 1-4	r = -.31	r = -.14	r = .42	r = .23
Code 8 – comparison of number				
Dyad Time 1 Problems 2-4	r = .48	-	-	-
Dyad Time 1 Problems 3-4	-	r = .07	-	-
Dyad Time 1 Problem 4	-	-	/	-
Dyad Time 2 Problems 1-4	r = -.36	r = -.18	/	r = -.18
Dyad Time 3 Problems 1-4	r = -.31	r = -.16	/	r = -.16
Code 9 – distance explanation				
Dyad Time 1 Problems 2-4	**r = .76 p=.005**	-	-	-
Dyad Time 1 Problems 3-4	-	r = -.23	-	-
Dyad Time 1 Problem 4	-	-	/	-
Dyad Time 2 Problems 1-4	**r = .75 p=.007**	r = .00	r = -.25	/
Dyad Time 3 Problems 1-4	r = .38	r = -.25	r = -.17	/
Code 10 – description of no.&pos				
Dyad Time 1 Problems 2-4	r = -.49	-	-	-
Dyad Time 1 Problems 3-4	-	**r = .57 p=.043**	-	-
Dyad Time 1 Problem 4	-	-	r = -.09	-
Dyad Time 2 Problems 1-4	r = -.26	r = -.18	r = .13	r = -.35
Dyad Time 3 Problems 1-4	r = .45	r = -.34	r = .34	r = .09
Code 11 - relationship between no.&pos				
Dyad Time 1 Problems 2-4	**r = .66 p=.018**	-	-	-
Dyad Time 1 Problems 3-4	-	**r = .50 p=.013**	-	-
Dyad Time 1 Problem 4	-	-	r = .20	-
Dyad Time 2 Problems 1-4	r = .21	**r = .56 p=.046**	r = .30	r = .30
Dyad Time 3 Problems 1-4	**r = .71 p=.010**	r = .19	r = -.12	r = -.12
Code 12 – torque rule explanation	/	/	/	/

N.B. Where (/) appears in the Tables, this indicates that the specific code was not used by either the adult or child during the problem(s) and so a correlation could not be computed. Where (-) appears in the Table, this indicates that analyses were not conducted between the column and row items (e.g. a (-) would appear between Adult problem 1 and Dyad Problems 3 and 4).

With regard to the Mixed dyads, Table 27c shows that, as with the relationship between the Mixed dyads' own dialogue and explanations (see Tables 22a to 22c), there was little impact of adult input on dyad dialogue, though there were vestigial signs of the impact found in the higher group. In particular, the adult's use of code 10 on problem 2 was associated with later use by Mixed dyads at Time 2, and there was some indication of a similar, more immediate effect of adult use of code 11 on problem 3, though both effects were short-lived. There was, in fact, a gradually significant negative relationship between codes 10 and 11 from Time 1 to Time 3 ($r = -.34$ at Time 1; $r = -.77$, $p=.022$ at Time 2, and $r = -.83$, $p=.011$ at Time 3), suggesting that dyads were beginning to appropriate this type of dialogue from the adult at Time 1, and use it effectively at Time 2, and Time 3, in place of code 10. However, from the means in Table 20, it can be seen that code 10 decreased to a minimum usage at Time 2, increasing again at Time 3 ($M = 6.43$, 4.57, 5.43, at Times 1, 2, and 3, respectively), whereas code 11 increased to an optimum usage at Time 2, but decreased again at Time 3 (1.86, 2.14, 1.29, at Times 1, 2, and 3, respectively). Thus, appropriation with respect to code 11 usage appeared to have its largest impact with the Mixed group at Time 2, although those dyads who did use this code at Time 3, did so very effectively.

Table 27c. Correlations between Codes 0 to 12 used by the adult during Problems 1, 2, 3, and 4 at Time 1, and the corresponding Codes used by Mixed dyads on subsequent problems.

	Adult Problem 1	Adult Problem 2	Adult Problem 3	Adult Problem 4
Codes 0 to 2	/	/	/	/
Code 3				
Dyad Time 1 Problems 2-4	r = -.17	-	-	-
Dyad Time 1 Problems 3-4	-	/	-	-
Dyad Time 1 Problem 4	-	-	/	-
Dyad Time 2 Problems 1-4	/	/	/	/
Dyad Time 3 Problems 1-4	/	/	/	/
Codes 4 to 6	/	/	/	/
Code 7 – weight explanation				
Dyad Time 1 Problems 2-4	r = -.18	-	-	-
Dyad Time 1 Problems 3-4	-	r = .59	-	-
Dyad Time 1 Problem 4	-	-	r = .34	-
Dyad Time 2 Problems 1-4	r = .13	r = -.16	r = -.18	r = -.11
Dyad Time 3 Problems 1-4	r = .40	r = .24	r = -.33	r = .56
Code 8 – comparison of number				
Dyad Time 1 Problems 2-4	r = -.42	-	-	n/a
Dyad Time 1 Problems 3-4	-	/	-	-
Dyad Time 1 Problem 4	-	-	/	-
Dyad Time 2 Problems 1-4	r = -.26	/	/	/
Dyad Time 3 Problems 1-4	r = .65 p=.059	/	/	/
Code 9 – distance explanation				
Dyad Time 1 Problems 2-4	/	-	-	-
Dyad Time 1 Problems 3-4	-	/	-	-
Dyad Time 1 Problem 4	-	-	/	-
Dyad Time 2 Problems 1-4	/	/	r = -.17	/
Dyad Time 3 Problems 1-4	/	/	r = -.17	/
Code 10 – description of no.&pos				
Dyad Time 1 Problems 2-4	/	-	-	-
Dyad Time 1 Problems 3-4	-	r = .28	-	-
Dyad Time 1 Problem 4	-	**-**	/	-
Dyad Time 2 Problems 1-4	/	**r = .70 p=.039**	/	/
Dyad Time 3 Problems 1-4	/	r = .09	/	/
Code 11 – relationship between no.&pos				
Dyad Time 1 Problems 2-4	r = -.27	-	-	-
Dyad Time 1 Problems 3-4	-	/	-	-
Dyad Time 1 Problem 4	-	-	r = .65 p=.059	-
Dyad Time 2 Problems 1-4	r = .58	/	r = -.56	r = -.04
Dyad Time 3 Problems 1-4	r = .42	/	r = -.35	r = -.08
Code 12 – torque rule explanation	/	/	/	/

N.B. Where (/) appears in the Tables, this indicates that the specific code was not used by either the adult or child during the problem(s) and so a correlation could not be computed. Where (-) appears in the Table, this indicates that analyses were not conducted between the column and row items (e.g. a (-) would appear between Adult problem 1 and Dyad Problems 3 and 4).

4.3.6. Reverse Appropriation of child codes to subsequent utterances spoken by the adult

As well as examining how adult dialogue was appropriated by the dyads, it was also important to ascertain the extent to which the opposite occurred, that is, how often utterances used by dyads on each problem at Time 1 were picked up by the adult during subsequent problems at this time-point. The analyses had the same structure as before. That is, during the first problem, each code (e.g. 0, 1, 2, etc) used by dyads were correlated with the total number of corresponding codes used by the adult during the second, third and fourth problems at Time 1. For the second problem, each code used by dyads was correlated with the total number of corresponding codes used by the adult during problems 3 and 4, and the use of codes by dyads during the third problem were correlated by those matching codes used by the adult on the fourth problem.

Those correlations were again computed separately for each pair type. The results of the correlations between Low-Low pairs and the adult can be seen in Table 28a, correlations between High-High pairs and the adult can be seen in Table 28b, and correlations between Mixed pairs and the adult can be seen in Table 28c.

It can be seen from Table 28a that there was very little reverse appropriation going on between the Low-Low dyads and the adult. The negative association with code 7 suggests that if children started referring to weight in their explanations (code 7), this suppressed the adult talking about it subsequently. This pattern for code 7 is identical to that seen in Table 27a, when the appropriation was in the opposite direction – e.g. from adult to dyad. Therefore, it could be suggested that the more often either adult or dyad used this code, the less likely the other was to use it subsequently. In contrast, however, the positive association with code 8 suggests that if children were showing sensitivity to number in their explanations, this encouraged the adult to talk about number subsequently. Therefore, the adult appeared to be acting contingently with this group of children, as support was taking place at a rudimentary level of understanding. This pattern is very similar to that found with the lower understanding continuously supported children in Study 2, where more explicit support was only introduced gradually over time.

Table 28a. Correlations between Codes 0 to 12 used by Low-Low dyads during Problems 1, 2, 3, and 4 at Time 1, and the corresponding Codes used by the adult on subsequent problems at this time-point.

	Dyad Problem 1	Dyad Problem 2	Dyad Problem 3
Code 0	/	/	/
Code 1			
Adult Time 1 Problems 2-4	r = -.10	-	-
Adult Time 1 Problems 3-4	-	r = -.10	-
Adult Time 1 Problem 4	-	-	/
Code 2	/	/	/
Code 3			
Adult Time 1 Problems 2-4	/	-	-
Adult Time 1 Problems 3-4	-	r = .22	-
Adult Time 1 Problem 4	-	-	/
Codes 4 to 6	/	/	/
Code 7 – weight explanation			
Adult Time 1 Problems 2-4	r = -.08	-	-
Adult Time 1 Problems 3-4	-	**r = -.64 p=.018**	/
Adult Time 1 Problem 4	-	-	r = -.28
Code 8 – comparison of number			
Adult Time 1 Problems 2-4	r = -.35	-	-
Adult Time 1 Problems 3-4	-	**r = .67 p=.012**	-
Adult Time 1 Problem 4	-	-	r = -.10
Code 9 – distance explanation			
Adult Time 1 Problems 2-4	r = .05	-	-
Adult Time 1 Problems 3-4	-	/	-
Adult Time 1 Problem 4	-	-	/
Code 10 – description of no.&pos			
Adult Time 1 Problems 2-4	r = -.29	-	-
Adult Time 1 Problems 3-4	-	r = -.44	-
Adult Time 1 Problem 4	-	-	r = .32
Code 11 – relationship between no.&pos			
Adult Time 1 Problems 2-4	r = -.44	-	-
Adult Time 1 Problems 3-4	-	r = -.02	-
Adult Time 1 Problem 4	-	-	r = .31
Code 12 – torque rule explanation	/	/	/

N.B. Where (/) appears in the Tables, this indicates that the specific code was not used by either the dyad or adult during the problem(s) and so a correlation could not be computed. Where (-) appears in the Table, this indicates that analyses were not conducted between the column and row items (e.g. a (-) would appear between Dyad problem 1 and Adult Problems 3 - 4).

It can be seen from Table 28b showing the associations between High-High pairs and the adult, that there was no reverse appropriation going on. In other words, the adult did not have to be contingent with the High-High dyads, as she only had to mention a code and the dyads picked it up and used it subsequently. Again, the High-High dyads showed the same pattern as for the higher understanding children in Study 2, who benefited more from discontinued support as they picked up on adult input very quickly and used it to increase their understanding of the task independently as time went on.

Table 28b. Correlations between Codes 0 to 12 used by High-High dyads during Problems 1, 2, 3, and 4 at Time 1, and the corresponding Codes used by the adult on subsequent problems at this time-point.

	Dyad Problem 1	Dyad Problem 2	Dyad Problem 3
Code 0 – rate of fall information			
Adult Time 1 Problems 2-4	r = -.11	-	-
Adult Time 1 Problems 3-4	-	/	-
Adult Time 1 Problem 4	-	-	-
Code 1 – implicit w/d prompt Number			
Adult Time 1 Problem 2-4	/	-	-
Adult Time 1 Problem 3-4	-	/	-
Adult Time 1 Problem 4	-	-	**r = .67 p=.018**
Codes 2 to 6	/	/	/
Code 7 – weight explanation			
Adult Time 1 Problems 2-4	r = .06	-	-
Adult Time 1 Problems 3-4	-	r = .07	/
Adult Time 1 Problem 4	-	-	r =-.35
Code 8 – comparison of number			
Adult Time 1 Problems 2-4	r = -.06	-	-
Adult Time 1 Problems 3-4	-	r = -.11	-
Adult Time 1 Problem 4	-	-	r = -.17
Code 9 – distance explanation			
Adult Time 1 Problems 2-4	r = .52	-	-
Adult Time 1 Problems 3-4	-	r = -.22	-
Adult Time 1 Problem 4	-	-	/
Code 10 – description of no.&pos			
Adult Time 1 Problems 2-4	r = .48	-	-
Adult Time 1 Problems 3-4	-	r = .14	-
Adult Time 1 Problem 4	-	-	r = -.36
Code 11 – relationship between no.&pos			
Adult Time 1 Problems 2-4	r = .37	-	-
Adult Time 1 Problems 3-4	-	r = -.22	-
Adult Time 1 Problem 4	-	-	r = .25
Code 12 – torque rule explanation	/	/	/

It can be seen firstly from Table 28c showing the associations between Mixed pairs and the adult, that the only significant correlation was with code 10 (explanation of number and position of nuts on problem 1 on the Balance Scale), the same code noted from Table 27c as being appropriated from adult usage, except at a later point. The implication is that, if dyads were using code 10 at the outset, the adult then amplified that usage and this had a positive impact on dyad usage at Time 2. This suggests that, as with the Low-Low dyads, the adult was acting contingently with this group of children, although the contingency focused on more sophisticated input. The fact that the Mixed dyads tended to benefit from more sophisticated input suggests that the adult was providing support and this was then picked up by the more sophisticated of the two children, who used it subsequently in discussion within the dyad.

Table 28c. Correlations between Codes 0 to 12 used by Mixed dyads during Problems 1,
2, 3, and 4 at Time 1, and the corresponding Codes used by the adult on subsequent problems at this time-point.

	Dyad Problem 1	Dyad Problem 2	Dyad Problem 3
Code 0			
Adult Time 1 Problems 2-4	/	-	-
Adult Time 1 Problems 3-4	-	/	-
Adult Time 1 Problem 4	-	-	r = 1.00
Codes 1 and 2	/	/	/
Code 3			
Adult Time 1 Problem 2-4	r = .17	-	-
Adult Time 1 Problem 3-4	-	r = -.26	-
Adult Time 1 Problem 4	-	-	/
Codes 4 to 6	/	/	/
Code 7 – weight explanation			
Adult Time 1 Problems 2-4	r = -.07	-	-
Adult Time 1 Problems 3-4	-	r = .40	/
Adult Time 1 Problem 4	-	-	r = .44
Code 8 – comparison of number	/	/	/
Code 9 – distance explanation			
Adult Time 1 Problems 2-4	r = .35	-	-
Adult Time 1 Problems 3-4	-	/	-
Adult Time 1 Problem 4	-	-	/
Code 10 – description of no.&pos			
Adult Time 1 Problems 2-4	**r = .68 p=.047**	-	-
Adult Time 1 Problems 3-4	-	/	-
Adult Time 1 Problem 4	-	-	/
Code 11 – relationship between no.&pos			
Adult Time 1 Problems 2-4	r = -.50	-	-
Adult Time 1 Problems 3-4	-	r = -.37	-
Adult Time 1 Problem 4	-	-	r = -.47
Code 12 – torque rule explanation	/	/	/

4.3.7. <u>Secondary appropriation within Mixed understanding dyads</u>

The above suggestion that children belonging to Mixed dyads were acting differently in terms of the higher understanding child picking up and using more sophisticated dialogue from the adult than the lower understanding child, prompted further analyses of this group of children. These analyses explored whether ‘secondary appropriation’ was taking place between the higher and lower understanding children, and were conducted for children in both supported and unsupported conditions. The analyses followed the same pattern as before, with bivariate one-tailed correlations calculated on the frequency of use of each code (e.g. 7, 8, 9, etc) by one child within the dyad on one problem and the total number of usages of the corresponding code by the other child on all subsequent problems up to the final problem at Time 3. Following the model established above for analysis of appropriation and reverse appropriation between adult and dyad, both high to low and low to high appropriation was analysed in this way.

Supported Children

High to Low child (n = 14)

Tables 29a, 29b and 29c show the relationship between the supported higher understanding children's use of codes on each problem at Times 1, 2 and 3, respectively, and the lower children's total use of corresponding codes on all subsequent problems.

Table 29a. Correlations of Codes 0 to 12 used by the Supported Higher understanding children (High child) during Problems 1, 2, 3, and 4 at Time 1, and the corresponding Codes used by the Supported Lower understanding children (Low child) on subsequent problems.

	High child Time 1 Problem 1	High child Time 1 Problem 2	High child Time 1 Problem 3	High child Time 1 Problem 4
Codes 0 to 2	/	/	/	/
Code 3 – implicit w/d prompt-No.&Dis				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = -.17	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	/	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	/	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	/
Codes 4 to 6	/	/	/	/
Code 7 – weight explanation				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = -.21	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	r = -.11	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .12	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = .23
Code 8 – comparison of number				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = .26	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	r = .47	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	/	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	/
Code 9 – distance explanation				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = -.26	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	/	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	/	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = -.17

Code 10 –description of no.&pos				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = .14	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	r = .00	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = -.07	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = .03
Code 11 –relationship between no.&pos				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = .00	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	r = .29	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = -.03	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = -.11
Code 12 – Torque rule explanation	/	/	/	/

N.B. Where (/) appears in the Tables, this indicates that the specific code was not used by either the High child or Low child during the problem(s) and so a correlation could not be computed. Where (-) appears in the Table, this indicates that analyses were not conducted between the column and row items (e.g. a (-) would appear between High child Time 1 problem 1 and Low child Time 1 Problem 2 – Time 3 Problem 4).

Table 29b. Correlations of Codes 0 to 12 used by the Supported Higher understanding children (High child) during Problems 1, 2, 3, and 4 at Time 2, and the corresponding Codes used by the Supported Lower understanding children (Low child) on subsequent problems.

	High child Time 2 Problem 1	High child Time 2 Problem 2	High child Time 2 Problem 3	High child Time 2 Problem 4
Codes 0 – 6	/	/	/	/
Code 7 – weight explanation				
Low child Time 2 Problem 2 – Time 3 Problem 4	r = .34	-	-	-
Low child Time 2 Problem 3 – Time 3 Problem 4	-	**r = .96 p<.001**	-	-
Low child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = .21	-
Low child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = .52
Code 8 – comparison of number	/	/	/	/
Code 9 – distance explanation				
Low child Time 2 Problem 2 – Time 3 Problem 4	/	-	-	-
Low child Time 2 Problem 3 – Time 3 Problem 4	-	/	-	-
Low child Time 2 Problem 4 – Time 3 Problem 4	-	-	/	-
Low child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = -.17
Code 10 –description of no.&pos				
Low child Time 2 Problem 2 – Time 3 Problem 4	r = .14	-	-	-
Low child Time 2 Problem 3 – Time 3 Problem 4	-	r = .51	-	-
Low child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = -.06	-
Low child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = .31
Code 11 –relationship between no.&pos				
Low child Time 2 Problem 2 – Time 3 Problem 4	r = .60 p=.079	-	-	-
Low child Time 2 Problem 3 – Time 3 Problem 4	-	**r = .68 p=.045**	-	-
Low child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = -.13	-
Low child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = -.20
Code 12 – Torque rule explanation	/	/	/	/

Table 29c. Correlations of Codes 0 to 12 used by the Supported Higher understanding children (High child) during Problems 1, 2, 3, and 4 at Time 3, and the corresponding Codes used by the Supported Lower understanding children (Low child) on subsequent problems.

	High child Time 3 Problem 1	High child Time 3 Problem 2	High child Time 3 Problem 3
Codes 0 to 6	/	/	/
Code 7 – weight explanation			
Low child Time 3 Problem 2 – Time 3 Problem 4	r = .05	-	-
Low child Time 3 Problem 3 – Time 3 Problem 4	-	r = -.28	-
Low child Time 3 Problem 4	-	-	r = -.26
Codes 8 and 9	/	/	/
Code 10 –description of no.&pos			
Low child Time 3 Problem 2 – Time 3 Problem 4	r = -.08	-	-
Low child Time 3 Problem 3 – Time 3 Problem 4	-	**r = .77 p=.022**	-
Low child Time 3 Problem 4	-	-	r = .00
Code 11 –relationship between no.&pos			
Low child Time 3 Problem 2 – Time 3 Problem 4	r = -.26	-	-
Low child Time 3 Problem 3 – Time 3 Problem 4	-	r = .65 p=.059	-
Low child Time 3 Problem 4	-	-	/
Code 12 – Torque rule explanation	/	/	/

It can be seen from Table 29 that the supported lower understanding children were not appropriating any dialogue used by the higher children at Time 1 when the adult was present. However, at Times 2 and 3 when they were working in the absence of the adult, both basic (code 7) and more sophisticated (codes 10 and 11) dialogue used by the higher understanding children was being picked up by those of lower understanding and used on subsequent problems. The very strong association with code 7 suggests that the lower understanding children were much more likely to pick up on dialogue focussing on weight and use this subsequently than they were with the other codes. The fact that code 10 appropriation in particular was slower to emerge is consistent with the impact of continuous support on lower understanding children reported in Study 2.

Low to High child (n = 14)

Tables 30a, 30b and 30c show the relationship between the supported lower understanding children's use of codes on each problem at Times 1, 2 and 3, respectively, and the higher children's total use of corresponding codes on all subsequent problems.

Table 30a. Correlations of Codes 0 to 12 used by the Supported Lower understanding children (Low child) during Problems 1, 2, 3, and 4 at Time 1, and the corresponding Codes used by the Supported Higher understanding children (High child) on subsequent problems.

	Low child Time 1 Problem 1	Low child Time 1 Problem 2	Low child Time 1 Problem 3	Low child Time 1 Problem 4
Codes 0 to 6	/	/	/	/
Code 7 – weight explanation				
High child Time 1 Problem 2 – Time 3 Problem 4	r = .43	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	r = .59 p=.081	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .19	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = .59 p = .082
Code 8 – comparison of number				
High child Time 1 Problem 2 – Time 3 Problem 4	r = -.42	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	r = .43	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .43	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	/
Code 9 – distance explanation				
High child Time 1 Problem 2 – Time 3 Problem 4	r = .09	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	/	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = -.26	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	/
Code 10 –description of no.&pos				
High child Time 1 Problem 2 – Time 3 Problem 4	r = .37	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	r = .56 p=.095	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .55	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = -.42
Code 11 –relationship between no.&pos				
High child Time 1 Problem 2 – Time 3 Problem 4	/	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	r = .09	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .24	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = -.46
Code 12 – Torque rule explanation	/	/	/	/

N.B. Where (/) appears in the Tables, this indicates that the specific code was not used by either the Low child or High child during the problem(s) and so a correlation could not be computed. Where (-) appears in the Table, this indicates that analyses were not conducted between the column and row items (e.g. a (-) would appear between Low child Time 1 problem 1 and High Child Time 1 Problem 3 – Time 3 problem 4).

Table 30b. Correlations of Codes 0 to 12 used by the Supported Lower understanding children (Low child) during Problems 1, 2, 3, and 4 at Time 2, and the corresponding Codes used by the Supported Higher understanding children (High child) on subsequent problems.

	Low child Time 2 Problem 1	Low child Time 2 Problem 2	Low child Time 2 Problem 3	Low child Time 2 Problem 4
Codes 0 to 6	/	/	/	/
Code 7 – weight explanation				
High child Time 2 Problem 2 – Time 3 Problem 4	r = .40	-	-	-
High child Time 2 Problem 3 – Time 3 Problem 4	-	r = .51	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = .17	-
High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = .22
Code 8 – comparison of number				
High child Time 2 Problem 2 – Time 3 Problem 4	/	-	-	-
High child Time 2 Problem 3 – Time 3 Problem 4	-	r = -.25	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	/	-
High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	/
Code 9 – distance explanation	/	/	/	/
Code 10 –description of no.&pos				
High child Time 2 Problem 2 – Time 3 Problem 4	r = .24	-	-	-
High child Time 2 Problem 3 – Time 3 Problem 4	-	r = -.56 p=.098	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = .51	-
High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = -.10
Code 11 –relationship between no.&pos				
High child Time 2 Problem 2 – Time 3 Problem 4	r = .12	-	-	-
High child Time 2 Problem 3 – Time 3 Problem 4	-	r = -.09	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = -.23	-
High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = -.42
Code 12 – Torque rule explanation	/	/	/	/

Table 30c. Correlations of Codes 0 to 12 used by the Supported Lower understanding children (Low child) during Problems 1, 2, 3, and 4 at Time 3, and the corresponding Codes used by the Supported Higher understanding children (High child) on subsequent problems.

	Low child	Low child	Low child

	Time 3 Problem 1	Time 3 Problem 2	Time 3 Problem 3
Codes 0 to 6	/	/	/
Code 7 – weight explanation			
High child Time 3 Problem 2 – Time 3 Problem 4	r = -.07	-	-
High child Time 3 Problem 3 – Time 3 Problem 4	-	r = .30	-
High child Time 3 Problem 4	-	-	r = -.26
Codes 8 and 9	/	/	/
Code 10 –description of no.&pos			
High child Time 3 Problem 2 – Time 3 Problem 4	r = .48	-	-
High child Time 3 Problem 3 – Time 3 Problem 4	-	**r = .86 p=.006**	-
High child Time 3 Problem 4	-	-	r = .65 p=.059
Code 11 –relationship between no.&pos			
High child Time 1 Problem 2 – Time 3 Problem 4	r = .48	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	r = -.17	-
High child Time 1 Problem 4	-	-	r = -.17
Code 12 – Torque rule explanation	/	/	/

It can be seen from Table 30 that there was no appropriation taking place between the lower and higher understanding children until Time 3, where the higher children picked up on the lower children's use of code 10 on the third problem and used it on the final problem. The higher children were beginning to pick up on this code at earlier time-points, but were not using it significantly more often subsequent to those of lower understanding until the end of the final time-point. Given the pattern for appropriation of adult usage, and for higher child usage, the following pattern would appear to emerge: adult usage of code 10 was picked up on by the higher child at Time 2 (the adult using this code more where that child showed some initial signs of grasp). The higher child, having introduced and explained this at Time 2, tended to use it less where the lower used it too, but otherwise both converged on using it on Problem 2 at Time 3, cementing their grasp at this point, apparently. In fact, from Table 22b it can be seen that Time 2 was the only point at which on-task code usage predicted end of problem explanations for these dyads.

Unsupported Children

<u>Appropriation from High to Low child</u>

Tables 31a, 31b and 31c show the relationship between the unsupported higher understanding children's use of codes on each problem at Times 1, 2 and 3, respectively, and the lower children's total use of corresponding codes on all subsequent problems.

Table 31a. Correlations of Codes 0 to 12 used by the Unsupported Higher understanding children (High child) during Problems 1, 2, 3, and 4 at Time 1, and the corresponding Codes used by the Supported Lower understanding children (Low child) on subsequent problems.

	High child Time 1 Problem 1	High child Time 1 Problem 2	High child Time 1 Problem 3	High child Time 1 Problem 4
Codes 0 to 6	/	/	/	/
Code 7 – weight explanation				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = .28	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	r = .58 p=.085	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .04	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = .08
Code 8 – comparison of number				
Low child Time 1 Problem 2 – Time 3 Problem 4	/	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	r = -.28	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .33	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = -.33
Code 9 – distance explanation				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = -.09	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	/	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	/	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	/
Code 10 –description of no.&pos				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = -.18	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	r = -.13	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .15	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = -.28
Code 11 –relationship between no.&pos				
Low child Time 1 Problem 2 – Time 3 Problem 4	r = .12	-	-	-
Low child Time 1 Problem 3 – Time 3 Problem 4	-	r = .28	-	-
Low child Time 1 Problem 4 – Time 3 Problem 4	-	-	/	-
Low child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = -.33
Code 12 – Torque rule explanation	/	/	/	/

N.B. Where (/) appears in the Tables, this indicates that the specific code was not used by either the High child or Low child during the problem(s) and so a correlation could not be computed. Where (-) appears in the Table, this indicates that analyses were not conducted between the column and row items (e.g. a (-) would appear between High child Time 1 problem 1 and Low child Time 1 Problem 3 – Time 3 problem 4).

Table 31b. Correlations of Codes 0 to 12 used by the Unsupported Higher understanding children (High child) during Problems 1, 2, 3, and 4 at Time 2, and the corresponding Codes used by the Supported Lower understanding children (Low child) on subsequent problems.

	High child Time 2 Problem 1	High child Time 2 Problem 2	High child Time 2 Problem 3	High child Time 2 Problem 4
Codes 0 – 6	/	/	/	/
Code 7 – weight explanation				
Low child Time 2 Problem 2 – Time 3 Problem 4	r = -.44	-	-	-
Low child Time 2 Problem 3 – Time 3 Problem 4	-	r = -.19	-	-
Low child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = -.06	-
Low child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = .03
Code 8 – comparison of number				
Low child Time 2 Problem 2 – Time 3 Problem 4	r = -.22	-	-	-
Low child Time 2 Problem 3 – Time 3 Problem 4	-	/	-	-
Low child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = .52 p=.094	-
Low child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	/
Code 9 – distance explanation				
Low child Time 2 Problem 2 – Time 3 Problem 4	r =-.14	-	-	-
Low child Time 2 Problem 3 – Time 3 Problem 4	-	r = -.14	-	-
Low child Time 2 Problem 4 – Time 3 Problem 4	-	-	**r = 1.00 p<.001**	-
Low child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	**r = 1.00 p<.001**
Code 10 –description of no.&pos				
Low child Time 2 Problem 2 – Time 3 Problem 4	r = -.10	-	-	-
Low child Time 2 Problem 3 – Time 3 Problem 4	-	r =-.04	-	-
Low child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = -.05	-
Low child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = .29
Code 11 –relationship between no.&pos				
Low child Time 2 Problem 2 – Time 3 Problem 4	**r = .68 p=-.032**	-	-	-
Low child Time 2 Problem 3 – Time 3 Problem 4	-	/	-	-
Low child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = -.21	-
Low child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	/
Code 12 – Torque rule explanation	/	/	/	/

Table 31c. Correlations of Codes 0 to 12 used by the Unsupported Higher understanding children (High child) during Problems 1, 2, 3, and 4 at Time 3, and the corresponding Codes used by the Supported Lower understanding children (Low child) on subsequent problems.

	High child Time 3 Problem 1	High child Time 3 Problem 2	High child Time 3 Problem 3
Codes 0 to 6	/	/	/
Code 7 – weight explanation			
Low child Time 3 Problem 2 – Time 3 Problem 4	r = -.29	-	-
Low child Time 3 Problem 3 – Time 3 Problem 4	-	r = -.31	-
Low child Time 3 Problem 4	-	-	r = -.27
Code 8 – comparison of number			
Low child Time 3 Problem 2 – Time 3 Problem 4	/	-	-
Low child Time 3 Problem 3 – Time 3 Problem 4	-	**r = .66 p=.039**	-
Low child Time 3 Problem 4	-	-	/
Code 9 – distance explanation	/	/	/
Code 10 –description of no.&pos			
Low child Time 3 Problem 2 – Time 3 Problem 4	r = .26	-	-
Low child Time 3 Problem 3 – Time 3 Problem 4	-	r = .33	-
Low child Time 3 Problem 4	-	-	r = .15
Code 11 –relationship between no.&pos			
Low child Time 3 Problem 2 – Time 3 Problem 4	r = .49	-	-
Low child Time 3 Problem 3 – Time 3 Problem 4	-	r = -.14	-
Low child Time 3 Problem 4	-	-	/
Code 12 – Torque rule explanation	/	/	/

With respect to the unsupported children, the pattern for appropriation of dialogue from higher to lower understanding children was similar to those who were supported, as there was no appropriation of dialogue occurring until the second time-point. However, the emphasis was more on basic than on more sophisticated codes being picked up and used by the lower children subsequent to their use by the higher children, with code 8 and code 9 more dominant than code 11, and code 10 not featuring at all. The fact that the code 11 relationship at Time 2 is not repeated at Time 3 is suggestive of echoing rather than genuine understanding. Thus, the significant relationship between codes 10 and 11 shown earlier, suggests that it was primarily the higher understanding children who were using code 11, and where lower children did use it, they were imitating the higher child rather than showing any genuine understanding of this type of dialogue.

The perfect correlation with code 9 is due to the lower understanding children using this code the same number of times subsequent to the third and final problems as the higher children had on those problems (M = .25 and M = .13, respectively)

Low to High child

Tables 32a, 32b and 32c show the relationship between the supported lower understanding children's use of codes on each problem at Times 1, 2 and 3, respectively, and the higher children's total use of corresponding codes on all subsequent problems.

Table 32a. Correlations of Codes 0 to 12 used by the Unsupported Lower understanding children (Low child) during Problems 1, 2, 3, and 4 at Time 1, and the corresponding Codes used by the Supported Higher understanding children (High child) on subsequent problems.

	Low child Time 1 Problem 1	Low child Time 1 Problem 2	Low child Time 1 Problem 3	Low child Time 1 Problem 4
Codes 0 to 6	/	/	/	/
Code 7 – weight explanation				
High child Time 1 Problem 2 – Time 3 Problem 4	r = .05	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	r = -.46	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = -.20	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	**r = .86 p=.003**
Code 8 – comparison of number				
High child Time 1 Problem 2 – Time 3 Problem 4	r = -.18	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	r = .09	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = -.43	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	/
Code 9 – distance explanation				
High child Time 1 Problem 2 – Time 3 Problem 4	r = .27	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	r = .55 p=.080	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .27	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = .27
Code 10 –description of no.&pos				
High child Time 1 Problem 2 – Time 3 Problem 4	r = -.19	-	-	-

High child Time 1 Problem 3 – Time 3 Problem 4	-	r = -.19	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	r = .09	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = .04
Code 11 –relationship between no.&pos				
High child Time 1 Problem 2 – Time 3 Problem 4	r = -.20	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	/	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	/	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	r = -.11
Code 12 – Torque rule explanation				
High child Time 1 Problem 2 – Time 3 Problem 4	r = -.14	-	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	/	-	-
High child Time 1 Problem 4 – Time 3 Problem 4	-	-	/	-
High child Time 2 Problem 1 – Time 3 Problem 4	-	-	-	/

N.B. Where (/) appears in the Tables, this indicates that the specific code was not used by either the Low child or High child during the problem(s) and so a correlation could not be computed. Where (-) appears in the Table, this indicates that analyses were not conducted between the column and row items (e.g. a (-) would appear between Low child Time 1 problem 1 and High child Time 1 Problem 3 to Time 3 problem 4).

Table 32b. Correlations of Codes 0 to 12 used by the Unsupported Lower understanding children (Low child) during Problems 1, 2, 3, and 4 at Time 2, and the corresponding Codes used by the Supported Higher understanding children (High child) on subsequent problems.

	Low child Time 2 Problem 1	Low child Time 2 Problem 2	Low child Time 2 Problem 3	Low child Time 2 Problem 4
Codes 0 to 6	/	/	/	/
Code 7 – weight explanation				
High child Time 2 Problem 2 – Time 3 Problem 4	r = -.02	-	-	-
High child Time 2 Problem 3 – Time 3 Problem 4	-	/	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = -.20	-
High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = -.39
Code 8 – comparison of number				
High child Time 2 Problem 2 – Time 3 Problem 4	/	-	-	-
High child Time 2 Problem 3 – Time 3 Problem 4	-	r = .05	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	/	-
High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	**r = .75 p=.017**
Code 9 – distance explanation				
High child Time 2 Problem 2 – Time 3 Problem 4	/	-	-	-
High child Time 2 Problem 3 – Time 3 Problem 4	-	/	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	/	-
High High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	/
Code 10 –description of no.&pos				
High child Time 2 Problem 2 – Time 3 Problem 4	r = -.18	-	-	-
High child Time 2 Problem 3 – Time 3 Problem 4	-	r = -.19	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = .22	-
High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = .05
Code 11 –relationship between no.&pos				
High child Time 2 Problem 2 – Time 3 Problem 4	r = -.28	-	-	-
High child Time 2 Problem 3 – Time 3 Problem 4	-	r = .11	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	r = -.15	-
High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	r = .57 p=.070
Code 12 – Torque rule explanation		/	/	/
High child Time 2 Problem 2 – Time 3 Problem 4	**r = 1.00 p<.001**	-	-	-

High child Time 2 Problem 3 – Time 3 Problem 4	-	/	-	-
High child Time 2 Problem 4 – Time 3 Problem 4	-	-	/	-
High child Time 3 Problem 1 – Time 3 Problem 4	-	-	-	/

Table 32c Correlations of Codes 0 to 12 used by the Unsupported Lower understanding children (Low child) during Problems 1, 2, 3, and 4 at Time 3, and the corresponding Codes used by the Supported Higher understanding children (High child) on subsequent problems.

	Low child Time 3 Problem 1	Low child Time 3 Problem 2	Low child Time 3 Problem 3
Codes 0 to 6	/	/	/
Code 7 – weight explanation			
High child Time 3 Problem 2 – Time 3 Problem 4	r = -.23	-	-
High child Time 3 Problem 3 – Time 3 Problem 4	-	**r = .80 p=.008**	-
High child Time 3 Problem 4	-	-	/
Code 8 – comparison of number			
High High child Time 3 Problem 2 – Time 3 Problem 4	/	-	-
High child Time 3 Problem 3 – Time 3 Problem 4	-	r = .49	-
High child Time 3 Problem 4	-	-	/
Code 9 – distance explanation			
High child Time 3 Problem 2 – Time 3 Problem 4	/	-	-
High child Time 3 Problem 3 – Time 3 Problem 4	-	/	-
High child Time 3 Problem 4	-	-	/
Code 10 –description of no.&pos			
High child Time 3 Problem 2 – Time 3 Problem 4	r = .44	-	-
High child Time 3 Problem 3 – Time 3 Problem 4	-	r = .27	-
High child Time 3 Problem 4	-	-	r = -.15
Code 11 –relationship between no.&pos			
High child Time 1 Problem 2 – Time 3 Problem 4	r = .00	-	-
High child Time 1 Problem 3 – Time 3 Problem 4	-	r = -.20	-
High child Time 1 Problem 4	-	-	r = -.22
Code 12 – Torque rule explanation	/	/	/

With respect to the unsupported dyads, the higher understanding children appeared to show some contingent reiteration of basic codes used by those of lower understanding across all three time-points. The one exception is at Time 2, where there was a perfect correlation with code 12 reflecting the fact that the higher understanding children used this code the same number of times on all problems subsequent to the second problem as the lower children had on this second problem (M = 0.13). The fact that this did not sustain to Time 3 is suggestive of a chance occurrence.

4.4. Discussion

This section will serve to summarise the key points of interest emerging from the data, focusing particularly on how they bear on the hypotheses, how they fit in with the data from Studies 1 and 2, and what else they reveal about the adequacy of the RR-based tutoring model.

The first key point that emerged from the results was that as far as attempts were concerned, support only had an immediate impact, and this was only apparent in the Low-Low and Mixed dyads. The impact on explanations was more sustained, but this applied only in the Mixed pairs, and the effect was not actually significant.

It was argued in the introduction to this study, that it would be appropriate to use dyads to gain more insight into the impact of support because it would merely provide a logical reason for children to engage in verbal commentary on their thinking, and would only affect performance itself over a longer time period. Put simply, there would be no contamination of the effects of support. However, the general lack of difference between performance profiles of the dyads in the supported and unsupported conditions suggests this was not the case. There are three possible explanations of this; the first being that support had no effect on children's performance on the Balance Scale task. However, this would contradict the clear effects that it had in Studies 1 and 2, and in any case, it did have some limited effects that were consistent with those earlier outcomes, for example, the suppression of Time 1 attempts amongst those with lower levels of understanding, followed by a rise in attempts at Time 2.

The second possible explanation is that the interactions between members of the dyads hindered, or undermined the impact of support. This is consistent with the argument posited by Howe, Tolmie, Duchak-Tanner & Rattray (2000), that scaffolding and peer collaboration are mutually antagonistic except under very specific conditions, one of which was that the research had to take place in a formal environment with the adult being very clear of their role in the task. This was seen from the adult in Howe *et al*'s study who gave only low-level support, never directly challenging the children's ideas. In line with this, the adult in the present study also maintained low-level support, only assisting when needed. However, this argument again would not concur with the fact that there were patterns of effects in line with those observed in one-to-one support, nor with the fact that Tolmie *et al.* (2005) found adult-small group support to be clearly effective without particular constraints being imposed, contrary to Howe *et al.*.

This leaves the third possibility that dyads were in some ways capable of generating similar effects to support. This would be consistent with the findings of Tolmie *et al.* (2005), that adult-small group interaction had an effect over and above that of support for individual children, an outcome attributed to the impact of peer dialogue. It would also be consistent with the fact that it was the dyads with higher initial understanding who were least differentiable across support condition, since it might be anticipated that collaboration with another child with relatively good grasp might not be so different to support from an adult. The lower understanding dyads performed worse, relative to these, whether supported or not, the only difference being that support led to a suppression of attempts whilst it was ongoing. Again, one might anticipate that collaboration between two lower understanding children would be relatively less effective, and we know from Study 2 that discontinued support is not especially effective at promoting growth of understanding among such children. All in all, then, the third explanation looks to be the most plausible. However, there was the further implication that Mixed dyads working on their own were the least able to generate the effects achieved when support was provided. This is curious given the vast amount of literature that peer collaboration is *most* effective when it involves those with different understanding (see e.g. Piaget, 1932; Howe & Tolmie, 1998; Doise & Mugny, 1984), unless of course, the provision of support *interacted* with the nature of growth through socio-cognitive conflict, as Tolmie *et al.* (2005) argued was the case. Studies 1 and 2 provided little interpretive assistance on this point, since the circumstance of 'mixed' understanding is the furthest from what could have been captured by an adult working with a *single* child.

With respect to support condition, children who were supported at Time 1 showed similar patterns with regard to the relationship between their attempts and explanations, regardless of pair type. There were no concurrent negative correlations (with the exception of the Low-Low dyads at Time 2), but there was a carry-over of explanations for those with higher levels within their pair types and a tendency to learn from making more attempts earlier on, despite support. This may have been true particularly for the Low-Low group. However, it is necessary to bear in mind that this weakness of concurrent correlations may have been due, in part, to the fact that attempts were *joint* values whereas explanations were individual. There was also the possibility that there were social influences on attempts, for example, from turn-taking conventions. That is, under these circumstances where children work together on a task, attempts are not only a reflection of cognitive condition, but also of the need to respect conditions of fairness in 'having a go' at using the equipment. This has been observed to be something that primary school children are often intensely conscious of.

With regard to children who were unsupported, they looked for the most part very similar to their supported counterparts, as far as the relationship between attempts and explanations were concerned, although the Mixed group here were more like those belonging to Low-Low dyads, who they resembled most in performance profiles generally. There was one key difference, however, which was that there were much reduced signs of learning from experience in all of the unsupported dyad types, whereas this process appeared to be more consistent within the supported pairs. The implication of this may be that, if adult support did have any extra impact, it was to resource this type of learning, perhaps by providing explicit terminology to enable the dyads to grasp these lessons. Given that it was the Mixed dyads who looked most different across support condition, the further implication is that this additional advantage was particularly operative with them.

Turning to analysis of the process of interaction, and looking at the amount of dialogue generated, it could be seen that Supported dyads talked more than those who were unsupported, especially at Time 1, with this advantage being maintained longer by the Mixed dyads. This finding is consistent with the argument that discussion in the Mixed dyads had been more effectively resourced, although it could of course also reflect the fact that these children actually had more to discuss because of their differences in understanding. Over time, simple constituent element explanations, in terms of weight or distance only, were abandoned in favour of more integrated explanations during problem-solving by both supported and unsupported dyads, but the supported Mixed dyads, who engaged in most dialogue, showed a more pronounced shift in this direction. The fact that it was the Mixed groups who showed this shift in dialogue to a somewhat greater extent is in line with previous literature on socio-cognitive conflict, where collaborating children with initially different conceptions were found to show greater conceptual development on-task than those who held similar theories of the task (Doise & Mugny, 1984; Howe, Tolmie, and Rodgers, 1992; Williams and Tolmie, 2000). Furthermore, as it was the supported Mixed dyads who showed this pattern more so than those who were unsupported, this again contradicts Piaget's (1932) argument that conceptual growth in collaborating children could only occur successfully in the absence of adult support, as the presence of an adult tutor would be "counter-productive" (Howe *et al.*, 2000).

However, from the general lack of correlations for the supported Mixed children between on-task dialogue and explanations – and these children only, it initially appeared as though adult input served mainly to promote early and greater explicit exploration of problems, as opposed to laying the foundation for appropriation to take place fuelling a process of appropriation, as hypothesised. Once again, the implication is of some form of interaction between adult support and peer discussion taking place amongst children in these dyads.

Research by Tolmie and his colleagues (Howe, Tolmie, Duchak-Tanner & Rattray, 2000; Tolmie *et al.*, 2005) further support the present findings that adult support was more beneficial to children collaborating on a task than when no support was given. Nonetheless, appropriation of adult accounts was very much apparent in the High-High supported dyads, whilst the Low-Low pairs looked much as they did in Study 2. Consistent with the argument put forward above, the Mixed dyads showed much less sign of appropriation than the High-High pairs, but there were signs of contingency from the adult which impacted on subsequent dialogue in a limited fashion, namely in the form of explanations giving a description of number and position (code 10), for example, "we put one there and there's two there and we put one on the second one, and if you put more there it would fall down". Examination of the High to Low and vice versa secondary appropriation in the supported Mixed dyads found contingent usage by the higher understanding child at Time 2, and then convergence of this dialogue taking place at Time 3. This appropriation process started at Time 1, where the adult provided more code 10 statements subsequent to the first problem if the dyad (and presumably more specifically the member with higher understanding) showed awareness of these ideas on this problem, and this led in turn to greater usage by the children at Time 2. At Time 2, the higher understanding child used code 10 explanations less if the lower understanding child showed awareness of them, perhaps letting them express this understanding where they had it, and doing themselves when they did not. Finally, at Time 3, the two children were using code 10 in a coordinated fashion, with usage being highly correlated between them.

Unsupported Mixed dyads showed some similarity of dialogue interchange, but focused more on lower levels of explanation, such as those referring only to weight (code 7), those comparing the number of nuts on each side of the Balance Scale (code 8), or those referring only to distance (code 9). Where higher levels were picked up on there were signs of this being more a matter of echoing than genuine convergence. For example, code 11 – an explanation of the relationship between number and position (e.g. "you put less at the end 'cos it's heavier at the end"), appeared to be appropriated at Time 2 from the higher to the lower understanding child, but this relationship was not repeated at Time 3, indicating no genuine development of understanding regarding this type of dialogue. In addition, there was no appropriation of code 10 at all in the unsupported group, where this was the main type of dialogue appropriated between the supported children.

This difference between the supported and unsupported Mixed groups lends further weight to the importance of adult input, not least from the finding that the contingency of support provided by the adult transferred to the more sophisticated child within the dyad, and this child then contingently worked with the less sophisticated child subsequently, to the extent that the latter child appropriated this dialogue and used it themselves. This finding was very similar to the effects of continuous support on the lower understanding children in Study 2, except that here, responsibility for providing that support, and for leading them into more explicit explanations has effectively been delegated successfully to the higher understanding child. This has considerable practical implications for classroom practice.

The fact that it was code 10 (description of number and position), that was central to the Mixed supported progressing, has important implications, as this type of dialogue is such that it leaves the nature of the relationship between number and position somewhat implicit, with the details having to be worked through via concrete examples. The strategic advantage of this is that it is exactly at the boundary of what *both* children in the Mixed dyads were likely to be able to work with. That is, it was sufficiently accurate for the higher understanding child to accept, and sufficiently implicit for the lower child not to become confused by detail. The difference between the supported and unsupported Mixed dyads suggests that it was the adult introduction of exactly this strategically optimal code that was the crucial difference they made. It was of no small interest that it was adult dialogue on Problem 2, picked up on in Problems 3 and 4, that seemed especially influential, given indications from both Study 1 and the present study, that Problem 1 was typically devoted to refocusing on the task, and that it was Problems 2 and 3 where most effective exploration of the principles at work took place. The following example illustrates the dialogue used by the adult subsequent to the dyad achieving balance of Problem 2 (one nut each on the second and fourth pegs), but having difficulty explaining how their method of placing two nuts on the first peg and one on the fourth peg led to equilibrium:

Child A: "It's because that one (nut on their peg 4) keeps that one (nuts on their peg 1) steady."
Child B: "It's because you have more on that side (nuts on their peg 1) than on that side. (nut on their peg 4)"
Adult: "Well, the nuts on the ends are the same, aren't they, and there's two on that one (their peg 1) and one on that one (researcher's peg 2), but what is it about them that make it balance?"
(no answer from children)
Adult: "That nut (on researcher's peg 2) is further along than them (their peg 1 nuts), isn't it, and you need less to balance it as you move further out to the end."

In essence, it can be concluded from the findings of this study that, firstly, it did not, in fact, add much more to our understanding of the process of appropriation, since the High-High and Low-Low dyads showed similar patterns to those seen in Studies 1 and 2. Nonetheless, it did serve to reveal an important mechanism by which adult support can resource subsequent child-child dialogue under conditions where dyad members have different levels of understanding, a mechanism that has substantial implications for effective classroom activity. Finally, this mechanism is again entirely consistent with the RR-based model of tutoring, exhibiting yet again how the nature of appropriation and learning from tutor support is a function of children's initial representational level, and contingent adaptation of tutor input to this, not at a moment-to-moment level as suggested by Wood, but at a more strategic level, across a series of linked problems.

Chapter 5

GENERAL DISCUSSION

5.1. Summary of theoretical background to present research

The Vygotskian belief that social and cultural influences are vital to children's effective cognitive growth has been widely advocated in contemporary research. The scaffolding process in particular has been found to be very effective in advancing children's performance and understanding of a task as long as support is administered contingently, thus pertaining to the child's needs at that moment in time. The evidence supporting the importance of social factors on children's learning then runs counter to the Piagetian view that cognitive development is innately structured, and depends on interactions between the environment and innate processes designed to structure information from the resulting experience. Karmiloff-Smith held this Piagetian view as her Representational Redescription (RR) model was based on the premise that the process through which children shift from having procedural, implicit knowledge to more explicit knowledge embedded in language, is largely endogenous, with social processes only being helpful in the sense that they provide contact with experiences that are productive for the endogenous progress but have no *direct* influence on change.

5.2. Summary of nature of present research

The present research set out to examine the effects of adult input on children's performance and understanding on a Balance Scale task, with respect to whether and how the linguistic exchange between adult and child impacts directly on the child's actions and their subsequent growth of knowledge of the main balance properties of weight and distance. The adult comprised the child's parent (Study 1) and an assistant of the researcher who was previously unknown to the child (Studies 2 and 3). A balance task was used as this was deemed a suitable activity to promote detailed discussion of specific concepts of weight and distance, due to the opportunity it presented for fine-grained manipulation of these factors. In a small number of cases, the emphasis on manipulation led to much trial and error activity without verbalisation, but this was not generally an issue, as the revealing nature of the data on the performance and explanation relationships makes clear.

The studies examined the hypotheses that, in general, adult (e.g. parental) support was necessary for enhancing cognitive growth, and also that this input in the form of linguistic mediation, facilitated a shift from implicit or immature explicit (E1) level representations to more explicit or advanced explicit level representations (cf. Karmiloff-Smith, 1992). It was also hypothesised that the outcome of support would be different for children depending on their prior level of representation (i.e. Level I or E1/2) about the main balance properties of weight and distance.

5.3. Discussion of findings in relation to previous research

All three studies provided evidence that adult influence on a Balance Scale task does indeed impact on children's performance and understanding concurrently and subsequently, producing very different results to that of control children working alone. In Study 1, for example, although the latter group of children did, in line with Pine *et al.* (1999) catch up with the former at Time 3 in terms of the number of attempts taken to balance the scale, the supported children increased in their explanations from Time 1 to Time 3 to a much higher level than those who were unsupported. In Study 2, children of lower understanding progressed in performance and understanding when support was provided across all three sessions as opposed to just one, whereas the opposite was true for children of higher understanding. With regard to Study 3, however, the evidence for impact was restricted to differences in the pattern of performance on-task, especially for the Mixed dyads, rather than any differences in outcome.

The hypothesis that support would facilitate representational redescription was also upheld, supporting findings by Tolmie *et al.* (2005), although the scaffolding process varied considerably depending on a number of factors which will be outlined below.

One factor which affected the scaffolding process was the adult's prior relationship with the child, and this difference had profound implications with regard to the way in which support was administered. Parents' scaffolding procedures, for example, varied enormously, with some providing only minimal assistance such as non-specific prompts ("what do you think you could try now?"), others taking full control of the task, for example, carrying out the actions themselves with their child only looking on, and others still, focusing on giving explicit explanations of sophisticated balance concepts (i.e. torque rule explanations). This level of variation supports previous studies examining the impact of parental input on children's learning on a task (Pratt *et al.*, 1988; Pratt, Green, MacVicar and Boutrogianni, 1992; Nilholm & Saljo, 1996; Wood & Middleton, 1975), where intervention ranged from non-specific prompts to direct control measures such as the parent completing the task for the child. As expected here and previously, the more controlling aspects were completely detrimental to the child's learning, whereas more contingent techniques were beneficial to both actions and cognitive growth, as the child was able to follow the parents' guidance in a way that allowed them to appropriate the strategies needed to complete the task alone later on.

However, it appeared that the input provided by parents in the present study was actually based on an *expectation* of how their child would perform, as opposed to being tailored to the child's present needs. This was seen from the greater degree of difference in adult input according to child level in Study 1 than in Study 2, as although the adults in Study 2 did also provide different levels of input, the fact that they did not know the child beforehand provided evidence that their support was based purely on their observations of what the child was doing at that present time.

This finding could also help to explain the mothers' behaviours in other studies, especially those who used direct control measures, and would perhaps provide an explanation to Wood & Middleton's (1975) findings that relatively few mothers used contingent support in the way that they defined it.

Nonetheless, the nature of parental input in the present study did generally appear to support the majority of studies which have found that overall, parents do tend to scaffold contingently and within their child's 'region of sensitivity' (Wood, 1986; Wood & Middleton, 1975), and thus facilitate their child's learning and understanding of task procedures (Baker *et al.*, 1996; Conner *et al.*, 1997; Conner & Cross, 2003;

McNaughton & Leyland, 1990; Wertsch *et al.*, 1980; Wood & Middleton, 1975). Here, however, contingency appeared to be at the level of general strategy, rather than a moment-to-moment adaptation to progress, and this may have been a reflection of reasonably accurate expectations about level of performance on the part of parents. For example, children at a higher performing level (Level E1 at least) tended to receive more explicit assistance in the form of torque rule explanations, and lower performing children (Level I) received more implicit input in the way of direct control measures.

In essence then, and in line with the hypotheses, where parents gave fully explicit support, this resulted in the child appropriating the torque explanations, using their new found knowledge and understanding of this rule to guide them effectively through the task when working alone. By the final time-point, those children were providing explicit explanations of how the scale balanced in a way that showed they had successfully made the transition to Level E3 in Karmiloff-Smith's (1992) RR model, although in contrast to her view, this transition was entirely dependent on parental assistance, and thus, lends support to the role of linguistic mediation.

In stark contrast, parents who provided implicit assistance in the form of direct control measures, such as telling their child to make a specific move, or carrying out the action themselves, did not, in line with Wood & Middleton (1975), benefit their child's cognitive growth at all at Time 1, although this group of children were showing some sign of progress at Time 3. Overall, however, this type of assistance led to the recipient children performing poorly in terms of making more attempts and giving less sophisticated explanations overall.

Those direct control measures used by parents in Study 1 were not used by the adults in Studies 2 or 3 at all, supporting past research where input provided by an adult unknown to the child, usually either the researcher or an associate of the researcher (Peters *et al.*, 1999; Pine *et al.*, 1999 and Wood, Bruner & Ross, 1976) does not include the direct control measures favoured by some parents. The most explicit input observed in Study 1 involving torque rule explanations, was also rarely provided in Studies 2 and 3, with support instead focusing on prompts and lower level explanations. Those differences in scaffolding methods were suggested to be due to the fact that, firstly, the adults used in the second and third studies were all trained in contingent scaffolding techniques whereas the parents in the Study 1 were not. However, even the trained adults here showed relatively little sign of contingent support in the sense used by Wood & Middleton. Furthermore, as the adults did not know the children before the start of the study, they were conscious of administering a consistent level of input with all children, at least until they realised their present capabilities.

Despite not knowing the children beforehand, the adults in Study 2 did appear to recognise the children's present abilities relatively quickly, as those of lower understanding received more support overall than those whose understanding was at a higher level. The lower understanding children in this study also received the same type of input, in the form of non-specific and implicit weight/distance prompts, and weight-based explanations, as those of lower ability did from the parents in the first study. Whereas parental support was apparently based on a prior knowledge and expectation of their children's abilities, however, this was obviously not the case for the adults in the second study, who had no previous relationship with the children. This suggested, therefore, that the adult was actually responding to the present needs of the child, and providing constructive and contingent scaffolding techniques but again in terms of general strategy, and – in the continuous support condition – a gradual shift in this over time. However, as mentioned above, their scaffolding methods did differ with respect to the lack of direct control measures and few instances of torque rule explanations used here, where they were administered frequently by a number of parents.

An alternative argument to the notion that scaffolding differed as a result of the adult's prior relationship with the child was suggested by Pratt *et al.* (1992), in response to their findings regarding parental scaffolding on different elements of children's homework. They suggested that individual parental differences in scaffolding techniques may simply be down to the extent and confidence of their *own* abilities in that area. That is, if the parent has difficulty with the task requirements, they may be more likely to administer direct control measures as they themselves try to learn how to complete the task. In contrast, parents who have more task-relevant skills may not only possess the skills required for the task, but would be more likely to articulate their instructions in a way that could be understood and appropriated by the child. This suggestion supported findings by Nilholm & Saljo (1996) that socio-cultural factors, e.g. the mothers' professions, were very important in determining the type of support administered to their children. In the present research, there was no knowledge of the parents' backgrounds, although one parent who effectively taught her child the torque rule did state that she was trained and worked as a teacher.

The effects of support condition on children in Study 2, depending on their initial level of understanding, were also found to be very prominent, supporting findings by Tolmie *et al.* (2005), and also the hypotheses that lower understanding children benefited more from continuous input and higher understanding children from discontinued support. It was suggested that the above findings were due to the fact that, as children of lower understanding do not yet hold the degree of explicit representation required for the particular task, then a one-off session of support would not be enough to promote development of this knowledge. This was found in all three studies regarding this group. The extra support sessions therefore, allowed them to gradually gain understanding of the task over time, leading to a decrease in attempts and increase in their explanations, and this was coupled with the gradual shift towards more explicit forms of support by the tutor. In contrast, due to the higher understanding children already possessing at least some prior knowledge of the weight and distance balance properties, the one session of support was enough to allow this group to appropriate the adult's input and develop the necessary conceptions to further advance their actions and understanding at Times 2 and 3. More support than this simply seemed to lead them to abdicate responsibility for the task.

It could be argued therefore, that although Studies 1 and 2 differed in terms of both the adult's relationship with the children and whether they received training or not, together they were powerful in showing the ways in which completely different styles of scaffolding can impact on the children's actions and understanding, with this primarily being dependent on the child's prior level of understanding.

With regards to Study 3 in which children worked in same-sex dyads on the Balance Scale task, the results were similar to those of the individual children in Studies 1 and

2. insofar as those dyads who already showed signs of having at least some explicit grasp of the weight/distance properties of balance equivalent to E1/E2 level, at the outset (High-High dyads) appropriated the adult's dialogue and used this to effectively complete the task and explain their methods when completing the task subsequently in their dyads without the adult presence. This level of appropriation was not found with the unsupported dyads.

The positive effects of adult support on collaborating children was also shown by Tolmie *et al.* (2005), who found that this helped to prevent the unproductive aspects of peer collaboration, such as disagreement of strategies with no explanation of why this disagreement occurred, and encouraged children to explore their ideas with one another. It was suggested by Tolmie *et al.*, and supported by the present research, that this verbal strategy exploration between peers, as a direct result of adult support, led to a higher understanding of the task than with children who worked alone or one-to-one with the adult. The unproductive nature of child peer collaborators working in the absence of an adult has been found in past peer collaboration studies (Garton & Pratt, 2001; Gauvain & Rogoff, 1989; Murphy & Messer, 2000; Radziszewska & Rogoff, 1988), where they have been on par with children working alone.

Other studies, however, (Fawcett & Garton, 2005; Phelps & Damon, 1989; Pine & Messer, 1998; Tudge, 1992; Williams & Tolmie, 2000), have found results to the contrary, as they showed that when a higher able child worked with one of lower ability, this led to gains in the lower child. However, the one factor that appeared to be vital for this to take place was that the higher level child had to use a degree of sophisticated dialogue, such as explanations, which would allow the lower child to learn this type of dialogue and appropriate it for their own gains.

This was also found in the present research, where there were signs that dyads could arrive at a similar explication of representation when working on their own, albeit not so well-linked to actual experience of the problem solutions.

With respect to the Low-Low dyads, although adult support had an immediate positive impact on their attempts (as it did with the Mixed groups), it did not appear to benefit them overall, even with their peer working beside them.

The supported Mixed dyads in the present study had the most interesting shift from Time 1 to Time 3 primarily in their usage of sophisticated dialogue which explained the relationship between number and position (code 11). At Time 1 they generated the least amount of this type of dialogue, but by Time 3 they were using it to a similar extent as the High-High pairs. They did appear to show a shift towards using this type of dialogue in place of code 10 at Time 2, but then dropped in usage again at Time 3. Where dyads were still showing usage of this code at Time 3, however, they were doing it very effectively, showing a shift to an E3 level of representation.

Furthermore, as predicted, secondary appropriation was apparent, but only in the Mixed group. The more sophisticated child tended to appropriate the dialogue used by the adult, and then used this contingently with the less sophisticated child, who then appropriated the dialogue and used it themselves. This seemed to be most apparent with dialogue describing number and position (code 10) and that describing the relationship between number and position (code 11), possibly due to the fact that the details of this type of dialogue had to be worked through via concrete examples. However, with regard to code 11, it appeared that subsequent to being used by the higher understanding child, it was then used by the lower understanding child, but only in the form of imitation, and not through any genuine understanding, as seen from the rather weak/marginal correlations.

It appears then that code 10 seemed to be the only type of dialogue effectively appropriated from high to low child, due to the fact that it was at the boundary of what both children in the Mixed dyads were able to work on. That is, it was sufficiently accurate for the higher understanding children to accept, and sufficiently implicit for those of lower understanding not to become confused by detail.

Thus, the present evidence supports previous studies showing that when children of mixed ability work together it is possible for linguistic mediation to take place between them. Whereas this study showed that this was only true for those mixed dyads who were originally supported by an adult, however, the evidence outlined above (e.g. Fawcett & Garton, 2005, Tudge, 1992), showed that it may be possible in the absence of adult input, as long as the higher level child uses the appropriate language to allow linguistic mediation to take place between them and the lower child.

5.4. Significance of present findings

There are thus both theoretical and practical implications with respect to the findings of the present research. One key issue, for example, is that the attempt to integrate the RR model with accounts of the effects of scaffolding led to very specific predictions about the mechanisms underlying representational change, and variation in these according to initial representational level, almost all of which were borne out. This evidence provides very powerful confirmation of the general validity of this approach, and perhaps more importantly suggests that this is the long sought after point of rapprochement between Piagetian and Vygotskian accounts of development – one that deals in even-handed fashion with both internal cognition (strong in Piagetian accounts but weak in Vygotskian), and processes of external support for its development (strong in Vygotskian accounts but weak in Piagetian). There is, of course, much that remains to be worked out. For example, there were glimpses here of the complex nature of the relationship between representation and performance, and how the relative balance of these shifted over problem and time-points, but considerably more detail is required on these relationships, and in the context of other activities.

The issue about other contexts is also pertinent to the scaffolding effects identified. The analyses conducted here were greatly facilitated by the nature of the task employed, which was one of the main reasons for using it, but it is possible that it actually helped shape the effects rather than merely helping reveal them. Analyses in other contexts are therefore crucial.

The differences in the nature of support depending on whether it is administered by parents or an unfamiliar adult, are also quite striking. Parents, on the one hand, have been found to be more likely to occasionally use less contingent scaffolding procedures, such as carrying out actions on the task without letting the child do it, although they are generally contingent in their approach. Unfamiliar tutors, on the other hand, tend to be more structured in their support, basing their level of input on their observations of what the child is actually able to do rather than what they *believe* the child's capabilities are.

Along with providing support based on an expectation of what they believe their child is capable of doing, there is also the possibility that parents can only help their children within the boundaries of their own abilities, and so if those are relatively weak, there is the chance that their child will not benefit as much as they could do. Generally, unfamiliar tutors have already been trained in the task, and so are aware of the nature of it and how to complete it in the most effective way, thus using efficient scaffolding techniques to guide the child through it and enhance their understanding as they go. However, what is not yet known is how parents would structure their level of support if they were actually trained in effective scaffolding techniques prior to the study. Thus, research could examine whether their own understanding of the nature of the task, now increased through training, their history with the child, and thus, their expectations of their child's current abilities, are still factors that would affect their input.

The nature of support provided by teachers is similar to both that observed by parents and obviously the unfamiliar adult. That is, they are trained in their profession to provide the necessary information to children regarding the various activities undertaken, but are also fully aware of the children's capabilities of how they will cope with particular activities. However, in the classroom they do not have the time to devote their full attention to all children, which would have a negative effect on children of lower ability who is unsure of how to progress with a task.

Thus, the finding that children of lower understanding benefited more from continuous assistance, whereas children of higher understanding thrived when support was only given once, could have major implications for teaching and learning. That is, if a teacher is teaching the children a new mathematical problem, it may not be enough to give an instruction once and expect all children to continue with their lesson. The importance of working more closely with children who are of lower understanding was evidenced in this research, and suggested that with the appropriate type <u>and</u> amount of assistance, those children could successfully advance in their cognitive learning

More research on support with collaborating children is required to explore the impact of this. Tolmie *et al.* (2005) found that support facilitated a degree of generalisation to another task, which differed from that used during the supported session, but required the same operationalisations and types of explanation. Therefore, the impact that support with small groups of children had on one task generalises to another, similar task, may be a viable area of research to undertake.

CONCLUSIONS

It can be concluded that the present research has confirmed Vygotskian theory regarding the importance of social influences in facilitating children's cognitive learning, or Representational Redescription (Karmiloff-Smith, 1992). However, the *extent* to which children's cognitive growth occurred was found to be dependent on three key factors. Firstly, the nature of support was shown to impact on children's learning differently depending on its degree of contingency, in the general sense of this term. That is, the more direct control measures observed by parents in the first study did not appear to benefit the children's subsequent performance or understanding. Other scaffolding techniques, such as providing appropriate explanations of the weight/distance elements of balance, were very much more successful in advancing the children's subsequent actions and understanding.

Secondly, the time-frame of support, alongside the amount of knowledge children brought to the task prior to undertaking it was found to be very important in determining how they would benefit from adult input. Thus, children who possessed lower understanding of the task properties were found to benefit more from continuous input that focused on introducing gradually more explicit input over time. In contrast, those with a higher level of understanding, at least at E1 level, benefited from discontinued support that focused on more sophisticated, explicit dialogue.

Finally, it was shown that collaborating children also benefit from adult input, but the effects are lagged, and again, appropriation of adult dialogue can only take place when children possess knowledge consistent with a minimum E1/E2 level representation. In addition, secondary appropriation from a higher understanding child to his lower level partner is possible, but again, adult support (in this study, the adult being one previously unknown to the child) is vital in facilitating this process.

Those factors all have major implications for teaching and learning both at home and in the classroom. That is, once the child's *current understanding level* of the task-in-hand has been established, the appropriate measures of support, taking the above factors into account, should be considered.

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Appendix 1

Letter of approval from local education authority to conduct research in primary schools

Department of Educational and Social Services
Director: John Mulgrew
Head of Service : Schools Support - John McCarney
Direct Dial : (01563) 555642
Fax : (01563) 574079
E-Mail : john.mccarney@east-ayrshire.gov.uk

East Ayrshire COUNCIL

Our Ref: JMcC/EO'N

7 January 2004

Sharon Philips
Centre for Research into Interactive Learning
Department of Psychology
Graham Hills Building
40 George Street
GLASGOW
G1 1QE

Dear Ms Philips

PhD RESEARCH ON PROBLEM SOLVING STRATEGIES IN CHILDREN

Thank you for your letter of 5 January 2004 to Mr Mulgrew, Director of Educational and Social Services, which has been forwarded to myself.

I approve your request to approach a number of primary schools within East Ayrshire to conduct research for your PhD. Please ensure that you follow the following procedure:

1. Make direct contact with the Head Teacher of the relevant primary school.

2. Fully explain the purpose of your research and the nature of your interaction with children, parents and staff.

3. Include all relevant details such as your Disclosure Number etc.

The Head Teacher has the final decision with regard to the school participating in your research. However, you may find it helpful to attach a copy of this letter with your request.

I hope you find this to be helpful and I wish you every success with your PhD studies.

Yours sincerely

John McCarney

JOHN McCARNEY
Head of Service : Schools Support

Appendix 2

Letter to parents asking for permission to conduct research with their child

UNIVERSITY OF STRATHCLYDE

23 April 2004

Dear Parent

I am currently undertaking a PhD in Psychology at the University of Strathclyde in Glasgow, and my research will involve studying the formation of problem solving strategies in children and the influence of parental support on their methods.

I will be undertaking research at Annanhill Primary School over the following month. I am wondering if would be possible to conduct research with you and your child on one of two simple tasks. Your role would be to assist your child on the problem, and work together to successfully complete it. However, not all of the conditions require parental assistance so if you are happy for your child to be involved in the research, but you would not like to be involved that would be fine.

The children should find the problem-solving activities fun and interesting to do.

The research will also involve the use of videotaping to record and code the moves that the children undertake on the tasks. However, all records will be strictly confidential, and they will be destroyed after coding has been completed.

Please could you tick the relevant boxes on the attached form and return it to the school.

If you have any issues that you would like to discuss further my office number is 0141 548 4391, or alternatively you could contact me on 0778 6253677.

Many Thanks

Sharon Philips

CENTRE FOR RESEARCH INTO
INTERACTIVE LEARNING

Tel: 0141-552 4400 ext
Direct Line: 0141-548 + extensio

Name of Child ________________________________

- ❖ **I would like my child to take part in this research** ☐

- ❖ **I would not like my child to take part in this research** ☐

(Please tick preferred box)

- ❖ **I would like to take part with my child in this research** ☐

- ❖ **I would not like to take part with my child in this research** ☐

(Please tick preferred box)

Signed ....

Appendix 3a

Study 1 transcript: Fully Explicit Input

Tape 38 5 mins 47 secs

Balance Scale

Name of Child: R

School:

Condition: **Time:** 1

T1 = 0

1 & 0

~~1 torque~~

1 ins corr m

1 x ~~torque 3~~

T2 = 0
1

~~1 n v enc~~

~~1 x prompt~~

~~1 x torque 4~~

1 x ins corr

~~1 torque 4~~

~~n v ea~~

~~mum lev 4~~

T3 = 0

T4 = 0

~~2 n v enc~~

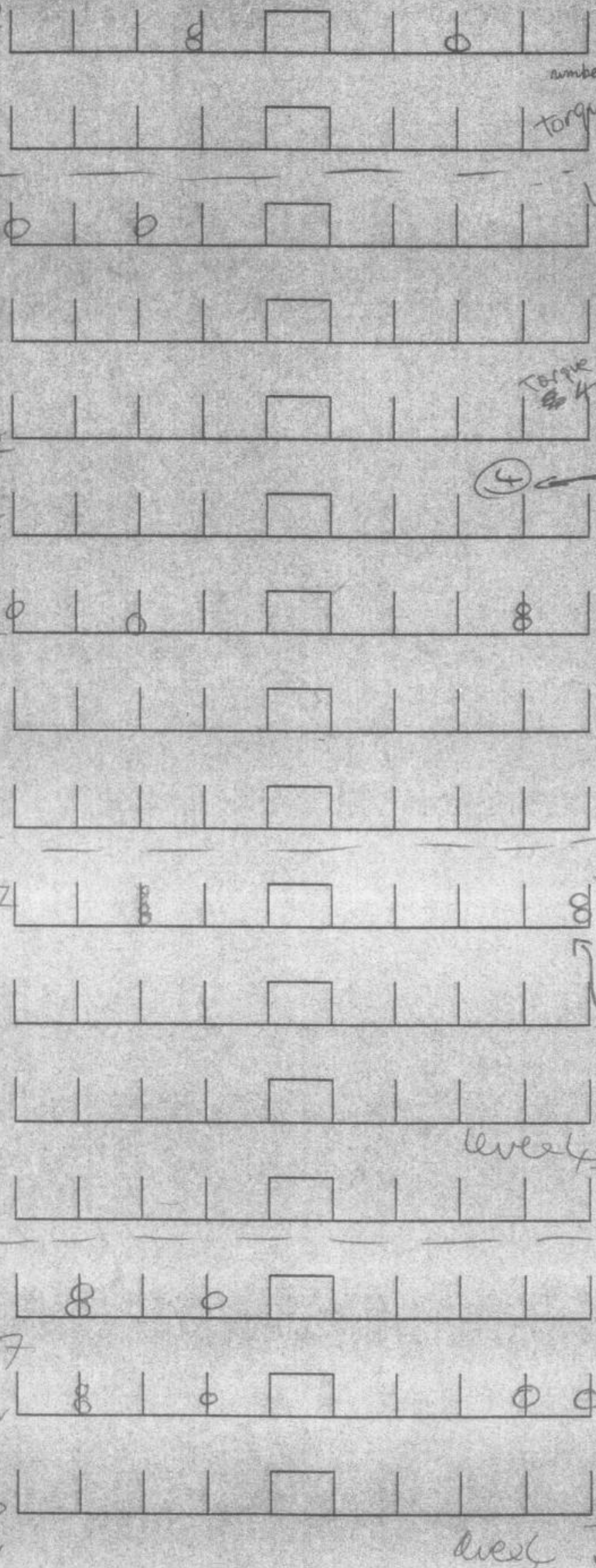
1 x ins corr

Totals

1 lev

3 ins corr

1 torq...



Mum points to peg 1 and says 'do you think it goes there.' R shakes her head and puts it on peg 2. Mum tells her to take rest out. (ins corr m)

When it balances mum points at her pegs & says that's ^number one, number two. Then points to my peg 1 and says that's two on there (Then points to her peg 2 & says) & that's the same as that. R[redacted] nods. Mum then points at her pegs 3 & 4 and says, 'and that's number 3 & number 4.' Mum points to my peg 2 and says, 'that's number 2' then she points at my peg 4 and says, 'And that's ~~number~~ ....' Looking at R[redacted]. Mum says it again. R[redacted] says 'twelve and three' mum says 'No' and points at number 2 again – R[redacted] says, 'two and four (when mum points at peg 4). Mum says, 'And what's that?' R says, 'And that makes six.' Mum says, 'Right, you need to make that side make six (points to hers) to be ^prompt the same as that (points to mine) R says '5 and 1' Mum says 'you can't make up a five.' R says 'three add.... three.' 'Try that ^ins corr then.' R[redacted] puts 2 nuts on peg 3. Mum looks at her & says 'try that?' Mum takes rest out and sits back looking proud of Rachael. (n v enc)

Explanation: 'I did the adding up thing. Three add three makes six, five add one makes six. All the sums that make six.' Asked her why she was trying to make six & she said (looking at my side) four add 2 makes six. Level 4

Here mum says, 'Ohh' – R[redacted] points to my peg 2 & says 'that's two' then she counts up my peg 2 and says, 'two, four, six, eight' (n v enc) – after she says 8 she looks at mum who says mhm. She put a nut on her peg 4 and said 'four ... add four makes eight.' So put another nut on peg 4. Mum asks if she wants her to take rest out. R nods.

I ask her how it balances. She says 'I added up coz four add four is eight and (pointing at mine) two ~~fours are eight~~. Mum points at my side and says, 'four twos' R[redacted] then says, 'four twos are 8.' Level 4

→ Mum ~~...~~ Torque 4

R[redacted] points at my peg 3 and says, 'that's number 3... six (then points at my peg 1 and says, 'seven.' If that's seven, need to make seven. Then uses fingers to count to seven. She says, 'four add three.' Mum nods & ^n v enc says, 'You ^ins corr try it.' When she does this mum says, 'Now will I take it (rest) out?' R nods – when it balances mum looks at R in really proud way. n v enc

'I added up the sums – four add three makes seven.' Mum points to my side & says, 'What about that side?' R says, 'three add 3 is six add one makes seven.'

Level 4

Appendix 3b

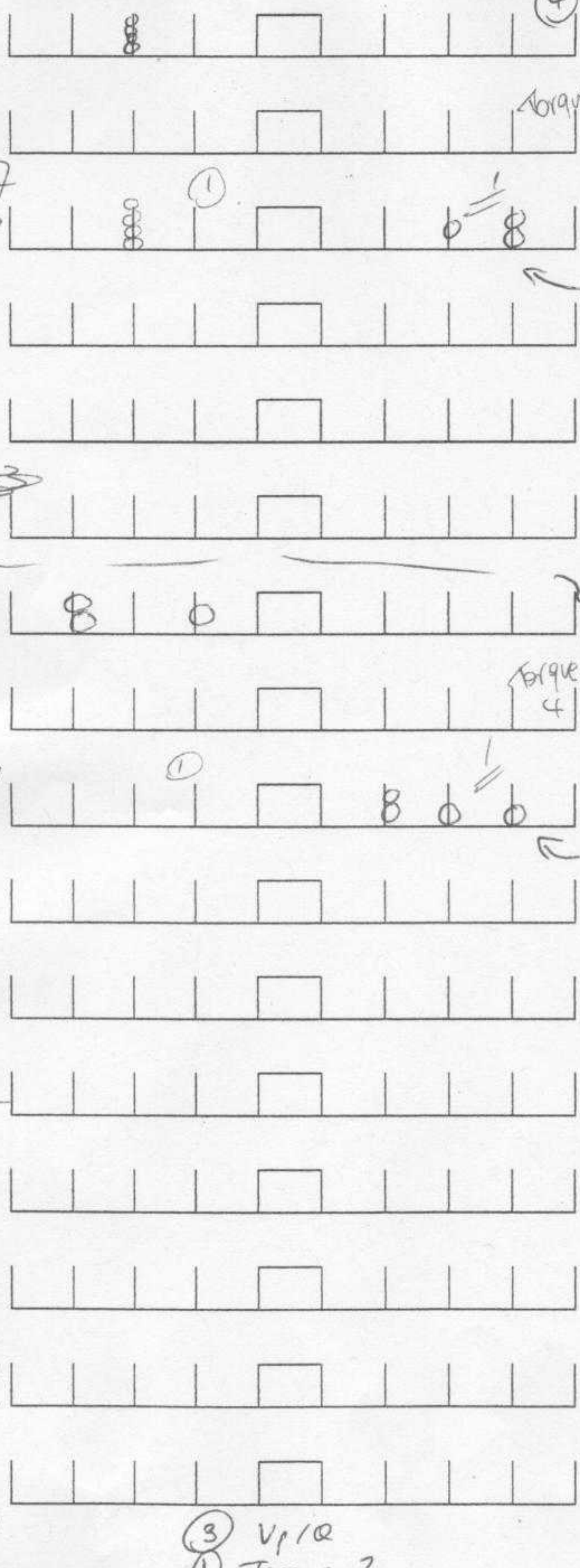
Study 1 transcript: Partially Explicit Input

(2)

Tape 48 10mins 5secs.

Balance Scale

Name of Child:
School:
Condition: **Time:** 1.



(4) N hovers a nut over peg 2. Mum says, 'wait a minute, count them up, can't do the same, remember.' Points to my peg 2, 'that's on peg 2, so, 2, 4, 6, 8, so how do you make 8 on there (points to her side) N puts nut on peg 3. Mum says, 'three'. Then N puts nut on peg 2. Mum says, 'Four, five.' N hovers nut over peg 4. Mum says, 'that would be 9, wouldn't it. So N puts it very slowly on to peg 3. Mum says, 'three, six, yeah try that, so N puts it on. Mum tells her to take rest away. Balances. Mum says, 'that's it. Just add them up, isn't it' I ask N how it balances. Mum says, 'How does it balance, hm?' N says as a question, 'There were lots on it?' Mum motions to her side & says, 'and it was further up, and it's the same weight on both sides now, isn't it.' N just smiles.

Mum leans in & says, 'what's that? That's peg (pointing at it) Look, add it up, 3 add 3 is..?' N says, '6'. mum says, 'and one is ...?' (pointing to my peg 1). N says, '7'. N puts nut on peg 2. Mum says, 'two'. then N puts nut v. slowly on peg 3, whilst looking at mum. Mum says, '5'. Mum then tells N to put 2 on peg 1, which N does. "There we go."

"Don't know how it balances." [illegible]

Margin notes: rules prompt; Torque 4; Torque 3; prompt; ins corr move; Torque 3; Torque 3 4; prompt; prompt; ins corr move; ven; er

1 rules
1 prompt
1 Torque 4
1 ins corr
7
1 torque 3

T3 = 1

~~mum twe 3~~

T4 = 0
7

1 ven
2 prom
1 Torque 4
1 ins corr m

Totals
3 vene
2 rule
7 prompt
5 Ques
2 Torque 2
2 block inc m
6 ins corr ma
4 takeover
3 torque 4
1 ins inc m
1 torque 3

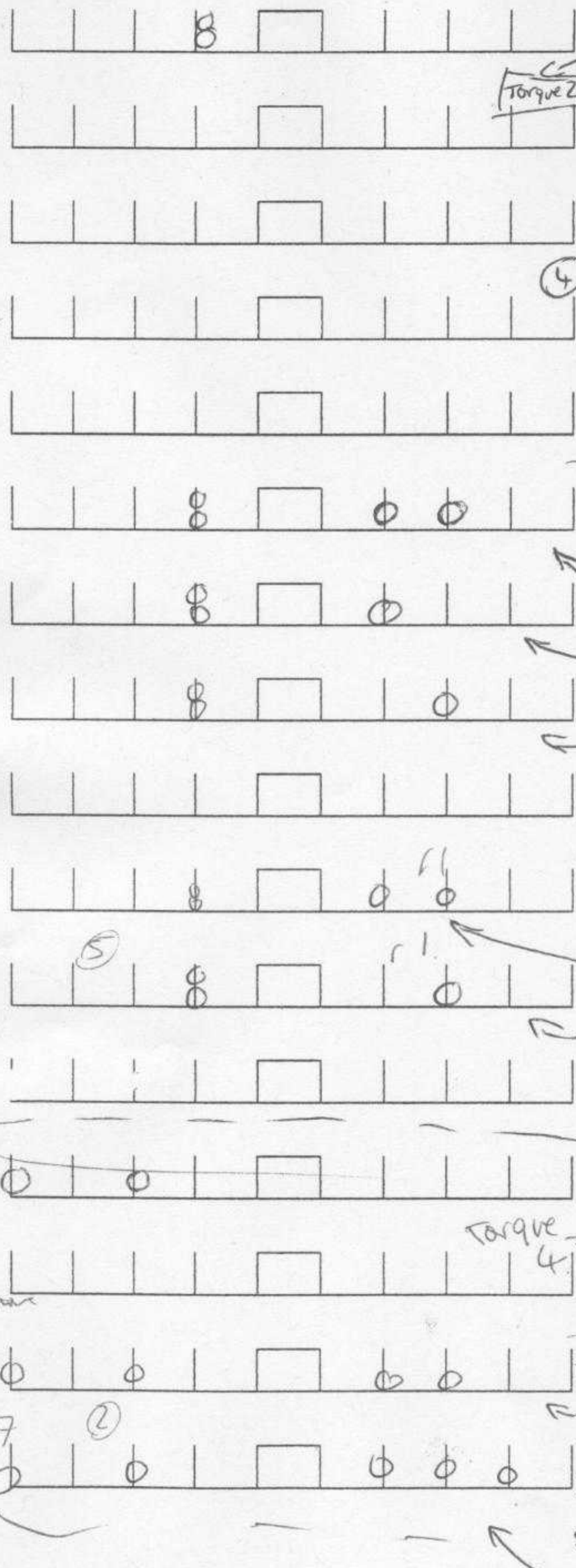
(3) Vp/Q
(1) Torque 2

(1)

Tape 48 7mins 24 secs

[redacted]ance Scale

Name of Child: [redacted]
School: [redacted]
Condition: **Time:** 1



1 venc
1 rule
2 prompt
3 Ques
~~Torque~~
2 Torque 2
1 block unc m
3 uns corr move
4 take over
17
16
6
-5
T1 = 2
Torque 2 = 1
+6
+7
(5)

1 ~~venc~~
2 ~~Ques~~
1 ~~Torque 4~~
1 - Blocks unc move
+ uns unc 3
1 uns corr
T2 = 0 +7
(2)

(4) ⊘

"Where should we put them" [redacted] puts one on peg 2. Mum says, "that's right." *(venc)*

Then mum says, "Do you think one would be good there - a bit further out?" Then N puts another nut on peg 2 & one on peg 3. Mum says, "That'll be too heavy won't it (points to her side then my side)" *(block unc move)* N asks her if she can put nuts on my side. Mum says No, just your side. *(rules)* N puts another nut on peg 4. Mum says, "don't put them all on" *(prompt)* "there's only 2 there (points to my side)." Mum takes nut off peg 4 but then puts it back on & says again, "Don't put them all on." *(take over; prompt)* N takes nut off peg 4 & mum takes it off peg 3 leaving 2 nuts on peg 2. *(Take over)* Mum then takes nut off peg 2 & says, "Why don't you leave one there, it's more further out, isn't it?" *(take over; uns correct move; Torque 2)* But then N puts another nut on peg 1. Mum says "will we see if it balances?" N nods. Mum asks me if they can see what happens. Falls. Mum says: "take one of these off" *(uns corr move)* so N takes peg 2 nut off. Scale falls other way. "Nope" "Try putting that one on (peg 2) and taking that one off (peg 1). *(uns corr move)* Balance. Mum says, "do you think that's it?" N shakes her head. Mum says, "Balancing isn't it?" N looks indifferent. Mum says (pointing at mine), "that's the 1st peg & that's the 2nd peg (pointing at her side). *(torque 2)* N then puts another nut on peg 1 & scale falls. Mum says, "that's just going to wobble, isn't it?", and mum takes it off & says, "You've worked it out, as soon as it balances that's it done." *(take over)* I Don't ask her how it balances as she looks really confused here. Level 0.

Torque 4. "Maybe if we count the points (leans over to scale & puts arm round back of Naomi's chair) that's one, two, three & four (points at each peg on my side. That's 2 (points at my peg 2) and 4 (points to my peg 4) so it's 6, so count along (side) one, two, three, four." N puts nut on pegs 1 & 2. Mum says "try that" *(uns unc m)* Falls. Mum points at peg 1 then peg 2 saying "one, two, That's 3, how do you get 6?" N puts nut on peg 4 but mum says "that's 4" so N takes it off. Mum says. "where will we put it?" *(Blocks unc move)* N puts it

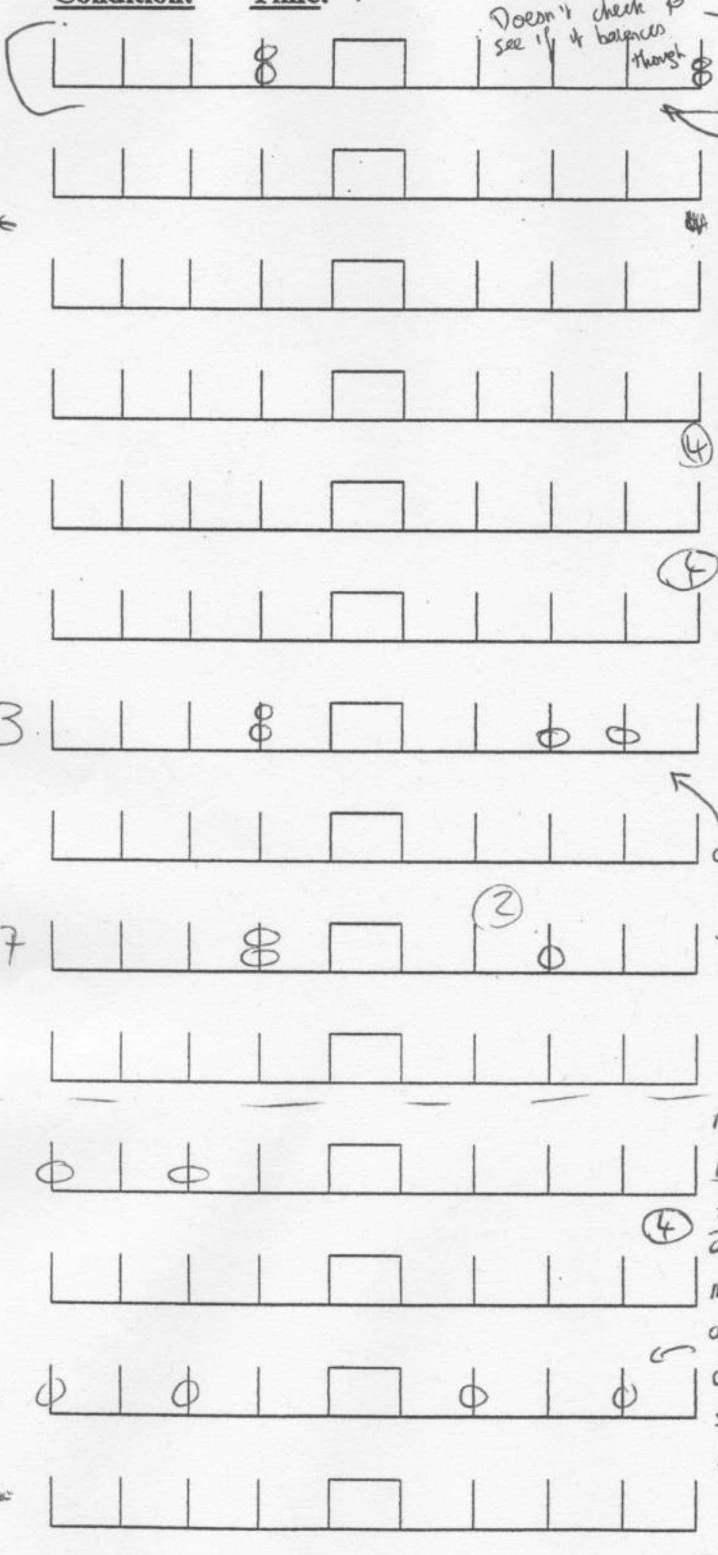
Appendix 3c

Study 1 transcript: Minimally Explicit Input

Tape 52 1h 9mn
37secs

Balance Scale

(1) **Name of Child:** L
School:
Condition: **Time:** 1



(4) "Right, there's 2 there, where do you think yours have to go on your side (points to their side & says..) this is ~~rules~~ your side, to make it balance. [redacted] does this. Mum says, "Right, do you think these 2 will balance ~~this~~ out that one? (points to her peg 4 then my peg 1) Coz there's 2 there... Do you think that'll make it balance? [redacted] shakes her head and says, No' Mum says (pointing at her 2), "how do you think you could make that balance, would you have more, less.. to make this (points (4) to my peg 1) – coz that's in the middle." [redacted] says, 'I don't think it should be there.' Mum (4) says, 'Right, so where do you think it should go' [redacted] puts her 2 nuts on peg 1. Mum says, "mm nope, because you can't copy the same as that (Rules) one (points to [redacted]'s peg 1 then my peg 1) [redacted] says, Ok and moves them to peg 3. Mum says, " You were closer then, but ok. (V. enc) [redacted] then puts one on peg 2 & one on peg 3. Mum says, 'Right, ok, if that's what you want to do. See if it (v. enc) balances. Nope, too heavy, ok, do you want to try again (torque 1)
L does this. Mum says, "Well done (Venc)
I ask L how it balances. she says, Well.. I don't actually know." (lever O)

Mum says here, " two balance there (motions to my peg 1), one balance there (her peg 2) How do you (4) think this'll balance? [redacted] puts nut on peg 2 & nut on peg 3. Mum asks, " do you think that'll make that side balance?" [redacted] shakes her head and moves the nuts to peg 1 & peg 3. Mum says, 'Ok, do you think that'll make it balance now?' [redacted] Shakes her head but tries it anyway. [redacted] says, 'My side's too heavy now. Mum says 'What side's too heavy?' L says 'mine' Mum (4) says, 'You need to ~~prompt~~ look at the pegs.' Mum motions to [redacted]'s pegs 1 & 3 & my pegs 2 & 4 & says 'Look at the pegs. (Prompt)' Mum says, 'Do you think you need 2? Remember last time you had 2 (4) on that side & one (Prompt) on this side?' L nods & takes one away leaving one on peg 3. Mum says, "Do you want to try it?" [redacted]
" Oh, too hea..."

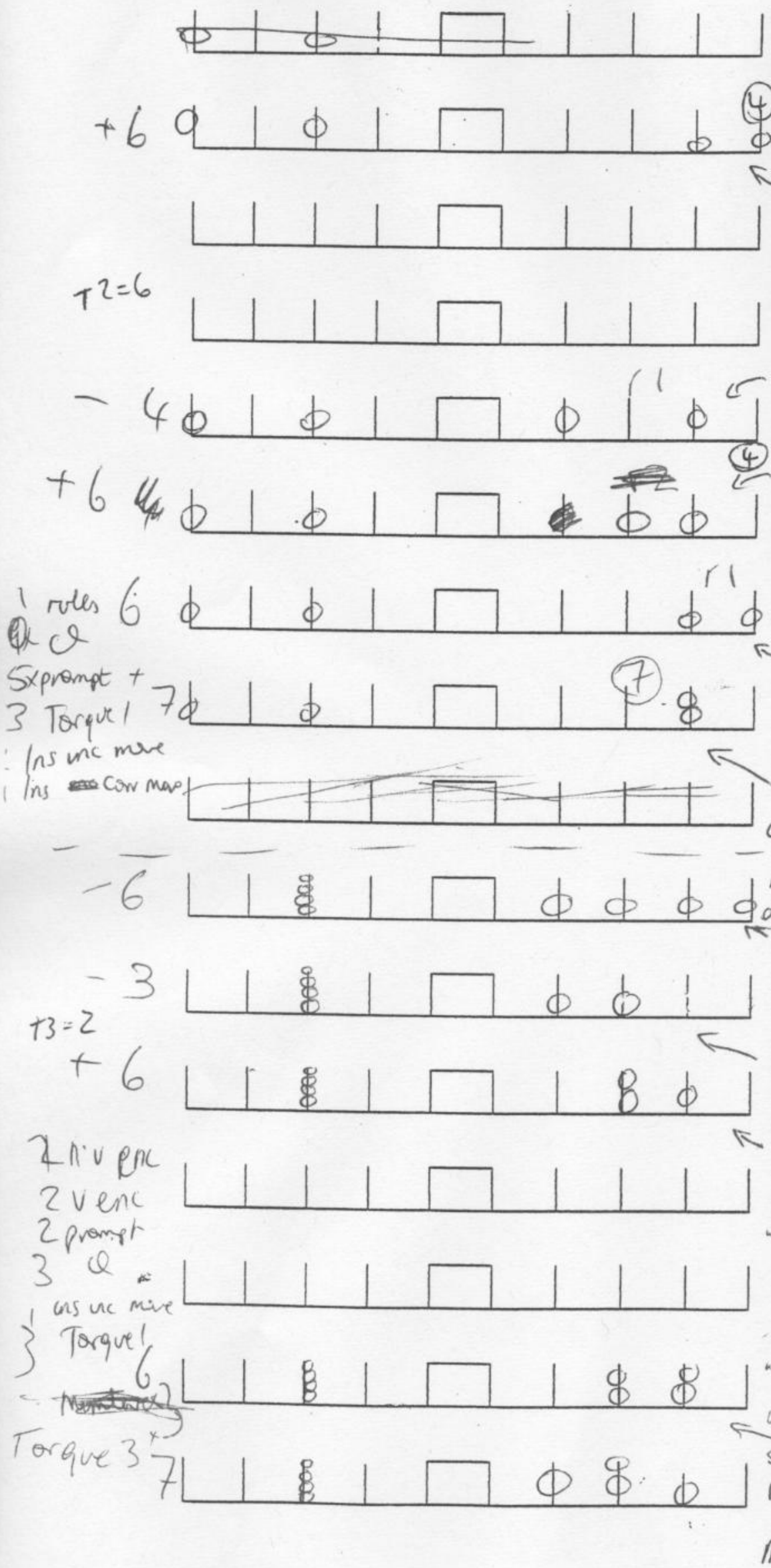
Balance Scale

Tape 52 1hr 12mins 10sec

(2) **Name of Child:** L

School:

Condition: **Time:** 1.



Mum now tries to work it out based on the first arrangement (even though I've shown her what to do beforehand!) Right, two there (point to peg 1 on my side) balanced one there (points to (4) peg 2 on my side), you still ~~prompt~~ need another one on this side to balance that side." L[redacted] puts another nut on peg 4 & looks at mum. Mum says, 'Well, you try it.' Falls. Mum says, "Right, that's too heavy so could you maybe move this one (points to peg 3). [torque!] L[redacted] takes peg 3 nut off & puts it on peg 2. [Same Mum says, 'try that then.' [insti inc move] L[redacted] says, 'that's the same as that one. Mum repeats that. Leah then does this. Mum says, 'Oh' Falls. Both say, 'Now that's (my side) too heavy [torque!]. Mum says, 'So (4) what have we not tried? L[redacted] puts nut on peg 2 & one on peg 3 & looks at mum. Mum says 'try' [ins inc move]. Falls. - still too heavy, so what do you think it needs. - we've to balance this side (point to their side) & L[redacted] ~~nods~~ rules.

L[redacted] does this & asks mum if they've already tried that one. Mum asks question back to L[redacted] but they try it anyway. So what have we not tried (4) Mum asks. "Two on that one?" [ins corr move] & points to peg 3. L[redacted] puts 2 on peg 3.

Can't tell me how it balances level 0

Mum says, "Right, there's 4 on that now so what do you think we have to do this time. (4) L[redacted] puts 1 on each peg. Mum says, 'Right do you want to try it?' Falls. Mum says, "So this side's too heavy (motions to their side) need to move them more to that side (middle of scale). [torque!] [prompt] L[redacted] now does this. Falls other way. Mum says, "Right, so we're half way there [V. enc] L does this. Mum says, Oh [v enc] Falls. "Right, so it's still too heavy, we'll have to use another one: [Torque!] (4) [prompt] L[redacted] puts another nut on peg 3. Mum says, "Right what way did it go last time?" Both say, "It went that way (to my side). L[redacted] says, "So we want it to stay in the middle." Mum says, "So where ... - right, try that [ins inc move] (with 2 on peg 2 & 2 on peg 3) Mum says, "right, so this (their side) is too heavy now [Torque!] so ...' L[redacted] puts one peg 3 nut on peg 1

Mum smiles [n-v enc] at L[redacted] when it balances.

"Because they're all on the one (mine) & you're

(3)

Balance Scale

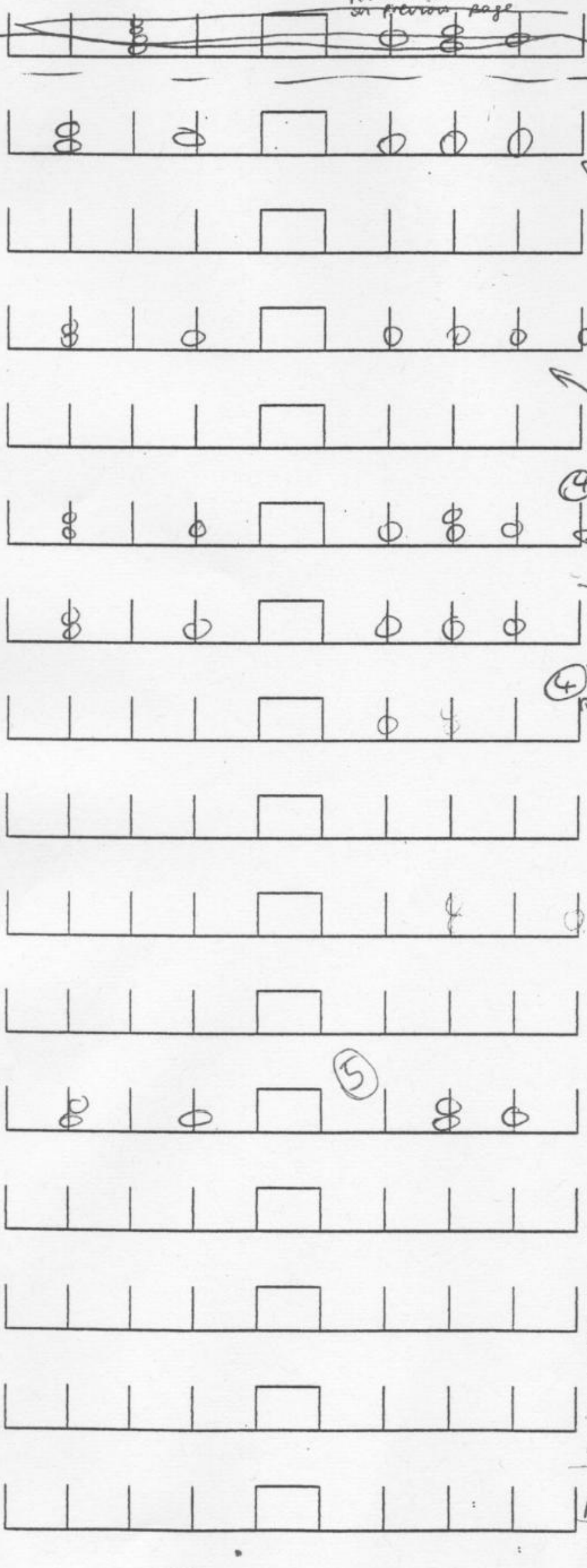
Tape 52 1hr 15 mins 11secs

Name of Child: L

School:

Condition: **Time:** 1

Already got this drawing on previous page



6

6

2 verbal enc
3 prompt
8 Q
1 Torque 1
Torque 3

6

6

T4=4

Totals
7 v enc
3 rules
27 Q
8 Torque 1
12 prompt (+7)
3 Ins incom
1 Ins corr
2 n.v enc
2 Torque 3
65

(5)

(15) Vp/Q

[explanation continued from page 2]

-- but you need one on either side (pegs 1 & 3) so this one with 2 will balance (points to peg 2), Mum says. L nods. Torque 3

Mum says here. Ok, so remember how we did the last one. (4) prompt

L[redacted] does this. Mum says, "Do you think that'll balance it" Q. L[redacted] says nothing but tries it anyway. Mum says, 'So there's still too much weight to this (my) side, so where do we need weight? Q What end do you need weight at to balance it?' Q Torque 1. L points to peg 4 on her side. Mum says, 'Ok' verb. L puts nut on peg 4. Mum says, 'do you think that'll balance?' Q. L[redacted] says nothing but tries it. Mum says, "Right, so that's too much putting that on there." (4) prompt. L now does this. Mum says, "Ok, still too much, so do you think you've got too many, coz on that side (mine) there's only 3." Q (4) prompt. Leah says, 'Ok' & takes one nut off peg 2. (4) Mum says, 'Ok, so we need to switch this way about.' prompt. L takes all nuts off her side. She puts 2 on peg 2 and one on peg 1. ~~Mum points to her~~ peg 1 then mine & says "that would be the same. You're trying to get it to balance but that would be the same (peg 1's)." prompt. L[redacted] says, 'Ok' & puts peg 1 nut on peg 4. Mum says, 'do you think that's gonna work?' Q. L says, 'No'. Mum says, 'Why?' Q. L says, 'Coz that's the side that always weighs it down.' Mum says 'Ok' v enc. So L moves peg 4 out to peg 3.

Can't tell me how it balances. Mum says, 'Well, how did it work the last time?' Q. L says, 'Because you shared the weight out'. Mum says, & because that's there (my nut on peg 1) you can't put one there (her peg 1) so you have to go to the next peg. L[redacted] goes, so you put that one (my peg 1 nut) on top of that one? (her 2 on peg 2). Mum says, 'Yeah, coz you have to leave that blank (her peg 1) to make it balance. And you have to share the weights.

Appendix 3d

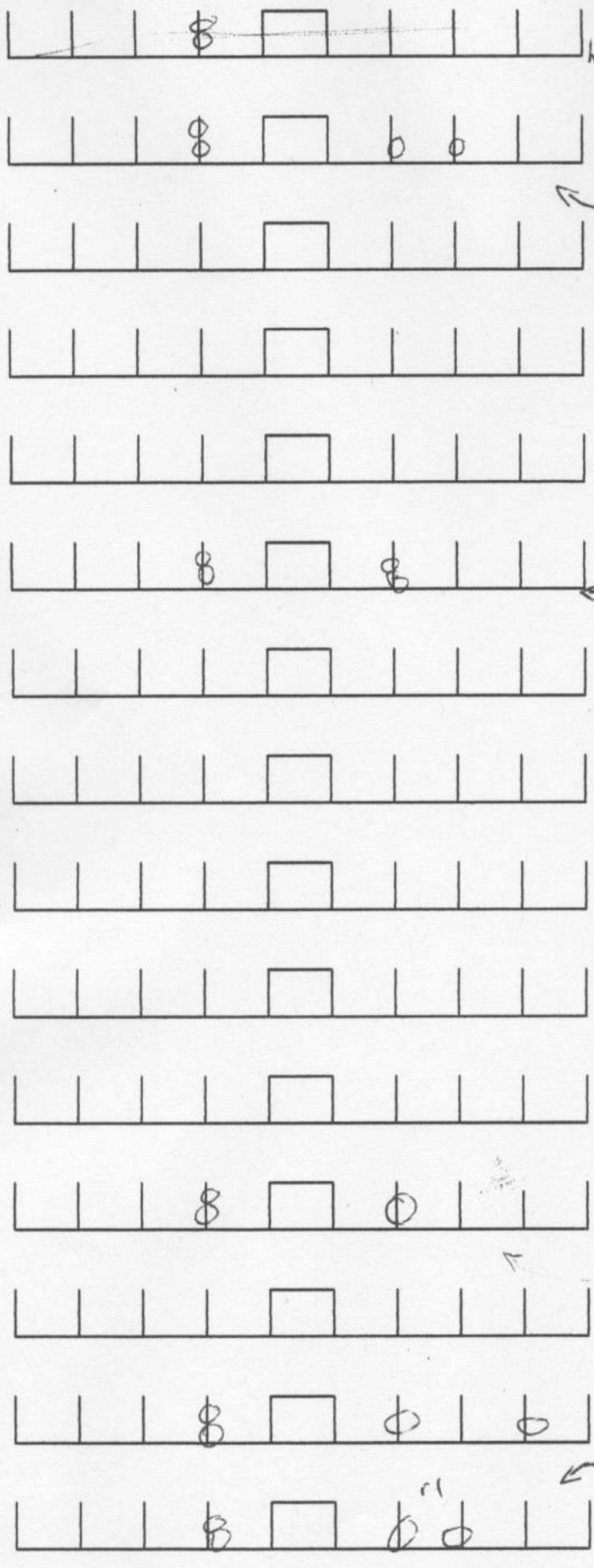
Study 1 transcript: Implicit Input

(i)

Tape 27 1hr 26mins 54secs

Balance Scale

Name of Child: La
School:
Condition: **Time:** 1



6
−2
+5
−3
+6

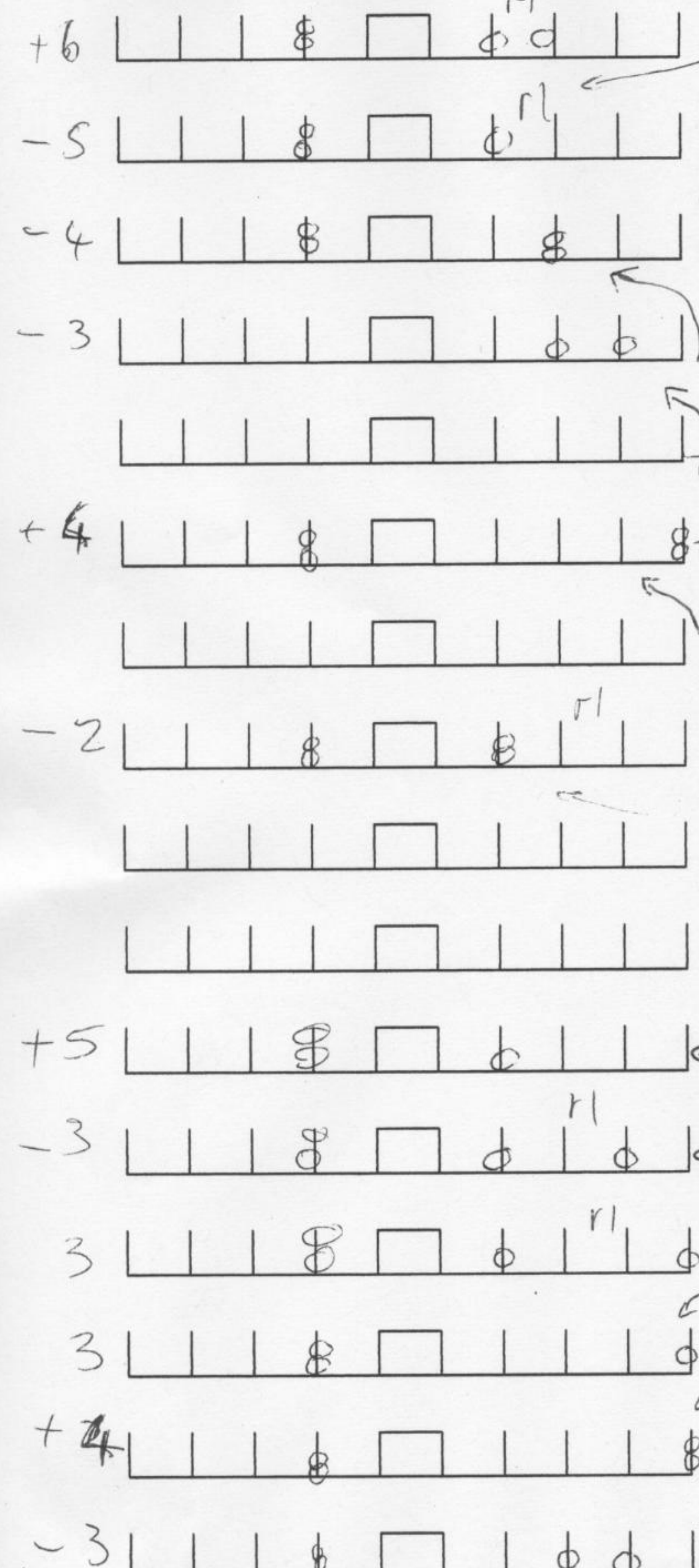
n. verc
v. enc
; prompt
Torque 1
Overs
joins in move
takeover
#27

La[redacted] puts one on peg 1 and 1 on peg 2 & looks at dad. He just looks at [redacted] scale. She asks him "is that ok?" [I told him how to do it before [redacted] came in but he lifts his arms up & says, "Do you think that'll balance?" - She just sits. He says, "pull it out & try it". Falls. Dad says, No, so, what do you think?. La takes nut off peg 2 & looks at me then her dad. Dad says, "do you think that's right?" She looks at him & says, "Don't know" He says, "Well, do what you think." He says to me, "She's not the best at maths, does it matter if she gets (V. enc) it wrong?" I say no. He says, "Try your best La[redacted]" He puts (Take over) another one on peg 1 and says, "Will we see if that works?" And he takes the rest out. He looks at her & says, "Would you say that balances. She nods excitedly. He's forgotten I've told him & her (he's heard it twice!) that you can't have both sides the same. I ask her what she notices. He asks me what I'm asking her. I ask her what she notices about the 2 sides. Although it balances, it's a bit slanty so she says, "one side's up & one side's down. I point to both peg 1's and she says, it's the same. I say "that's right but remember you have to make it different, the scale's got to look like that (level) but you have to do something a bit different." Dad is totally oblivious. So she takes nut off peg one leaving this. It falls. She looks at dad he looks at her & they smile to (v enc) each other. Dad says what about if (prompt ④) you even it out, & he puts (takes over) one on peg 3. Falls. He then takes it off peg 3 & puts (takes over) it on peg 2 - La[redacted] just looks on. He then takes (take over) nut off peg 1 & La[redacted] says "that" pointing to peg 2. Dad says what? & puts nut (takes over) back on peg 1, moving nut from peg 2 to peg 4

(2)

Balance Scale

Name of Child: La
School:
Condition: **Time:** 1



(1) Dad just looks on as she takes out off peg 2 leaving one on peg 1. La [redacted] looks at him smiling. She says, "Dad it's too heavy". Dad ~~looks~~ laughs then looks at me and asks me if "We've to balance this out for that one (my side), just in a different way?" I say yes. Dad then says, well, why don't you try, I don't know.. (he takes over puts one on peg 2 but then puts another on peg 2 & says), "2 on this side. Falls He takes out off peg 2 & takes over puts it on peg 3 and he tries to balance it (they've left the rest on the table.) Dad takes takes over it off peg 3 & puts it back on peg 2 & says, "I'm not even getting it here, I'm not the cleverest either." He asks if they can move more. I say no. He then takes over puts 2 on peg 4. He's now leaning forward over the scale while she sits back & watches. He then takes them off & takes over puts them on peg 1. He says, "So you want the same but in a different way?" I say yes, but you don't need to use 2, don't need to put them on top of another, you could use less, more, etc. Have to explain this again as he really doesn't have a clue. Dad says, "Right, will we take one off (this peg 1) & see how it goes?" (4) Q La [redacted] just looks on. "Hopefully move it about, share the weight. So he takes over puts it on p3 also. * Then puts it on p4. He says, "That's too heavy Torque 1 now. Takes over Takes out off peg 1 leaving one on peg 4. The scale has fallen to their side but he still adds another to peg 4

takes over

He does this himself also

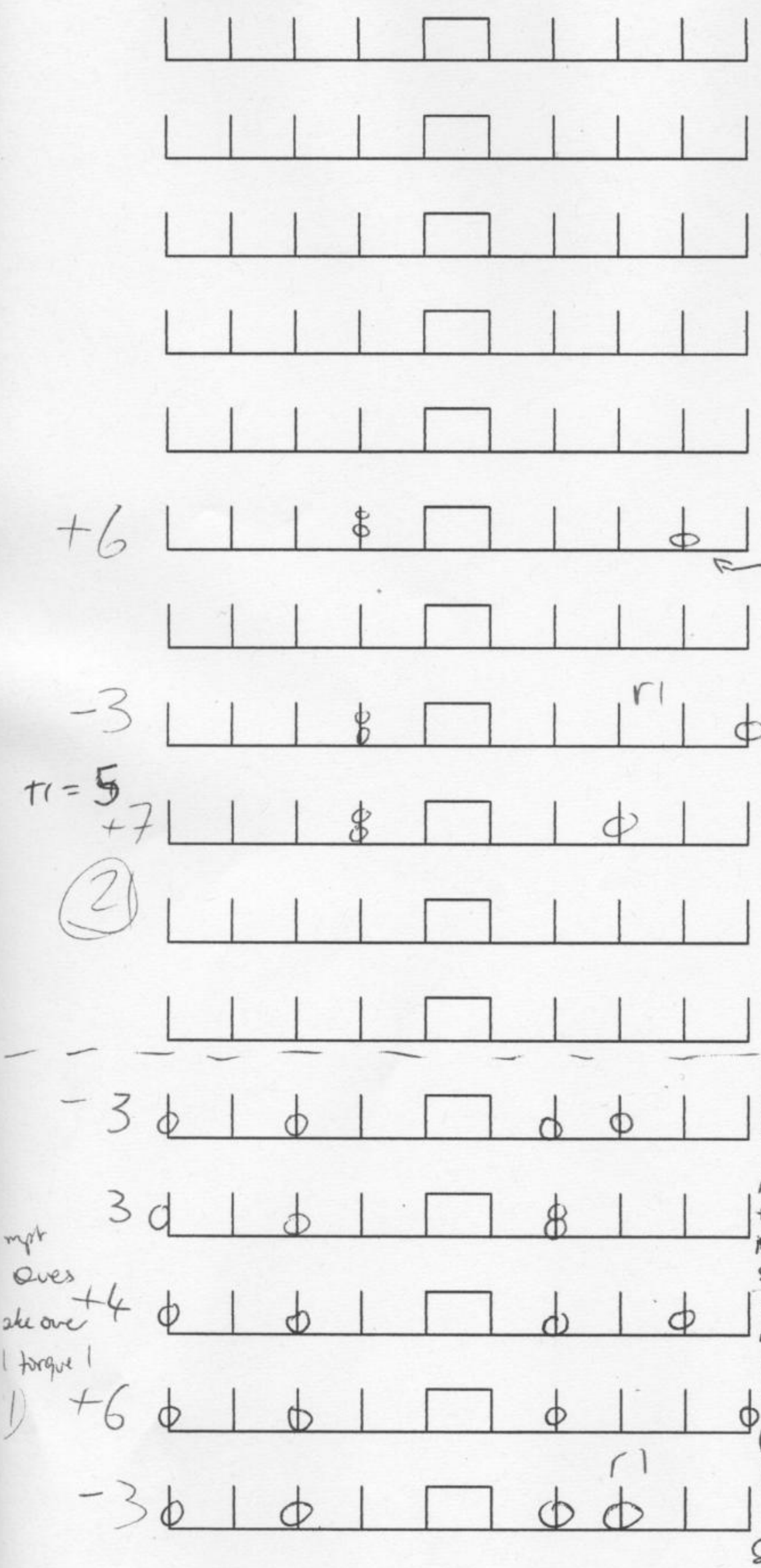
(3)

Balance Scale

Name of Child: La

School:

Condition: **Time:** 1



Tape 27 1hr 31 mins 45secs

Now he says, "You'll need to show us the answer, Miss Philips, I'm sorry." He says this whilst putting the 2 nuts on peg 1 again. I say that I will make it balance. He says to La[redacted], "take one ~~off~~ (peg 1) which she does and watches as scale falls. Dad says, "Well, you'd need to move (prompt ④) that one (nut). She takes it off. He says, "Well you need to move it. Put it on somewhere (prompt ④). She whispers something to him I don't catch. He says, "well try it." She puts it on peg 1. He says, "Well you need to put it somewhere else (prompt ④), that's the one you just took it off - You need to try it on one of these 3 (motions to pegs 2, 3 + 4). She puts it on peg 3 & looks at him. He looks at me. He takes the rest out. Dad says as he's doing this; I don't think this is gonna work. La[redacted] looks defeated. Dad says, "Why don't you try it on the end one, maybe?" And he puts it on peg 4 (take over). Falls. Dad says, "that one's not working so he takes it off and puts it on p2 (takes over) and says, "try this one." Balances. Dad says to her, "What would you say (e.g. does it balance?)"

Explanation: Coz they're both the same weight. One's at the first one & one's on the second one.

Tape (28)

No input from dad at all when La[redacted] does this. It falls. Dad says, "So that doesn't work, ok.

As this falls to my side dad says, "No". La[redacted] turns to dad and says, "Will you help me?" Dad says, "Well try. [redacted] Leans over & motions to my side & says that I've put 2 separate to one another so try & balance it. (prompt ④) She does this herself. Dad says, "Nope." He takes their nuts off & says, "Right. She puts one on peg one & one on peg 4 (take over)

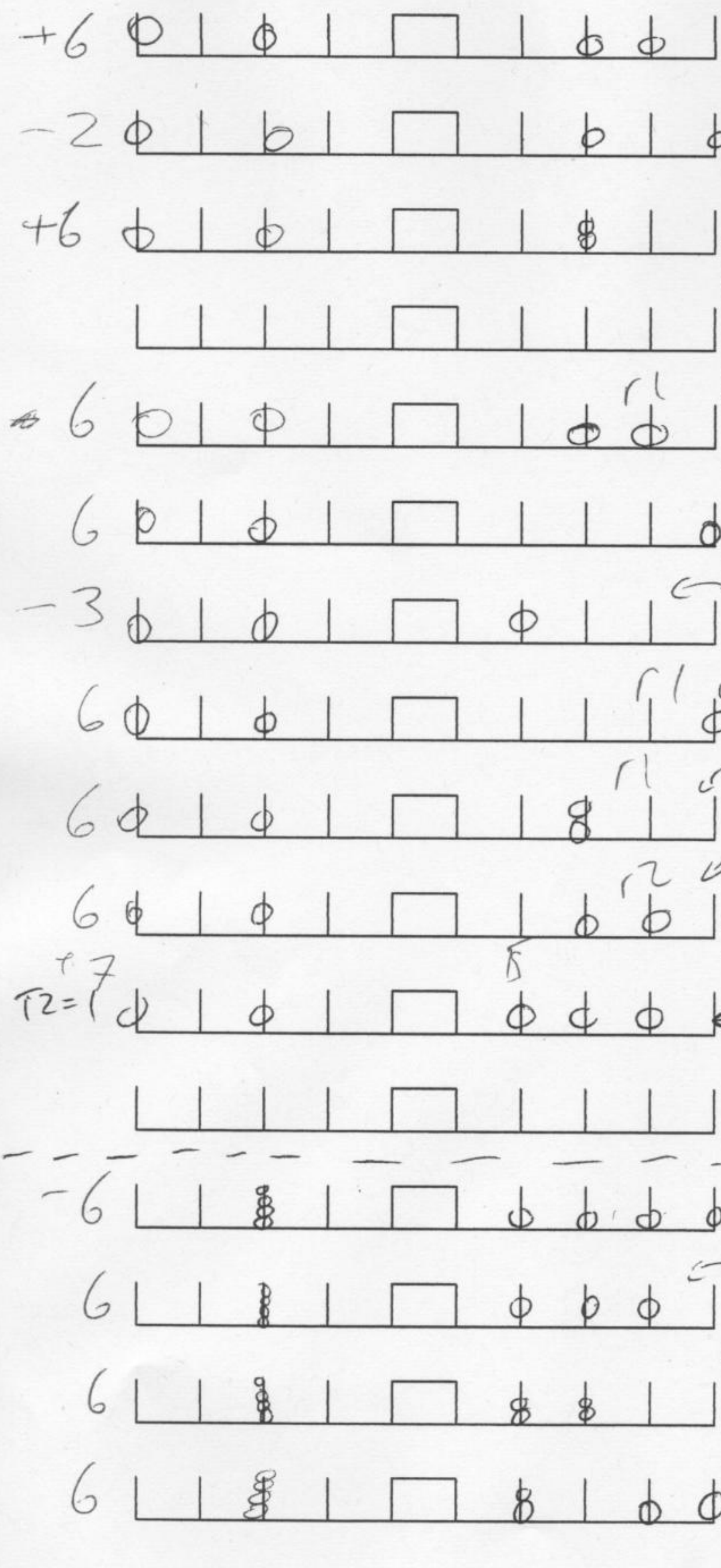
Dad now says, "that's us now tried the last one and this one (points to peg 1) tried that one (points to peg 1) & that one (points to peg 3). So La[redacted] points to peg 2 & says, "try that one." Dad says, "Right" so dad puts one on peg 1 & 2 (take over). Dad points to nut on peg 1 & asks where it should go. La[redacted] points to peg 3, looks at dad & says, "that one."

(4)

Tape 28 2 mins 14 secs.

Balance Scale

Name of Child: La
School:
Condition: **Time:** 1



Falls. Dad says, "that's not working either.

Dad then ~~takes~~ takes over nut off peg 3 & puts it on peg 4. Same. Had to remind them about that

La[redacted] then points to nut on peg 4 and says to put it on peg 2. So dad ~~lifts~~ takes over nut off peg 4 and puts it on peg 2. He says, "that'll be ~~too heavy~~ torque then." La[redacted] agrees. After this move dad turns to me & asks if there's another way to get the scale to balance. I tell them there's a few ways it'll balance. La[redacted] then points to pegs 2+3. Dad ~~puts~~ take over nut on peg 3 & says, "what one?" La[redacted] puts nut on p2. Falls. Dad says, "No that's not gonna work out La[redacted]." She takes nut off peg 2 and dad ~~puts~~ takes over nut from p3 onto peg 4 & sees that that doesn't work either. Dad then puts nut on p1. Falls. So La[redacted] puts it back on peg 4 & dad says, "Tried that before."

La[redacted] then points to pegs 1+4 & says "that one & that one but dad ~~puts~~ takes over both nuts on peg 2. Falls & he says, "That's not working either. La[redacted] then puts nuts on peg 2 + 3 again. Dad pulls rest out.

La[redacted] now says to dad, "try 3". Dad says "Three?" then laughs & says "You try."

So she puts them like this. Dad has NO clue. She said she knew that would work. I asked her how - "I thought it would balance over." - Dad then asks the actual answer coz he wouldn't have worked it out. I tell him there's lots of different answers

La[redacted] does this herself. Falls. Dad says, "No that's not gonna work Laure." So she takes nut off peg

She does this & looks at dad, who takes rest out. He says, "Nope."

Here he takes the rest out again & says, "Nope"

La[redacted] then turns to him & asks for his help. He just laughs as if to say, "I can't help

(5)

Tape 28 6 mins 46 secs

Balance Scale

Name of Child: La

School:

Condition: **Time:** 1.

He takes ~~out~~ [takes over] nut off peg 4 & puts it on peg 3 & looks like he actually knows that will balance. La[redacted] just looks on. When I ask her how it balances she looks at dad and shrugs her shoulders & says. "I don't know."

La[redacted] does this & looks at dad who takes the rest out.

Here La[redacted] does it herself & dad just takes rest out.

Dad says, when it falls, that's a wee bit heavy on that side. need to take one off. [prompt] [Torque!] (4)

She can't tell me how it balances.

No input from dad.

1 takeover

T3 = 0

6

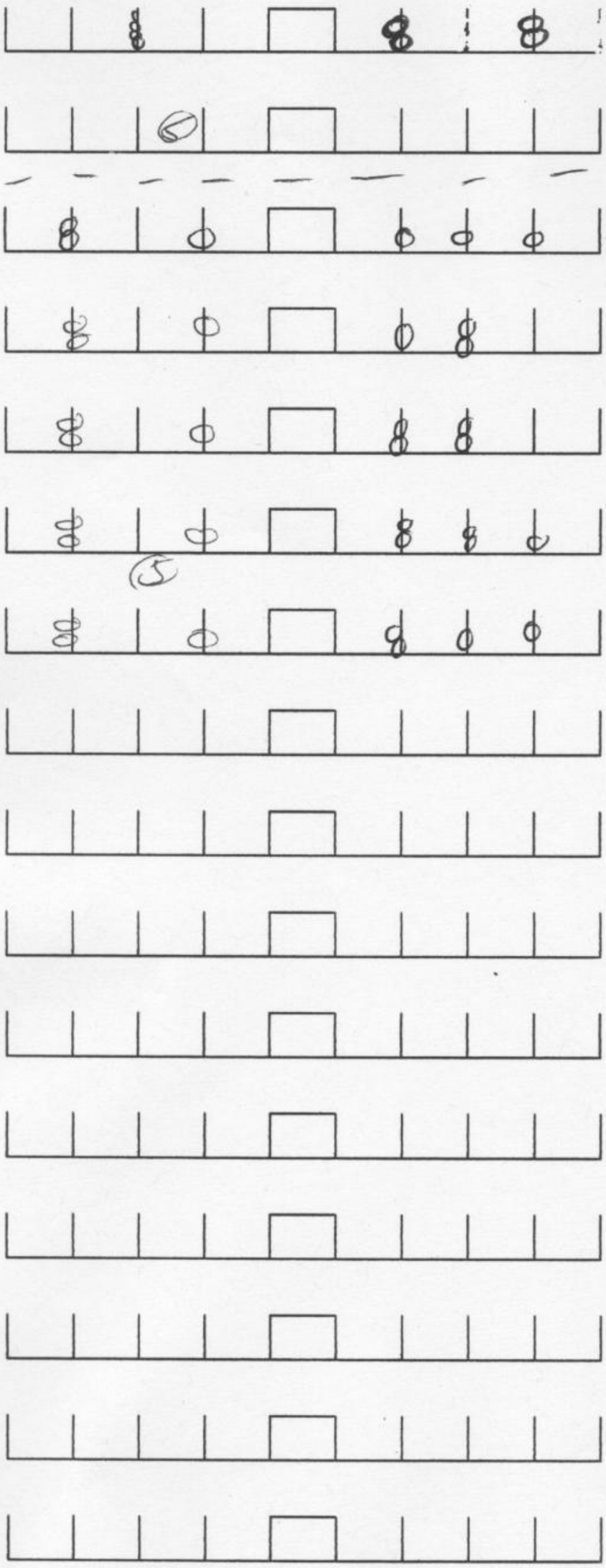
6

6

1 prompt 6

(5)

T4 = 1. T7



Totals
1 A verm
1 verm
7 prompt
2 Torque
3 Overs
1 ins un
25 takeover
40

(7) Verbal prom / Overs

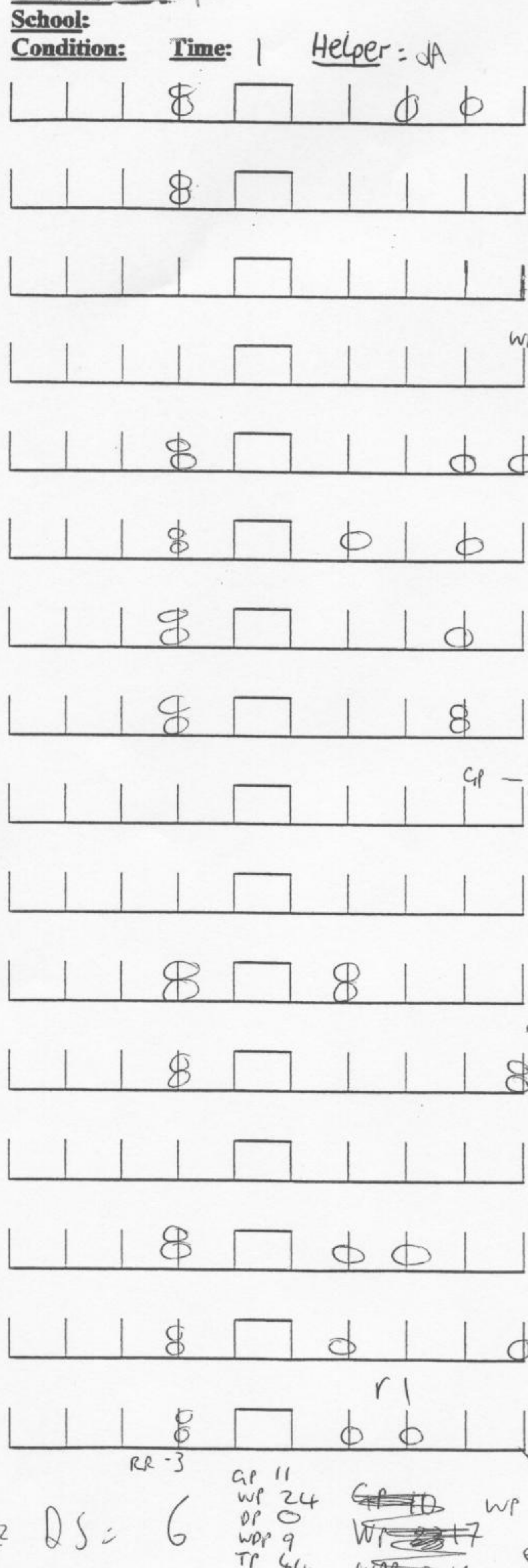
Appendix 4

Study 2 transcript: Input involving implicit weight/distance prompts

(Completely changed 1st prob data!)

Name of Child: R
School:
Condition: **Time:** 1 Helper: JA

Tape 14 14 mins 21s



3
3
T 18 3
R 2 +
R 5 − 6
SU 6 4
DS 12
ME 3
−2
VE 1 + 4
RR 3
1 - 15
2 - 0
3-4 5
+6
Prob − 3
+ 6

how can you make that balance GP P
It's a bit heavy isn't it. when it goes ...
it means it's too heavy doesn't it. so h...
can we make it lighter? P WP
What side do you think is heavier this si...
one here (middle) or this side over here (en...
She (R) puts p2 not on P4. JA - Do you think that gonna be hea... lighter. R says Heavy. JA. It was too heav...
WP last time wasn't it so we need to make it lighter. So we could either take something off a...
it to a light side couldn't we. So what do yo...
want to try. P GP
Tries this. That one's too heavy coz they're on a heavy bit and over here it's a bit. So what else could you do P GP
still a bit heavy isn't it. So you need to make it lighter TWP
Still a bit much so we need to make it lighter again don't we. TWP
will that not make it heavier? It has... hasn't it. Coz when we add something ... it makes it heavier doesn't it. So what ... we do? We need to make it lighter so we can either move where they are - thi... a light bit & this is a heavier bit (middle end of the scale) so we can either mov... where they are or take something off to ... it lighter or we can do both. P WDP
Can't do that though coz that's the same as Sharon RR
Sharon RR Not allowed to do the same
It's too much isn't it. Coz we said that ... the heavy bit (at the end) & they're on ... light bit (mine) so you've got the same ... as Sharon but they're both on a heavy b...
Still a bit heavy, we need to make it ligh... WP
It's too heavy. It was too heavy on that ... (p2) so moving it to a heavy bit's still go... make it too heavy isn't it. What else co... we do?. P GP
we need to make it lighter. +WP
WP to use 2? We don't need to use the same ... Sharon. We could use less or more ...

RR -3

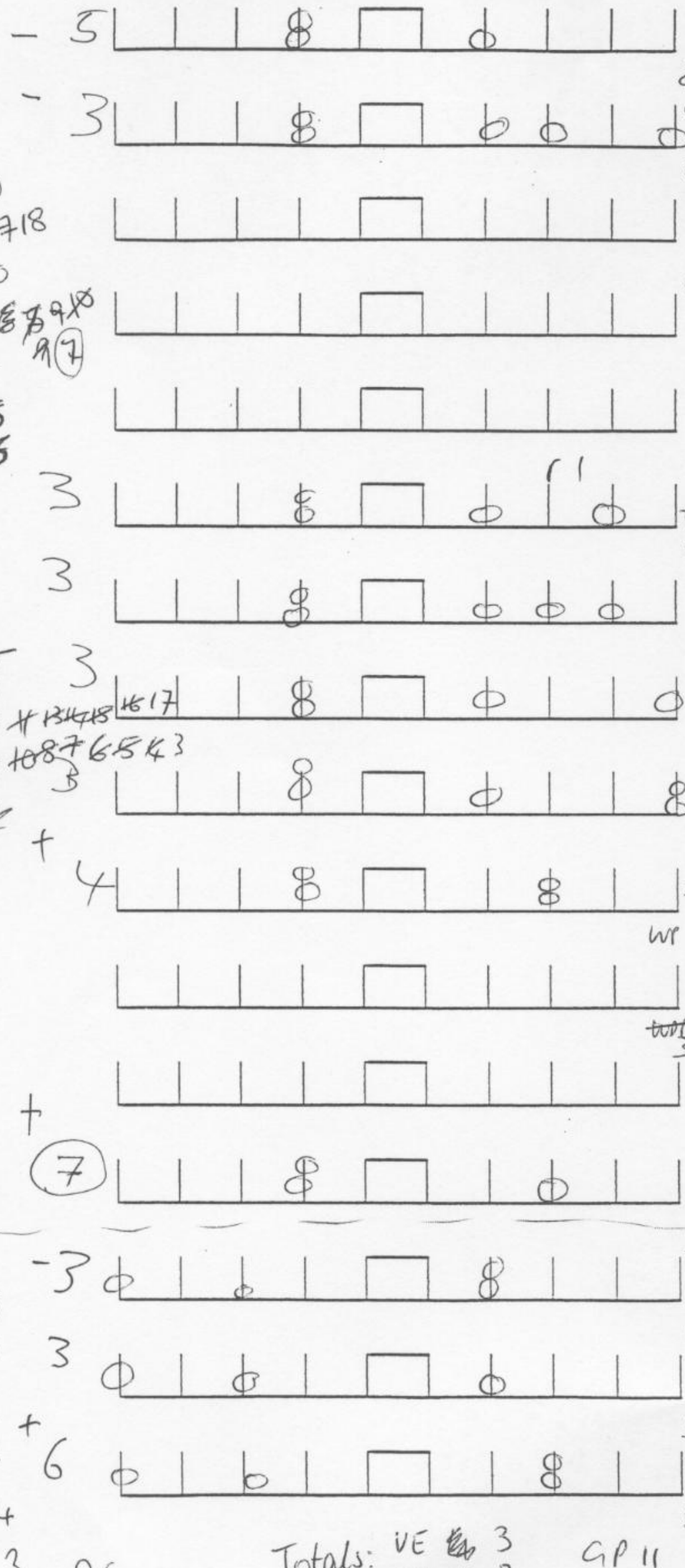
~~VE 3~~
~~RR 1~~
P ~~16~~ 20 21 22
DS: 6
GP 11
WP 24
DP 0
WDP 9
TP 44
~~GP 10~~
~~WP 23~~ 17
~~WDP 8~~ 7

Balance Scale

(2)

Name of Child: R
School:
Condition: **Time:** 1 Helper: JA

Tape 14 17 mins 37 secs



GP 10
WP 17 18
DP 0
WDP 8 9 10 (7)

TP 35
1-15
3-6

RR
P 17 18 16 17
10 8 7 6 5 4 3

T 5
R 0
R 2
SU 2
DS 4
ME 3
GP 1
DS 4

Totals: VE 3 GP 11
RR 3 WP 23
(P) — DP 0

533
That was too much coz it's going up the
So we need to make it a wee bit heavier. WP
could change where it is or add something on. P WDP
up to you
Too much isn't it. Have a wee think. GP P
it. You've got 2 here. are they on a l
bit or a heavy bit? WPP R says Light. JA
light bit. So we need to have something
on a light bit on the other side. + WDP.
2 on this bit, so we need to do what i
can on this side + keep it light & make
balance. WP + So this is the heavy bit (end) or 1
is 3 the light bit (middle) so we can use
many or as little as we want WP P so what do
you want to do. GP
Too heavy. We need something in between
don't we P GP
It was too much before we put it on, doe
that not make it heavier putting more on. + WP S
we need to make it light + WP
Still too heavy. Coz that's our heaviest
over there. What else can we do to make i
light? P WP 3
too heavy isn't it because we said putting
on makes it heavier doesn't it. We need t
make it lighter WP
still A wee bit too much so what can we do GP P
WP you want to use 2?? R nods. JA - you wa
use 2? It's too heavy there or if it's t
heavy there it's gonna be too heavy in the
3 bits isn't it? P And you can't put it there
it's the same as Sharon's RR so what else
you do? P GP

well done VE
ex: The other ones were too heavy and the W
2 there and that's the middle (he peg 2 n

So what can we do? P GP
A bit light so we can add on or change where
are or put them on heavier bits can't we P V
It's still too light but 2 were too light so a
gonna be too light isn't it. / WP
need to make it a bit heavier still don't +
So what can we do? P WP

Balance Scale

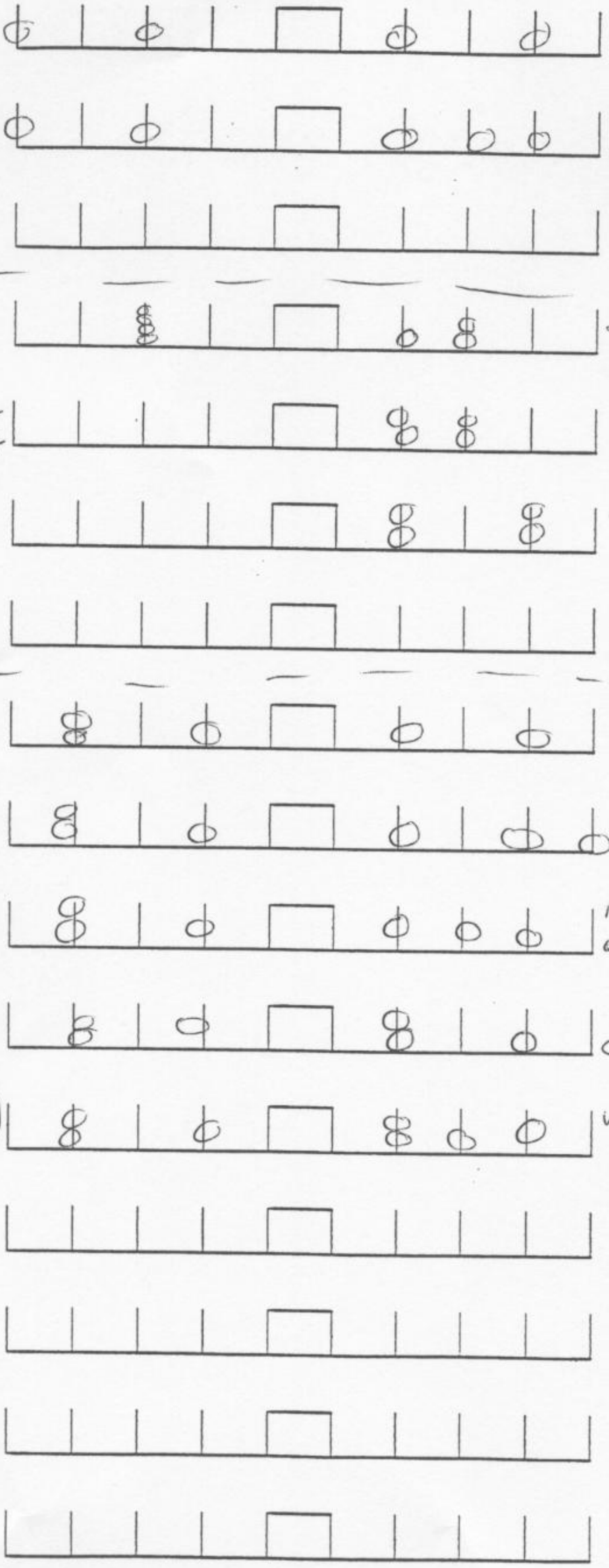
(3)

Name of Child: R

School: R

Condition: **Time:** 1 Helper = JA

Tape 14 21mins 38sec



VE 0 –
P 3/4
1 - 2 P2
3 - 1

4 (7)

ex: If you put that there (p4) it would go do[wn] and if there was one there (p3) that would fall down but if 2 are separate that's o[k] my side

JA - coz that's on heavy ones so you've got 3 lighter ones

1 3

T 3 -6
R 0
R 1 WP 6 2
SU 1
DS 2 (7)
ME 3
VE 1 DS = 2
P + Z 2
1 = 3 2
2 - 1

Too light. We need to make it heavier don't we 1 WP

we still need to make it heavier what can we do? P + WP

well done VE

ex: If you put 2 separate & 4 together so those 2 (peg 1) .... I can't copy the same so two there (p1) & 2 there (p3) & it'll balance JA so you've taken them & put them on either side haven't you. 2

-5

T 5 +6
R 0
R 2 6
SU 2
DS 4 - 5
ME 1
VE -1 + (7)
P 2 3
1 - 1
DS = 3

WP 2
WDP 1

A bit light so we need to make it heavier don't we (1) WP

To make it a bit heavier what can we do? We can add on or change where they are, can't we. WP P WDP P

well done VE

ex: If you put it there (p4 on her side) it would go down but if you put 2 there (p1) & 2 there (p2 & 3) it'll make it balance. W

If Shanen put it there (my p4) it would have went down

Appendix 5

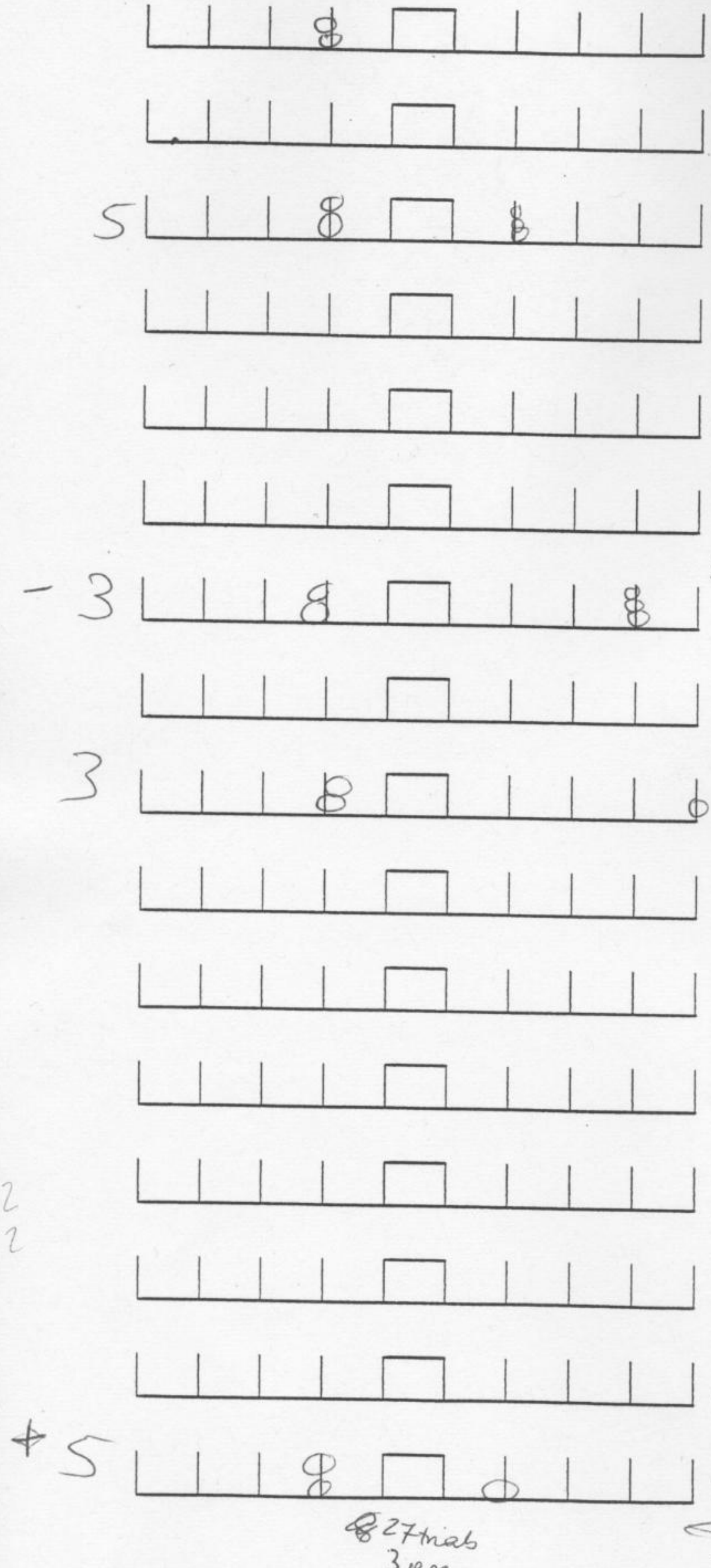
Study 3 transcript: Interaction between adult and dyad

① **Name of Child:** D + F Adult = K. right

School:

Condition: **Time:** 1

Tape 6 2nd half start



K ok, so that's your 1st one / you need to work together & see how it might balance. D to F - what do you think? 14 GP

D - I think 3 there (p1) F - so do I, so D puts 3 on p1 6

K so what happened? QO D - It fell to that side. K so what does that mean? D - It means that side (theirs) is heavier. K Yep that side heavier, so we need to get this side lighter. WP

D to F. What do you think. D I think 3 on that or that (points across pegs 2 & 3 & puts 3 nuts on p3). K - so what's happening? QO D Falling down. K yep so that side's still heavier. Expla 1 14 6

D to F - do you want to try one. So F puts one on p4 4

K so there's 2 there & only one here so why do you think this side's heavier? WDP

D cos that side's over to that way a wee bit (points to his left, e.g end of scale side) K right. so do you think you need less then at the end cos it weighs it down. So it makes a difference where it is? D - yes. K - what difference does it make? D that's heavier (my 2 nuts) So if you move it over that way (towards his end of the scale) it ..... (mumbles the rest so I don't catch it) K so how do you think you could balance it? GP Expla 3 Expla 2 WDP 7 8

F moves p4 nut to p1 K - so now that side's heavier isn't it. So what do you think you could do? D - put it on ... Expla 1 GP

2
2

27 trials
3 pegs
8 pegs
12 ...

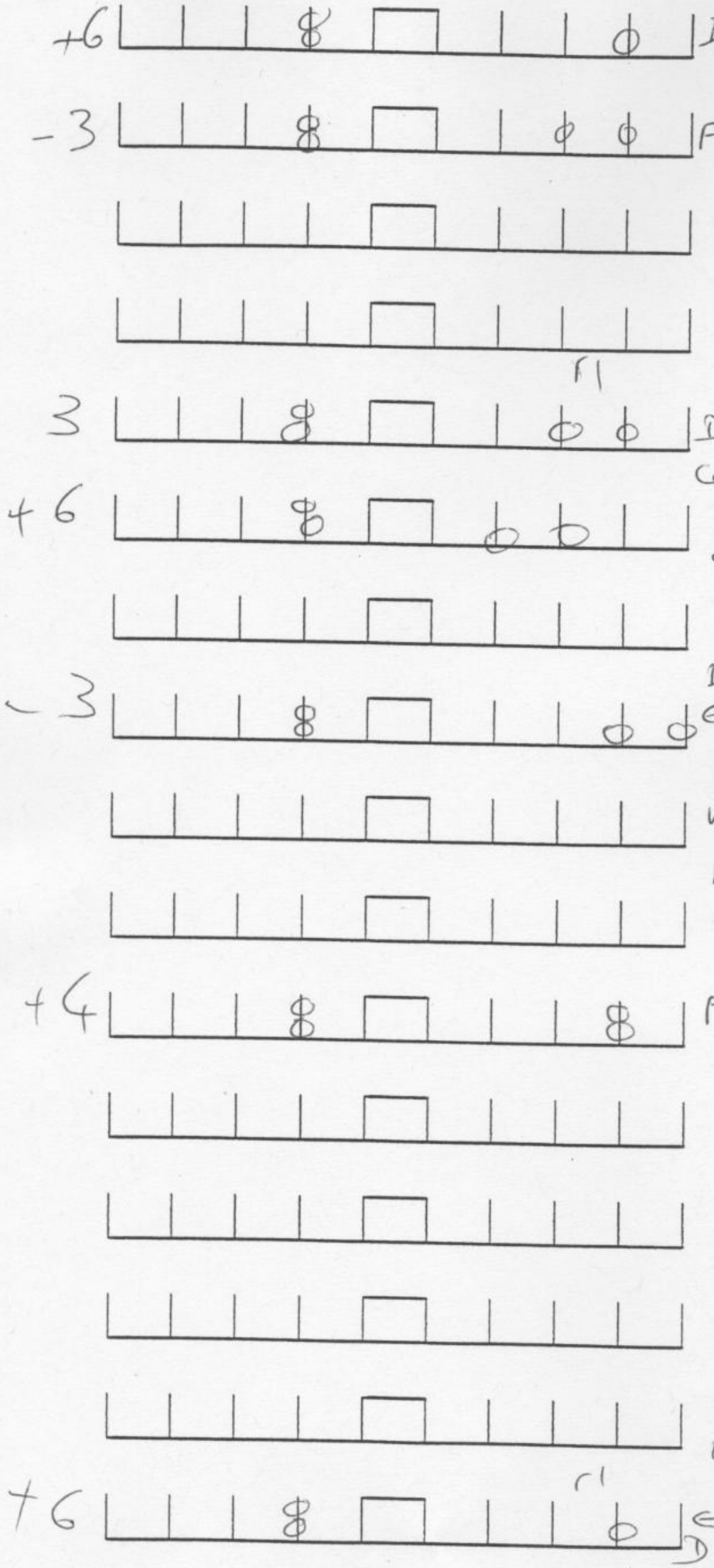
Balance Scale

Name of Child: D + F Adult = K

School:

(2) **Condition:** **Time:** 1

Tape 6 2mins 27secs.



Exple 1

D K so this side's heavier

F

D goes to put 2 extra on pegs 1 & 4.

K - what side was heavier before. D points to his. K so your side was heavier, so you're trying to make this side lighter CUP

D K so that side's still heavier, how can we make it lighter? D by putting that there & there

K so that side's still heavier, how can we make it lighter? WP

D does this

K will that make it lighter do you think? D looks at it. K - do you want to try it? D says yeah.

K - so that's too heavy. what do you think you could do? GP

F - Falls

K - ok so there's 2 on either side in different positions, but this side's heavier - Why do you think this side's heavier? NDP

D - because that's further away from it. (points towards his end of the scale)

K - So you think the further down you so it gets heavier? D - yeah. K - so if it's further down do you need more or less? D - less. K less, right

K so that's still slightly heavier what do you think you could do?

③

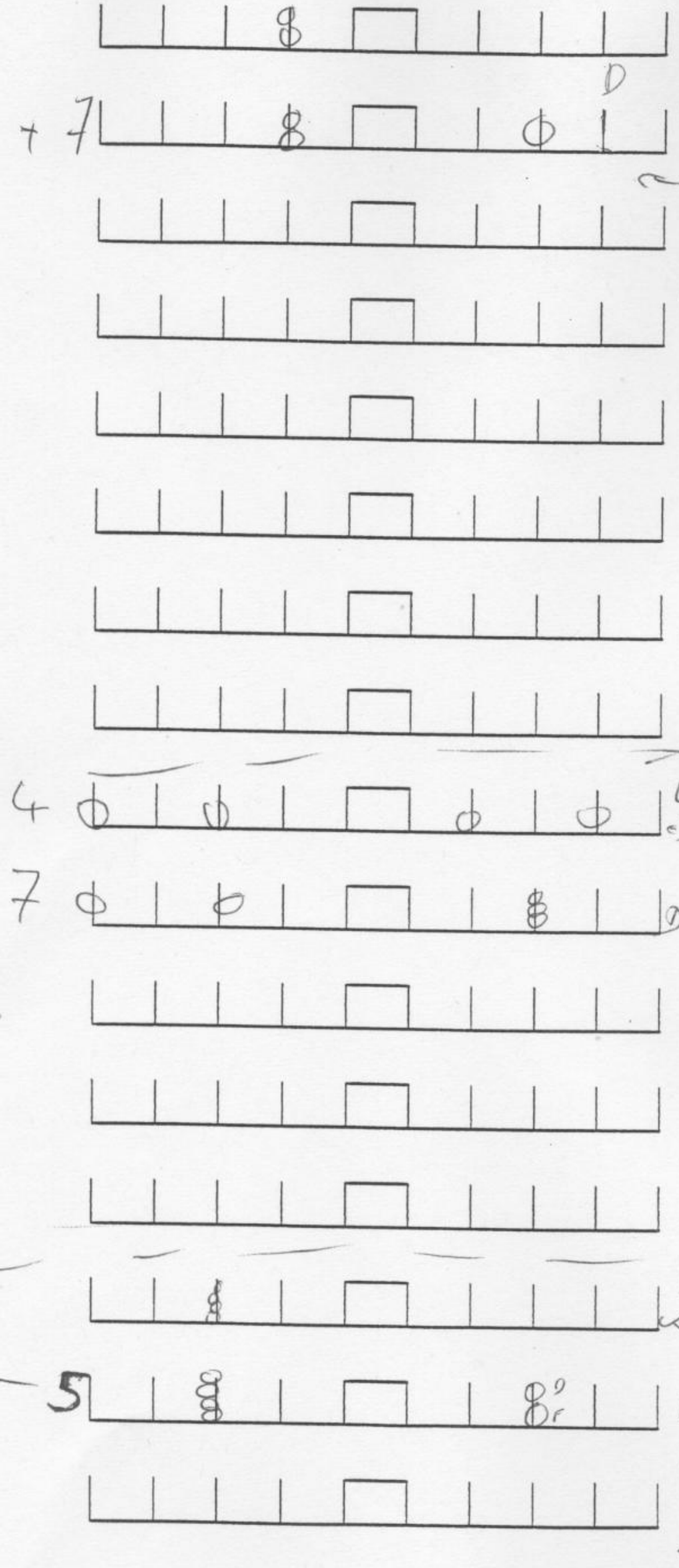
Balance Scale

Name of Child: D + F Adult = K

School:

Condition: **Time:** 1

Tape 6 4 mins 19secs



D turns to F & says: put one on that one (p2) [6] so F puts nut on p2 along with the one already on p3. D removes P3 nut

K there we go

~~Fr~~ I ask Fraser how it balances he says nothing

K - there's 2 on that side & one on this side, isn't there, so how do you think it balances? WDP2 F that's the same weight as that one. that's all he says.

D I think it's because that's further away from that, it makes that one heavier 3

K what do you think GP

K so what side's heavier? QO D That one (mine)

D - They two are seperate & they're together, & that one's closer (my peg 2) & that's further away (my p4) 3

F - says nothing, so K says; because there's 3 on that side & only 2 on that side so how do you think that balances WDP

F - cos that one's there (p2 nut) 2

K what do you think GP

K so what happened? QO D - that side fell down cos that side's heavier 7

K - oh so what do we need to do at this side. D - make it that bit heavier 7 K - make it heavier, that's GP

well

Balance Scale

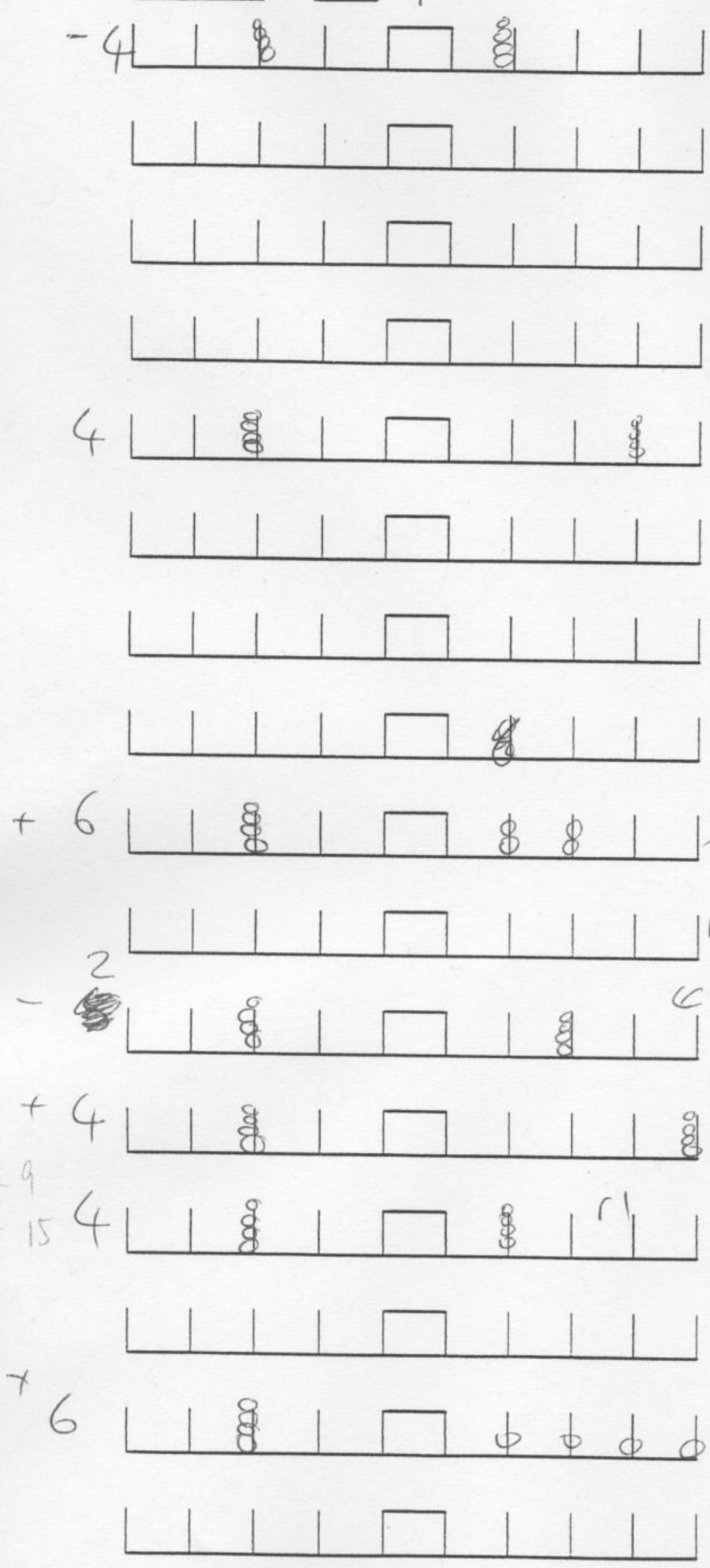
(4)

Name of Child: D + F Adult = K

School:

Condition: **Time:** 1

Tape 6 7mins 31secs



F K what happened? OO D That fell (my side) K right, but there's 4 on each side & they're on one peg each so why do you think that fell! WDP D - because they're further away (mine) than that one (theirs) 8

K so what do you think you could do? GP

F K now what happened OO D that fell cos that was heavier. K right 7

F puts 4 back on peg 1. K you can split them up, you don't need to use all four. WDP

D

F tries to put all 4 on p1 again but D does this 10 C

K look that, the same RR isn't it.

D - K - remember, you don't need to use all 4 WP

F K That side's heavier (mine) Expla1

K remember, you don't need to use all 4 & you can split them up. WDP

D K now this side's heavier! Expla1 What do you need to do at this side? WP D make that 7 lighter. K nods. make it lighter. How are we gonna do that? WP

Balance Scale

Name of Child: D + F Adult = K

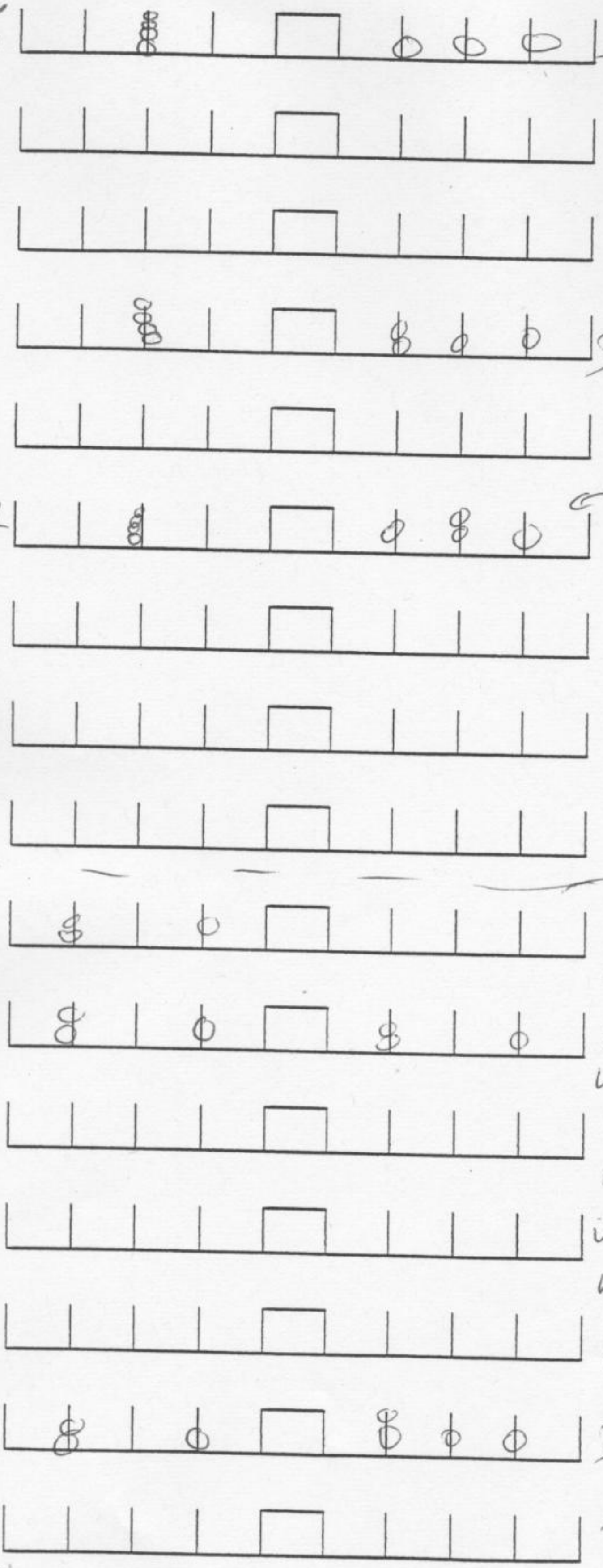
School:

Condition: **Time:** 1

(5)

Tape 6 9min

6 / 6 / + 7 / 10 9 / 17 18 / − 5 / + 7



D - by taking one away 4

F - try 3 (nuts)

K so what side's heavier now? QO

D - that side. K - so what do we need to do now? GP D - take one away 4 ---... no, put more on. K make it heavier aren't we. WP

D. K that side's still heavier. What do we need to do. Make it a bit heavier, ok. She says the last sentence as D does this. expla! WP

D - There's the exact same number but they're on different .... pegs 3

F There's 2 there (his p2) & 2 there (my bottom p2 nuts) and 2 there (his p1 & 3 nuts) & 2 there (my top p2 nuts.) 3

K what do you think about this one GP

F

K what happened there? D - it fell cos that side's heavier. K so what do we need to do at this side? D - make it heavier. K make it heavier, how we gonna do that? D - put more on. K ok QO 7 GP 7 WP 4

D K well done

D - That has more on it & that's using up 3 of the pegs. 3

F There's one there (p3 on his side) & 2 there (...

Children's performance on and understanding of the Balance Scale problem: the effects of parental support

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Children's performance on and understanding of the Balance Scale problem: the effects of parental support

Abstract

Efforts to integrate accounts of scaffolding with Karmiloff-Smith's (1992) RR model have produced renewed interest in the language that tutors use to guide activity, since this provides a mechanism by which redescription of learners' representations might be achieved. The present research examined the impact of two forms of parental input, explicit operationalisations of strategies and explanations of principles, on changes in children's performance and understanding across a series of Balance Scale problems. Children aged 6 to 8 years worked on these at three time-points, receiving assistance at the first. Relative to controls who received no assistance on these problems, these children showed more rapid gains in the accuracy of attempted solutions, and were unique in exhibiting improvement in explicit understanding. Gains of both types were most pronounced amongst children whose parents focused on verbalising the weight x distance computations necessary to solve the problems, and on providing explanations of the underlying principle at work. These children showed earlier integration between performance and understanding, and made earlier use of such explanations themselves, the frequency with which they did so being directly related to parental use. The study provides clear evidence that appropriation of tutors' language may be a significant mechanism in representational change, but it also indicates that initial representational level may constrain children's capacity to benefit from this.

Introduction

According to Vygotsky (1978), higher psychological processes originate in the child's internalisation of sign operations, which they use to control their actions. These operations are first acquired whilst undertaking a joint activity, working with a more able individual within the child's zone of proximal development. The more able individual uses sign operations, typically in the form of language, to guide the child's actions, and with this guidance the child is able to complete activities that s/he could not accomplish alone. The child then appropriates these operations and uses them to direct his or her own actions, first externally (often in the form of what Piaget, 1952, termed egocentric speech) and then internally.

This characterisation of the process of development emphasises two key elements, an external to internal shift in control, and a central role for symbolic or linguistic mediation in achieving this shift. Various contemporary theorists have tried to specify the nature of this process in more detail, but have tended to focus on the former at the expense of the latter. Bruner and Wood's elaboration of the concept of scaffolding in the context of problem-solving activity (Wood, Bruner and Ross, 1976), for instance, concentrates on the deployment of assistance by tutors, arguing that this varies as a function of both the individual concerned and the moment to moment performance of the child. Thus Wood and Middleton (1975) found that tutors (in this case, parents) differed in their ability to promote children's learning. Those who proved successful, though, exhibited assistance that was contingent in the sense that they only intervened when the child faltered, and then at the least intrusive level of control needed to move performance forward (e.g. using general verbal prompts if these were sufficient, rather than specific verbal instructions or direct interventions; see Wood, 1986). Sign operations remain implicitly involved in this process, but it is the contingent nature of interventions that is emphasised, this being seen as promoting appropriation and self-direction on the part of the child.

Rogoff's (1990) account of guided participation focuses more on task-related intersubjectivity than precisely definable regulatory sequences. The role of language is more central here, partly in terms of its role in negotiating a "meeting of minds" (Garton and Pratt, 2001) about the nature of the task and how to proceed. In addition, though, as adult and child work through a task together, it is claimed that their "dialogic exchange" (Fernyhough, 1996) becomes internalised by the child and facilitates his or her ability to employ similar strategies on subsequent occasions. In this way, s/he shifts from being a recipient of adult regulation to self-regulation (cf. Baker and Brown, 1984; Wertsch, 1977). It is control that remains focal in this account, however, and what is absent is any very precise consideration of what language *content* might be involved in this process, and what impact it might have.

There are in fact few empirical studies that focus systematically on the impact of external assistance on children's learning in terms of the relationship between the content of linguistic exchange and children's progress. Indeed, much research has tended to focus on whether external assistance leads to positive outcomes, and the factors that might affect those outcomes (e.g. Baker, Sonnenschein and Gilat, 1996; Conner, Knight and Cross, 1997; Kermani and Brenner, 200l; McNaughton and Leyland, 1990), rather than on the process of learning or the mechanisms involved (cf. Chen and Siegler, 2000). Where process-oriented research has been conducted, it is characteristically qualitative in nature, and focused on specific exchanges rather than attempting to extract more general principles across a range of cases (e.g. Gonzalez, 1996). In addition, there are almost no studies that examine the impact of external assistance over time, despite the fact that most theorising characterises this as the initial phase of a trajectory of change involving subsequent cognitive restructuring.

The need to refocus research into scaffolding onto the role of linguistic mediation and the trajectory of change is highlighted by attempts to integrate it with Karmiloff-Smith's (1992) more general representational redescription (RR) model of the cognitive changes that occur as expertise in a given area of functioning increases (see e.g. Murphy and Messer, 2000). This model proposes a four-level sequence of development, in which initially context-bound procedural knowledge (implicit or I level representations) is transformed into increasingly explicit and more coordinated or general formulations (E level representations), making it available in a growing range of other contexts, first to the self (E1 and E2 levels) and then to others via encoding in language (E3 level). The appeal of this model as a framework for thinking about scaffolding is that it makes a deliberate connection between cognitive change and the process of rendering the form of actions explicit and, ultimately, subject to full linguistic mediation. In doing so, it carries the implication that scaffolding may be an important means by which representational redescription can be achieved (see Tolmie, Thomson, Foot, Whelan, Morrison and McLaren, 2005; Tomasello, 1999).

Not only does this framework move the role of linguistic mediation in scaffolding back to centre-stage, it also points at the forms that are likely to be important. At a root level, successful scaffolding should shape performance on an activity into an effective strategy that can be recreated on different occasions. In terms of representational redescription, this ought to be assisted by input that not only helps *operationalise* that strategy (i.e. helps the child enact a sequence of actions which the tutor knows to be expedient), but which, as part of this, provides linguistic markers or tags for its key features so that these can be recaptured subsequently (cf. E1/E2 representations, which have similar properties, according to Karmiloff-Smith, 1992). For instance, in the context of scaffolding the solution of a jigsaw puzzle, the tutor might prompt the child to "*start* by looking for the *edge pieces*, and try to *fit those together*" (key features italicised). Beyond this, what also ought to be important is provision of more abstract or higher-level *explanations* of underlying principles, from which strategies might be recreated across a wider range of circumstances in more flexible fashion. For example, in the jigsaw puzzle context, the tutor might explain that "the basic idea is to collect pieces that have something in common, and work on fitting these together, building up the puzzle in sections". Such explanations ought to directly promote E3 level representations, since they provide a verbal formulation that subsumes a range of more specific, context-dependent strategies.

There has been little detailed research on these possibilities so far. Evidence relating to a role for linguistic mediation in promoting improved performance has focused on explicit operationalisations rather than more abstract explanations, and the distinction between the two in terms of their range of applicability has rarely been clearly drawn. The research that has been conducted is generally supportive, however. Pine, Messer and Godfrey (1999), for example, found that children who saw demonstrations and heard explanations of a number of specific balance beam solutions (i.e. explicit operationalisations) progressed more than those who worked independently, although the latter children had caught up at a delayed post-test. This input apparently served at least to accelerate progress, then, suggesting that such operationalisations do facilitate learning. Similarly, Murphy and Messer (2000), found scaffolding that focused primarily on contingent application of object-specific strategies was more effective in promoting transfer of understanding of balance beam solutions than unresourced group discussion or working alone. Peters, Davey, Messer and Smith (1999) found comparable effects for structured tuition focused on explicit operationalisations in the form of statements about strategies to be applied to different types of balance beam.

Evidence on the impact of more abstract explanations is limited. However, work by Tolmie *et al*. (2005), in the context of training children's pedestrian skills, found clear evidence that such higher-level explanations were central to progress amongst 5- to 8-year olds working one-to-one with an adult. In the course of assisting children through computer simulation exercises designed to sensitise them to features critical to road-crossing decisions, adults' prompts were initially accompanied by general explanations of the significance of features to which they had drawn attention (e.g. "if he can't see what's coming, it's not safe"). Over the course of four sessions, however, children began to provide these explanations themselves, and the extent to which they did so directly predicted pre- to post-training improvements in performance, both on simulations and at the roadside. The generalised nature of the gains, and their association with explicit higher-level explanations, led Tolmie *et al*. to conclude that the appropriation by children of adults' explanations had effected redescription of their representations of the road-crossing task to E3 level. A second study found less evidence of this effect, and signs that explicit operationalisations (i.e. scaffolding of context-specific strategies; cf. Murphy and Messer, 2000) were more predictive of progress. The children in this study had lower initial ability than those in the first, though. It was thus inferred that higher-level explanations might only be facilitative where children already possessed reasonably well-developed representations, at E1/E2 level, to provide a basis for more abstract redescription.

Whilst suggestive, however, the limited extent and disparate focus of past research makes firm conclusions about the impact of linguistic mediation of either type hard to draw. The present research was designed to address the need to track representational change in detail in relation to the provision during scaffolding of both explicit operationalisations (explicit guidance through an effective strategy for solving a specific problem) and higher-level explanations of general principles. Rather than imposing the occurrence of different forms of input within separate conditions, they were left free to vary within a semi-naturalistic setting (cf. Wood and Middleton, 1975; Tolmie *et al*., 2005). Children aged 6 to 8 years were asked to complete a series of Balance Scale problems plus the Tower of Hanoi task at three successive time-points, a few days apart. Approximately 30% of the sample received assistance on the Balance Scale at Time 1, from a parent who had received prior instruction on the principles involved, but no other guidance as to their input. The remaining children provided two forms of control condition, assistance on the Tower of Hanoi task (30% of the sample), and assistance on neither task (40%). This permitted not only the gains associated with scaffolding to be assessed, but also differences in the trajectory of change with repeated experience. The Balance Scale task was based on that devised by Siegler (1976), but in the present study children were allowed to manipulate weights on a series of pegs to achieve balance, rather than simply predicting outcomes. This task was preferred to the Balance Beam, because it permitted more precise specification of weight/distance relationships.

Data analysis centred on the impact of parents' input on problem-to-problem change in children's attempts to achieve balance and in the explanations offered for solutions over successive time-points. Attention was directed in particular at how far children's performance varied depending on whether parental input provided a) scaffolding of the weight x distance computations necessary to determine balanced configurations for specific problems (explicit operationalisations), and b) statements of the torque rule specifying that balance depends in general on weight x distance products on either side of the fulcrum being equal (higher-level explanations).

It was anticipated that children who received assistance on the Balance Scale task would outperform (i.e. require fewer attempts to arrive at solutions) and display greater understanding of the task than children in the control conditions, at least initially (cf. Pine *et al*., 1999, on the acceleration of gains). It was also thought likely that effects on understanding would be lagged, as a result of the time taken for appropriation to occur. Whilst it was anticipated that parental input would not be uniform, and would be contingent to some extent on children's actual performance (cf. Wood, 1986), more precise predictions with regard to the scale and effects of such variation were harder to make. The degree of benefit evidenced by children was expected to vary, though, as a direct function of parents' provision of explicit operationalisations and higher-level explanations. It was predicted in particular that gains in explicit representation, as measured by children's own explanations, would be directly related to parental provision of both types of scaffolding. However, in line with Tolmie *et al*. (2005), it was expected that higher-level explanations would only promote gains among those who evidenced some explicit grasp of problem solutions, equivalent to E1/E2 level, at the outset. For these children alone, it was predicted that such explanations would result in E3 level representations which would be applied consistently across different problems.

Method

Design

The study employed a two-way mixed design, with a repeated-measures factor of time-point of testing (three sessions over the course of a week, at each of which children completed both Balance Scale and Tower of Hanoi tasks), and a between-subjects factor of type of assistance provided by parents (Balance Scale only, Tower of Hanoi only, and none). The Balance Scale task required children to solve four problems at each time-point (the content of these being modified on successive occasions), by setting up and testing possible solutions for a given problem until balance was achieved. Assistance was provided only at the first time-point, with all children working alone at the second and third time-points. The sequence in which children carried out the Balance Scale and Tower of Hanoi tasks at each time-point was systematically varied to control for order effects. Data analysis focused on the impact of parental input on Balance Scale performance, in terms of 1) the number of attempts children made till success on a problem was achieved; 2) the proportion of attempts where performance was close to being accurate; and 3) the explanation they offered for successful attempts. Parental input was examined with regard to a) provision of explanations of the factors at work, especially via statements of the torque rule, and b) the nature of the assistance they provided for determining problem solutions, particularly in terms of making weight x distance computations.

Participants

Participants were 144 children from 10 primary schools within East Ayrshire, Scotland. There were 65 boys and 79 girls, aged between 6 years, 11 months and 8 years, 4 months, with a mean age of 7 years, 8 months. Of these, 42 children, 17 boys and 25 girls, were assisted on the Balance Scale task; 40 children, 20 boys and 20 girls, were assisted on the Tower of Hanoi; and 62 children, 28 boys and 34 girls, received no assistance. Children whose parents also volunteered to take part in the study were randomly assigned within school to one or other of the first two conditions; the remaining children were assigned to the no assistance condition. All children had English as their main or only language, and participated with full written consent. The participating parents comprised 71 mothers and 11 fathers, of whom 34 mothers and 8 fathers provided assistance on the Balance Scale task.

Materials

The Balance Scale apparatus comprised a wooden base with two wooden blocks situated in the centre, and a beam held between the two blocks via a screw that provided a fulcrum. Eight circular pegs were positioned along the beam, with four situated at equally spaced intervals on either side of the fulcrum separated by a central space. A wooden rest fitted into the centre of the scale on either side of the wooden blocks, to prevent the beam moving when weights were placed on it. The weights were eight hexagonal-shaped, metal nuts with a circular hole in the middle. The beam was 45cm in length. Materials for the Tower of Hanoi consisted of a similar wooden frame for the standard three-peg/three-disk version of the task. A video camera was used to record children's performance.

Procedure

All testing took place individually in a separate room within the child's school. Parents providing assistance on the Balance Scale were shown the apparatus immediately prior to the first time-point of testing, and instructed that the goal of the task was to make the beam balance when nuts were placed on it. They were told that the researcher would put an arrangement of nuts on "her side" of the scale, and the child was then to make it balance solely by arranging nuts on "their side", but without simply reproducing the researcher's arrangement, as this would make the task too easy. The parents were then given a brief explanation of the torque rule, whereby distance multiplied by weight had to be the same on both sides of the scale for balance to be achieved. Possible correct solutions for the first and second of the Time 1 problems were given as an examples. Parents were informed that their child would be asked to solve four problems of this kind in total, and that they could help their child in any way they considered appropriate.

Table 1 about here

The four problems used at Time 1 are shown in Table 1. When the parent understood their role, the researcher brought their child to the room (half of the children having already completed the Tower of Hanoi task independently immediately beforehand). The child was introduced to the task and what they had to do was explained to them. When the child understood, the camera was switched on and the researcher set up the arrangement of nuts for the first problem. The child proceeded by arranging nuts on their side of the scale in a configuration they thought appropriate, and then removing the rest to see if that solution worked. Parents assisted decision-making as they saw fit, but the process typically involved some degree of negotiation between child and parent, with the former making suggestions and the latter indicating potential modifications, until agreement on a solution to try out was arrived at. Each such effort was counted as a completed attempt, and if the scale did not balance the rest was inserted back into the equipment and the child tried again. Attempts continued until a correct solution was achieved. The only time the researcher intervened was to remind the child about the task rules if they made an illegal attempt (i.e. moving the nuts on the researcher's side of the scale, or reproducing the same arrangement). Immediately after the children had achieved a correct solution for a problem, they were asked, "Can you tell me how you made it (the scale) balance"? Once they had responded, the arrangement of nuts for the next problem was set up. The researcher provided no feedback on solutions or explanations at any time.

Parents who assisted on the Tower of Hanoi task were similarly shown that apparatus prior to assisting their child, and informed of the goal of the task and the rules regarding the movement of disks. As before, when the parent was happy with their role in the task, it was introduced to their child and the goal and rules explained. In view of the number of moves involved, children completed only one trial per session, at the end of which they were asked to explain how they had completed the task. On completion of assisted tasks, the parent was thanked and shown out. If this was the child's first task they were then introduced to the second, and completed that before returning to their class. Children who received no parental assistance also completed both tasks as part of a single session. In terms of administration, unassisted tasks were completed in identical fashion to assisted tasks.

A break of two days was given prior to the second time-point, and then again before Time 3. At Times 2 and 3, all children were taken out of class to work on the tasks alone, which were administered as before. As Table 1 shows, one new problem was introduced at Time 2 for the Balance Scale, and a further one was brought in at Time 3. As at Time 1, the children worked until they completed both tasks before returning to class.

Scoring

The videotapes of each session were transcribed to provide a written record of children's attempts, together with their explanations, and, where pertinent, parent-child dialogue. All coding was based on these transcripts.

<u>Coding of attempts</u>. Each attempt children made to solve a given Balance Scale problem was coded as being one of seven types, increasing in level of sophistication. These were based on the coding scheme used in Siegler's (1976) study. The seven levels are shown in Table 2. Since children made attempts at each problem until they were successful, they had to display a response at the highest level eventually. On the basis of this coding, two dependent measures were derived for performance on each individual problem across the three time-points: 1) *the number of attempts made*; and 2) *the proportion of attempts at either level 6 or 7*, in other words, the extent to which attempts indicated an appreciation of the need to manipulate both weight and distance, albeit without the child necessarily being able to determine their exact relationship. Since a perfect performance would be a single attempt at level 7, fewer attempts and a higher proportion at level 6/7 were indicative of better performance.

Table 2 about here

Coding of explanations. Children's explanations after they had successfully solved each problem were also coded individually for level, according to the criteria below:

0 – no explanation was given (e.g. "don't know")

1 – *weight explanations*: weight/number is important (e.g. "I've got as many on my side as you have"; "it was too heavy before, but now it's the same")

2 – *distance explanations*: distance/position is important (e.g. "I moved it in to the middle and it worked"; "mine are either side of the peg yours are on")

3 – *weight/distance explanations*: weight/number and distance/position are both important, but the relationship between the two is unclear (e.g. "if I put one there it would be too heavy, so I put it there instead and it balanced"; "when there were two and they were on top of each other it was too much, so I put them one apart")

4 – *torque rule explanations*: weight/number and distance/position both matter, and the need for equivalent unit x distance values on both sides of the scale is explicit (e.g. "two times one for that peg is the same as one on peg 2 for my side"; "if you count the numbers for each peg and add it up, it's the same on both sides")

It should be noted that scoring was based on *reference* to the constructs defined at each level (i.e. their explicit salience), rather than their correct usage. In line with the system used for coding attempts, explanations that focused solely on weight were treated as being less advanced than those that referred to distance. Both Inhelder and

Piaget (1958) and Siegler (1976) report that children characteristically perceive weight as salient to balance before they recognise the relevance of distance.

Coding of parental input. Parental interventions were coded according to a) the assistance they provided in children's efforts to formulate attempts at problem solutions; and b) the explicit references to underlying factors they provided as part of this assistance. Interventions did not necessarily take the form of the explicit operationalisations or higher-level explanations that were the subject of theoretical interest. These were therefore differentiated from other types of assistance and explanation, so that the relative impact of each on children's performance could be ascertained. Instances of parental explanations were coded at Levels 1 (weight), 2 (distance), 3 (weight/distance) or 4 (torque rule) of the system outlined above for children's explanations, with torque rule statements being defined as the higher-level explanations that were of focal interest. Elements of procedural assistance were coded as being one of four main types:

Direct control – interventions that directed the child to carry out a specific action without any explicit indication of the strategy being used ("put those two on peg 4", "take that off and put one on peg 2"), or else involved the parent carrying out such actions themselves

Non-specific prompts – statements reminding the child of the general rules (e.g. "you can't do the same on your side as on that") or otherwise blocking a move without specifying an alternative ("no, don't do that"), prompting an unspecified or general course of action ("make a start then", "try taking one of them off", "how about putting one nearer the middle"), or focused on broad comparison ("she's got three and you've got four")

Nut/peg prompts – statements drawing attention to the peg arrangement and/or the position of nuts, but without indication of how this information might be used to solve the problem ("if we count out from the middle, this is peg 1, 2, 3, 4", "how many nuts are on peg 2?", "there's two on her peg 3 and how many on yours?")

Weight x distance prompts – statements focused on nut x peg computations and comparisons involving these ("if there are four on peg 2, what does that make?", "four times two is eight, and two times four is…?", "so what does that come to on each side?"); these were defined as constituting explicit operationalisations of strategies for solving a problem

For each parent, a count was made of the number of times each type of assistance and explanation was used across the attempts relating to an individual problem. Scores on these eight variables (i.e. four assistance and four explanation codes) for the Time 1 problems formed the raw data for subsequent analysis.

Reliability. The reliability of the coding systems was checked via independent inspection of eight (approximately 20%) of the Time 1 transcripts. Since parental input was scored in terms of frequency of each assistance and explanation code type, reliability was evaluated by computing correlations between judges' scores for each category across the jointly coded instances. The mean correlation for the four assistance codes was +.99, with values ranging from +.99 to +1.00; for the explanation codes it was +.96, with values between +.89 and +.99. All values were significant at $p < .005$. The agreement rate for children's explanations was 100% (kappa = 1.00, $p < .001$). The coding of children's attempts was objective.

Results

Overview of analyses

Data analysis took place in four distinct stages. The first stage examined the profile of children's performance on the Balance Scale task across assistance condition (Balance Scale-assisted, Tower of Hanoi-assisted, and no assistance) and time-point. The objective here was to establish how far assistance on the Balance Scale task led to improved performance and understanding, and what the trajectory of change was relative to the two control conditions. The second and third stages focused on more in-depth analysis of the data relating to children in the Balance Scale-assisted condition. Stage two concentrated on the nature of the help provided by parents, how far this varied across children, and whether such variation was contingent upon children's performance. Stage three focused on examination of problem-to-problem changes in children's performance and level of explanation, and the relationship of these changes to specific elements of parental input at Time 1, especially explicit operationalisations and higher-level explanations. Finally, the fourth stage of analysis examined the differential effects of these key elements of parental input on the performance and explanations of children at different initial levels of task understanding. Results are presented below in this order.

Comparison across assistance condition

Figure 1 shows, for each time-point, the average number of attempts across all the Balance Scale problems made by children in the different assistance conditions. It also displays the mean level of explanation provided for solutions once these had been achieved. The error bars show the standard error for each data point. It can be seen from Figure 1a that Balance Scale-assisted children required fewer attempts to arrive at solutions at both Times 1 and 2, compared to those in the control conditions, who received no assistance on this task. At Time 3, control children had caught up to some extent, with some overlap between the three conditions now being apparent. A two-way mixed Anova (time-point x assistance condition) confirmed main effects of condition ($F(2,141) = 9.91$, $p < .001$) and time-point ($F(2,282) = 7.02$, $p < .01$), but also a significant interaction between the two ($F(4,282) = 3.05$, $p < .05$). Follow-up tests established that Balance Scale-assisted children made fewer attempts both overall and at Times 1 and 2 than those in the Tower of Hanoi-assisted and no assistance conditions ($p < .05$, Bonferroni), but that the latter two conditions did not differ from each other at any time-point. The interaction was attributable to the two control conditions exhibiting a decline in number of attempts Time 2 to Time 3 ($p < .05$ in both cases), whilst the performance of the Balance Scale-assisted children remained constant within the bounds of normal statistical variation. There were no differences between conditions at Time 3.

Figure 1 about here

Explanation levels had entirely the opposite pattern. All three conditions exhibited similar levels of understanding at Time 1, but the Balance Scale-assisted children then showed steady improvement across Times 2 and 3, whilst the control conditions remained more-or-less static. A two-way mixed Anova found no main effect of assistance condition, but a highly significant main effect of time ($F(2,282) = 16.50$, $p < .001$) and interaction between time and condition ($F(4,282) = 10.35$, $p < .001$). Follow-up tests showed significant increases Time 1 to Time 2 and Time 2 to Time 3 for the Balance Scale-assisted children ($p < .01$ for both), but no change for those in the no assistance condition, and change only Time 2 to Time 3 in the Tower of Hanoi-assisted condition ($p < .05$). Differences between conditions were not quite sufficient to achieve significance at Time 2, but at Time 3 the Balance Scale-assisted children differed from both the control conditions ($p < .05$). The Tower of Hanoi-assisted and unassisted children did not differ from each other in explanation level at any point.

The data establish clearly the general benefits of scaffolding for children's performance on the Balance Scale task, but also underline a degree of disjunction between the effects on ability to generate solutions to the different problems, and on explicit understanding of the factors at work. As far as the first was concerned, parental assistance appeared to be effective in developing children's skills at Time 1, with the impact of this sustained over later time-points. Growth in explicit understanding tended to lag somewhat behind this, however, not manifesting fully until Time 3. Children in the control conditions showed slower improvement in solving the Balance Scale problems, but little apparent gain in explicit grasp. The implication is that scaffolding had benefits over simple experience in terms of accelerated task performance, but perhaps more importantly in paving the way for growth in explicit understanding.

Detailed analysis of change in the Balance Scale-assisted condition

<u>Patterns of parental assistance</u>. Parental input showed substantial and apparently systematic variability in provision of procedural assistance and explanations at Time 1. Only 15 parents made use of explicit operationalisations in the form of weight x distance prompts, of whom only 13 also made use of the higher-level torque rule explanations. No other parent provided explanations at this level. Of these 13 parents,

4 gave other less specific explanations more frequently than torque rule statements, potentially diluting their impact (although all did refer to both weight and distance as factors). These 4 parents, and the 2 who used explicit operationalisations without torque rule explanations, also made more use of the less explicit nut/peg and non-specific prompts than weight x distance prompts. These characteristics defined two categories of input style, as follows:

5) *Fully explicit input*: procedural assistance via a focus on weight x distance prompts (explicit operationalisations), with torque rule (i.e. higher-level) explanations predominant (n = 9)
6) *Partially explicit input*: procedural assistance via nut/peg and non-specific prompts predominantly, with weight, distance, and weight/distance explanations most frequent (n = 6)

Of the remaining 27 parents, 16 gave non-specific prompts for 30% or more of their input, and weight explanations for 10% or more, with a clear preponderance (60% or more) of all their input being of these two kinds. For the final 11 parents, input was characterised by a substantial percentage of input (20% or more) taking the form of direct control. Some, though not all of these also gave substantial numbers of weight explanations. These characteristics defined two further categories of input style:

7) *Minimally explicit input*: primarily non-specific procedural assistance, with weight explanations predominant (n = 16)
8) *Implicit input*: substantial direct control, with some weight explanations (n = 11)

No parent was assignable to more than one category, but in order to confirm the validity of the categorisation, the data were subjected to a discriminant function analysis. This used the four categories defined above as the target grouping variable, and frequency of the four procedural assistance and four explanation codes as raw input. The analysis identified three significant discriminant functions accounting for 100% of the variance, with the first loading on weight x distance (.42) and nut/peg prompts (.78), the second on torque rule explanations (-.69), and the third on direct control (.84) and weight explanations (-.29). It will be noted that the first function reflects the distinction between fully or partially explicit input and minimally explicit or implicit input, the second between fully and partially explicit, and the third between minimally explicit and implicit. Of the 42 cases categorised as described above, only one was identified by the analysis as a potential misclassification (the implicit input case with the lowest percentage of direct control, which might equally have been classed as exhibiting a minimally explicit style). Relevant means for each category of input style on the eight variables are shown in Table 3. The high standard deviations associated with many cells reflect the fact that whilst *relative* occurrence of input of different types within style categories was of the pattern specified, the exact *extent* of input varied from parent to parent. Analysis of relationships between elements of parental input therefore controlled for this variation.

Table 3 about here

Despite the variation between parents in input style, there were only limited signs that they varied their approach from problem to problem, although this might be expected if the type of assistance offered were contingent upon children's performance (cf. Wood, 1986). Two-way mixed Anovas (problem x input style) on each of the parental codes found a main effect of problem and a problem x input style interaction only for weight x distance prompts ($F(3,114) = 6.36$, $p < .01$, and $F(9,114) = 3.68$, $p < .001$), and a further main effect of problem for torque rule explanations ($F(3,114) = 5.36$, $p < .01$). Parents who used these elements (i.e. those with fully and partially explicit input styles) provided them more often on later problems, especially problem 3 (for weight x distance prompts, mean = 1.00, 1.59, 2.31, 2.24 for problems 1 to 4; for torque rule explanations, mean = 0.21, 0.29, 0.55, 0.26), perhaps indicating a 'hammering home the point' strategy. Even then, they were broadly consistent in the scale of their use of weight x distance prompts across problems, with significant correlations being identified between problems 1 and 4 ($r = .68$, $p < .01$) and 2 and 4 ($r = .78$, $p < .01$), controlling for overall level of input (one-tailed values with df =12 in both cases).

For torque rule explanations, consistency of deployment across problems was less, with significant correlation only between problems 2 and 3 (partial $r = .46$, df = 12, $p < .05$, one-tailed). Since such explanations were only correlated with weight x distance prompts on problem 1 (partial $r = .79$, df = 12, $p < .001$, one-tailed), the data indicate that parents who used both explicit operationalisations and higher-level explanations tended to provide the whole framework of assistance and explanation on problem 1. They then persisted primarily with the first element, only providing explanations as they felt necessary to reinforce the rationale for the weight x distance computations. Variation in input that might indicate contingency upon children's performance was thus only apparent for torque rule explanations. No effects of problem were found for any of the other elements of parental input, and use across problems was generally well-correlated.

Problem-to-problem changes in children's performance and level of explanation. Table 4 presents a detailed breakdown of each child's number of attempts and explanation level on problems 1 to 4 at Times 1 to 3. To help clarify effects of parental input, children are grouped according to which input style their parent exhibited. Means across children and problems for each time-point are shown in Table 5. The presence of systematic trends within these data was examined by means of doubly-repeated three-way mixed Anovas (problem x time-point x input style), coupled with specific correlational analyses.

Tables 4 and 5 about here

a) Attempts. As far as number of attempts was concerned, this analysis revealed a main effect of input style ($F(3,38) = 4.35$, $p < .05$), with follow-up tests showing that children made fewer attempts if their parent adopted a fully explicit input style than if they adopted an implicit style ($p < .05$, Bonferroni; all other difference ns). As can be seen from Table 4, the former style dramatically constrained attempts at Time 1, where the modal performance was a single correct effort. Even at Times 2 and 3, though, this remained a frequent outcome for children in this grouping, despite the substantial increase in attempts shown by some. Children whose parents used a partially explicit style also made fewer attempts at Time 1, but this initial constraint was not as marked. Children whose parents used minimally explicit or implicit styles in contrast showed no corresponding constraint at Time 1, and this difference gave rise to an interaction between input style and time-point ($F(6,76) = 2.24$, $p < .05$) in addition to the main effect of input style (see Table 5).

The analysis also revealed a main effect of problem ($F(3,114) = 3.43$, $p < .05$), and an interaction between problem and time-point ($F(6,228) = 2.53$, $p < .05$). These effects were attributable to the average number of attempts tending to be higher on problem 1 (means = 7.23, 4.67, 5.41, 5.51 for problems 1 to 4, averaged across time-point), and to this pattern becoming more pronounced at Time 2 (means = 10.05, 4.73, 6.64, 5.10). As Table 4 makes clear, there was in fact substantial variation in this effect, with children who experienced implicit or minimally explicit assistance showing erratic variation problem-to-problem in number of attempts at Time 1 in particular. The average pattern held better at Time 2, with 17 out of these 27 children especially tending to make their peak number of attempts on problem 1 or problem 2. At Time 3, the majority of children made their largest number of attempts on either problem 1 or problem 4, the latter being somewhat more likely among those who had originally experienced minimally explicit or implicit assistance. These children also exhibited some tendency to make their peak number of attempts at roughly the same point in the problem sequence across successive time-points.

The broad picture, then, was that parental input constrained attempts, but only if it was at least partially explicit in style. In the absence of such assistance, children often spent at least one problem of a session, frequently the first, exploring or reorienting to the task before making more targeted efforts, though gains were often not sustained in any systematic fashion through to the next session. The relationship between attempts and degree of targeting was borne out by the proportion of attempts at level 6/7, since these were significantly negatively correlated with the number of attempted solutions for every problem, except the fourth at Time 1 (r ranged between -.22 and -.71, average = -.46). The greater the focus, the fewer the attempts needed to arrive at a solution, and conversely, the less clear children were about where to focus their efforts, the more attempts they made.

b) Explanations. The pattern for change in explanation level differed in as much as systematic shifts took place solely in relation to time-point. Analysis showed a main effect of time-point ($F(2,76) = 23.50$, $p < .001$), in line with the upwards trend seen in Figure 1b, but also an interaction between time-point and parental input style ($F(6,76) = 2.82$, $p < .05$). As can be seen in Table 5, children who were assisted by fully explicit input showed a steep increase to Time 2, whereas progress was more gradual, and to a somewhat lower level, for those whose parents gave partially or minimally explicit assistance. For children whose parents relied on implicit assistance, progress was delayed till Time 3.

Inspection of the individual data in Table 4 bears out the general trends. First, in terms of consistency of explanation level across problems, virtually all children gave at least two explanations at the same level at all three time-points, with exactly half giving three or more the same at Times 1 and 2, and nearly two-thirds (27) doing so at Time 3. Secondly, with regard to the effect of parental input, whilst the pattern was not uniform, children whose parents gave fully explicit assistance were the only ones who themselves gave torque rule explanations at Time 2. Moreover, the presence of explanations at this level at both Times 1 and 2 (as measured by the number of problems for which children gave them) was significantly correlated with the total number of torque rule explanations provided by *parents* ($r = .26$, $p < .05$ and $.36$, $p < .01$ respectively) and the number of weight x distance prompts they made ($r = .37$, $p <$

.01 for both), the two defining characteristics of this style of input. Children's torque rule explanations at Time 3, in contrast, were only significantly correlated with their *own* use of these explanations at Time 1 ($r = .40$, $p < .01$) and Time 2 ($r = .91$, $p < .001$; all analyses one-tailed with $n = 42$), providing clear evidence of the predicted process of appropriation.

It should also be noted that the effect of parents' provision of torque rule explanations and weight x distance prompts appeared to be cumulative and lagged, again consistent with a process of appropriation. Whilst total provision predicted total child use of torque rule explanations at Time 1, this association was absent on any individual problem. Instead, weight x distance prompts and parental torque rule explanations typically predicted child use of torque rule explanations on *subsequent* problems. Thus problem 1 usage by parents was associated with child torque rule explanations on problems 2 and 3 (for weight x distance prompts, $r = .49$ and .65 respectively; for parental torque rule explanations, $r = .67$ and .56, $p < .001$ in each case). A similar relationship was present for weight x distance prompts on problem 2 and child torque rule explanations on problem 3 ($r = .52$, $p < .001$). Conversely, the only sign of parental usage being contingent on children's performance was that child torque rule explanations on problem 3 predicted weight x distance prompts and parents' torque rule explanations on problem 4 ($r = .60$, $p < .001$ and .36, $p < .01$ respectively; all analyses one-tailed with $n = 42$). However, the relationship was *positive*, consistent with 'hammering home the point', not a response to faltering on the part of the child.

c) Relationships between attempts and explanations. The difference in pattern of change for performance and explanations begs the question of what relation, if any, the two had to each other. The data in fact indicate a complex relationship that shifted across problems. At Time 1, children's explanation level was inversely related to attempts and proportion at 6/7 on problem 1, i.e. the higher the explanation level, the *more* the attempts ($r = .38$, $p < .01$), and the *less* the focus ($r = -.29$, $p < .05$). On problem 2, the relationship was in a more expected direction ($r = -.27$ and .30 respectively, $p < .05$ for both), but on problems 3 and 4, there was no significant relation at all. At Time 2, the pattern was similar, explanation level being strongly related to attempts and proportion at 6/7 on problem 1 ($r = -.42$ and .40, $p < .01$), but the effect weakening to zero by problem 4. At Time 3, the impact of explicit grasp was maintained until problem 3 ($r = -.37$, $p < .01$ and .34, $p < .05$; all analyses one-tailed with $n = 42$), and only lost at problem 4. Since attempts generally *improved* across problems as the relationship to understanding weakened, this suggests that performance typically ran in advance of explicit grasp, though the two were better coordinated by Time 3.

This pattern was different for children who received fully explicit assistance, though. At Time 2 the relationship of explanation level to attempts maintained until problem 4 (as at Time 3 in the overall sample), whilst at Time 3 the relationship persisted after problem 1 ($r = -.38$, ns, $-.85$, $p < .01$, $-.74$ and $-.69$, $p < .05$ for both; $n = 9$, all one-tailed). The evidence is thus consistent with appropriation of torque rule explanations by these children having accelerated relationships between understanding and performance, and for these children having finally generated genuine E3 level representation capable of consistently guiding decisions.

Children who did not receive fully explicit assistance also benefited from intervention relative to children in the control conditions, however. The general pattern suggests progress for them occurred primarily via increasing approximation of attempts to correct solutions (perhaps based on attention to the rate at which the scale fell on unsuccessful efforts). This appeared to be followed by consolidation of the lessons learnt from such experience prior to the next set of trials, this grasp being superceded gradually by further exploration during those trials. The implication is that attempts at level 6/7, which indexed such approximation, were central to progress. If parental input had a positive effect for these children, then, it must have been via an impact on the proportion of such attempts. The only element of parental input that had this relationship was nut/peg prompts, totals of which were correlated with mean proportions of level 6/7 attempts at Times 1 and 2 among those not in the fully explicit grouping ($r = .36$, $p < .05$, and $.56$, $p < .01$, $n = 34$, both one-tailed). These prompts were of course present in all input styles, although only infrequently so for those who received minimally explicit or implicit assistance.

<u>Effects of explicit explanation on higher- and lower-performing children</u>. It had been predicted that the impact of higher-level explanation by parents would differ according to whether children's initial understanding of the task was at level I or E1/E2. To examine this, the Balance Scale-assisted children were divided into two groups, according to whether or not they made attempts scored at level 3 or below (see Table 2) during the first problem at Time 1. Since these essentially constituted trial-and-error activity, they were unlikely to have been promulgated by parents, and would not be expected to be produced by children at level E1/E2: explicit

representation should lead to more systematic behaviour, even if this is limited in terms of the principles manipulated. Of the 42 children, 20 produced attempts at level 3 or under on the first problem, and were categorised as lower-performing; whilst 22 produced attempts only at level 4 and over, and were categorised as higher-performing.

Children's classification as higher- or lower-performing is indicated by the prefix H or L in Table 4. It will be apparent from this table that while the four input styles were all found among parents of both higher-performing and lower-performing children, there was nevertheless considerable difference in their exact distribution. In particular, fully explicit assistance occurred predominantly among higher-performing children, whereas implicit assistance occurred mostly among the lower-performing. This association was significant (chi-square = 10.08, df = 3, $p < .05$), and does not appear to be explicable in terms of input style itself creating the basis for children's categorisation, as it predicted neither the number of attempts at level 3 and under, nor at level 4 and above on problem 1 at Time 1. The implication is that whilst problem-to-problem contingency between children's performance and parental input was broadly absent, it appeared to operate at the more general level of children's initial capability on the task.

One consequence of this difference in distribution was that lower-performing children had significantly less exposure to torque rule explanations (mean = 0.45 vs 2.09; $F(1,40) = 4.73$, $p < .05$), since these only occurred in input styles that were less common among their parents. Thus the evidence on the key point of interest is restricted. As far as it is available, however, it is supportive of the hypothesis that appropriation is dependent on level of grasp. The positive correlations between parental torque rule use and child use at Times 1 and 2 were maintained at the same level when the higher-performing children alone were considered ($r = .32$ and .31 respectively, $n = 22$, $p < .1$ for both), but not among the lower-performing ($r = -.10$ at Time 1, $n = 20$, ns; Time 2 value is not computable as torque rule explanations were not given here by these children). The same pattern obtained for weight/distance explanations, where there was no difference in exposure between the two sub-groups. For the higher-performing children, parental use of these was correlated with their own use at Time 1 ($r = .49$, $p < .05$) and to a lesser extent at Time 2 ($r = .35$; $p < .1$). For lower-performing children, these correlations once again disappeared ($r = .16$ and -.04 respectively, both ns).

Discussion

The data reveal a complex interactive relationship between type of parental input, children's attempted solutions and their explanation level, the precise nature of this relationship shifting over time, with the impact of parental input still being felt at Time 2, but dwindling at Time 3. Despite this complexity, in most respects the data were in line with the effects of linguistic mediation predicted to occur when parents provided assistance via explicit operationalisations of weight x distance computations and higher-level explanations.

To take the various points of correspondence in turn, the Balance Scale-assisted children showed an initial gain in focus in their attempted solutions, needing fewer efforts to arrive at answers than those in either control condition. In this respect, though, the controls caught up by Time 3 (cf. Pine *et al.*, 1999). However, the unassisted children showed none of the gains the assisted made by Time 3 in terms of *explanations*, with these gains being present regardless of style of parental input, albeit to differing extents. There was, moreover, some indication that they were still on an upward trend at this point. The implication is that, on the basis of simply exploring the task over three time-points, children could improve in terms of task performance and begin to carry over understanding from one problem to another, but only at a relatively inarticulate level, perhaps equivalent to E1 level representation (cf. Pine and Messer, 1999, 2003, on implicit understanding in the context of balance beam performance). Persistent gains in more explicit, E3 level representation over this time period were entirely dependent on parental input, and it was in this respect that scaffolding had its predominant impact, consistent with the proposed role of linguistic mediation.

Parental assistance was, as noted, variable in character (cf. Wood, 1986), with only two of the four broad styles identified making use of higher-level explanations that explicitly specified the relationship between weight and distance. In both cases, provision of such explanations co-occurred uniquely with explicit operationalisations of weight x distance computations. It was these two elements together that were associated with the most pronounced gains in children's performance and more especially their explanations, consistent with the predicted effects of these types of linguistic mediation on representational level. This was not simply a function of rote memorisation of explanations and solutions, since children's use of the torque rule went through a subsequent period of coordination with their performance before its impact was fully felt. By Time 3, when this coordination – and E3 level representation – had been achieved, child torque rule use was only associated with their own prior use, indicating that gains occurred by means of the predicted process of appropriation and redescription. In other words, then, adult input *resourced* growth rather than promoting wholesale adoption of a new perspective.

Two other points should be noted here. One is that it was the combination of explicit operationalisation and higher level explanation that led to progress, not the latter on its own. This indicates that to be effective, reference to more abstract principles has to be connected to concrete instantiation, as Tolmie *et al*. (2005) suggest. The other is that the effect of parents providing these two elements of input was not only lagged, as had been anticipated, but also cumulative rather than being dependent on contingent deployment, as Wood's (1986) account of scaffolding would predict. In particular, it was *total* usage that predicted gains, suggesting that consistent emphasis on the need for weight x distance computation and the principle underlying this was of greater consequence than strategic targeting of this input. Given that parental input in general tended to show consistency across problems rather than variation, and that even the less explicit styles of input were associated with progress, the data raise the question of whether the importance of contingency in previous accounts of scaffolding may have been overstated. Wood himself notes that it is difficult to achieve with any consistency, and the present data indicate that, at minimum, the process of learning via scaffolding is widely tolerant of its absence, at least at any fine-grained level.

The data are consistent with the anticipated effects of linguistic mediation in two further respects. The first is that as far as evidence was available, appropriation of higher-level explanations was dependent, as predicted by Tolmie *et al*. (2005), on children displaying an initial level of performance consistent with at minimum E1/E2 level representation. As far as torque rule explanations are concerned, confidence in this effect is necessarily restricted by the uneven distribution of their occurrence across higher- and lower-performing children, which renders the comparison potentially unfair. The same effect was also observed, however, for weight/distance explanations, which share with torque rule explanations an explicit reference to the combined importance of weight and distance, and thus a core aspect of the general principles at work. This comparison was not subject to concerns about uneven distribution. The implication is that, as suggested earlier, it is difficult for children to jump straight from implicit to E3 level without establishing interim representations.

The presence of this effect is an important one for various reasons. One is that it signals the capability of the linguistic mediation account to make detailed predictions that are meaningfully consistent with the general framework of the RR model, underscoring the potential power of this approach. Another is that this success in differentiating between processes that operate for children at different initial levels of representation indicates ways in which the linguistic mediation approach may go beyond the established contingency account of scaffolding. Wood (1986) emphasises the notion that scaffolding is only possible when the task is within the ambit of what the child is close to being able to do, rendering it essentially a unitary process. On the present data, though, scaffolding is also possible when the task is more removed from children's competence, but it needs to take a different form to be productive.

This point becomes evident when it is remembered that children who did not receive fully explicit input still managed to progress. They appear to have done so primarily via an approximation strategy that led to more targeted attempts in the area of a correct solution. Indeed, several children explicitly stated that this was what they were doing (e.g. " it was just another guess because of how slowly it was moving"; "that one there was too heavy cos it was too near the side so I moved it along one"). In this respect, these children may have been working in much the same way as those in the control conditions, but with one advantage. Once children start to adopt this strategy it opens the way for derivation of explicit weight/distance and even torque rule explanations, since it involves deliberate manipulation of number and position. To achieve this shift, however, these factors have to be disembedded from the background of potential variables, and made salient. Few unassisted children managed to do this. For lower-performing assisted children, on the other hand, parents not only helped increase their focus on the range in which correct solutions might be found via nut/peg prompts, but perhaps also, by using these, explicitly indicated the features to which they needed to attend; in other words, these also served as a form of explicit operationalisation, which helped promote E1/E2 level representations. Thus even at this level, it was possible to detect a process of linguistic mediation, albeit a different one to that operating for higher-performing children.

The data still leave two issues unclear. The first is that parental provision of weight x distance prompts and torque rule explanations appeared to be *necessary* for accelerated growth in understanding, in as much as only those who received this input exhibited such change. It cannot be regarded as *sufficient* in itself, though, since it did not uniformly produce this outcome even among higher-performing children. The reasons for this individual variation are not evident on present data, though wider language ability may be a plausible factor. This requires further investigation.

The second is the rather intriguing self-selection of parental input styles, contingent upon children's initial level of representation, rather than more moment to moment variation in performance. The tendency for parents to use different styles is itself well established (see e.g. Rogoff, Matusov and White, 1996; Wood and Middleton, 1975), but this targeted adoption has been less commonly reported. The problem in the present case is that while this variation was well-predicted by children's performance level, the criteria used to categorise children were subtle, and not on the face of it very likely to have been detected by parents. This begs the question of whether the determining factor might not in fact have been a more general (if reasonably accurate) *expectation* on the part of parents about how their child would perform. A precedent for this is provided by Rubie-Davies (in press), who reports that teachers with high expectations of their pupils provided them with large numbers of instructions and explanations about the concepts they were teaching, whereas teachers with low expectations made far more procedural statements and asked fewer questions.

This opens up the possibility that the differential pattern of behaviour and consequent impact of parental input for the lower- and higher-performing children is in part a function of a history of past parental support, and that this might therefore have been an additional source of influence on outcome in the present research. To clarify this, data from the present study need to be compared with one in which children at different initial levels work with the same, previously unknown adult. Initial level of understanding might also perhaps be established without risk of contamination (or reduced risk) by pre-testing on a closely-related, but different task, the balance beam (Pine *et al*., 1999). Research along these lines is currently in hand.

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Table 1. Configurations of nuts for Balance Scale problems at Times 1, 2 and 3.

Problem	Time 1	Time 2	Time 3
1	Two nuts on peg 1*	Two nuts on peg 1	Two nuts on peg 1
2	One nut on peg 2 One nut on peg 4	One nut on peg 1 One nut on peg 3	One nut on peg 1 One nut on peg 3
3	Four nuts on peg 2	Four nuts on peg 2	Four nuts on peg 2
4	One nut on peg 1 Two nuts on peg 3	One nut on peg 1 Two nuts on peg 3	Three nuts on peg 2 One nut on peg 4

*Peg 1 is nearest the middle of the scale, and peg 4 is at the end of the scale.

Table 2. Levels of scoring for children's attempts on the Balance Scale task.

Level	Description
1	Illegal moves I: manipulating the weights on the researcher's side
2	Illegal moves II: reproducing the researcher's arrangement of nuts
3	Different number and/or different arrangement of weights on different pegs to those on the researcher's side, but with unit x distance values being substantially inaccurate (<.67 or >1.5 times that of the researcher's configuration), indicating a trial-and-error attempt, and no conceptual understanding of the factors affecting balance
4	The same number and same arrangement of weights on different pegs to that of the researcher, implying that although the pattern of weights matter to the child, distance does not
5	A different number and/or different arrangement of weights on the same pegs to that of the researcher, indicating that distance matters to the child whereas the pattern of weights does not.
6	Different number and/or different arrangement of weights on different pegs to that of the researcher, with unit x distance values close to that on the researcher's side (=>.67 or =<1.5 times the researcher's arrangement), indicating an awareness that both weight and distance matter
7	Successful balance

Table 3. Mean frequency of elements of procedural assistance and levels of explanation provided by parents (total across problems), by input style category (standard deviations in parentheses).

Input style	Direct control	Non-specific prompts	Nut/peg prompts	Weight x distance prompts	Weight explns	Distanc e explns	Weight/ distance explns	Torque rule explns
Fully explicit (n = 9)	1.89 *(1.62)*	8.67 *(5.98)*	11.00 *(4.12)*	24.89 *(21.17)*	1.00 *(1.12)*	0.00 *(0.00)*	0.89 *(1.54)*	5.11 *(3.02)*
Partially explicit (n = 6)	2.17 *(2.32)*	17.00 *(9.74)*	17.33 *(9.31)*	12.67 *(10.31)*	2.33 *(3.44)*	0.67 *(1.03)*	3.17 *(4.87)*	1.50 *(1.87)*
Minimally explicit (n = 16)	2.12 *(2.58)*	12.81 *(10.42)*	1.06 *(1.65)*	0.00 *(0.00)*	7.37 *(4.41)*	0.94 *(1.69)*	1.37 *(1.54)*	0.00 *(0.00)*
Implicit (n = 11)	15.91 *(17.48)*	12.45 *(11.34)*	0.54 *(0.82)*	0.00 *(0.00)*	4.91 *(5.15)*	0.64 *(1.12)*	0.54 *(0.69)*	0.00 *(0.00)*

Table 4. Number of attempts and explanation level for correct solution for each child in the Balance Scale-assisted condition, on Problems 1 to 4 (P1 to P4) at Times 1, 2 and 3, ordered by parental input style. Obvious peaks in number of attempts (2+ > minimum for a given time-point) are shown in bold.

	Time 1								Time 2								Time 3							
	Attempts				Exp level				*Attempts*				Exp level				*Attempts*				Exp level			
	P1	*P2*	*P3*	*P4*	P1	P2	P3	P4	*P1*	*P2*	*P3*	*P4*	P1	P2	P3	P4	*P1*	*P2*	*P3*	*P4*	P1	P2	P3	P4
Fully explicit																								
H1	1	2	1	1	1	0	0	1	**7**	1	5	4	4	4	3	4	1	1	1	1	4	4	4	4
H10	1	1	1	1	0	0	0	4	2	1	**7**	2	2	2	3	3	1	**4**	1	2	3	2	3	3
H12	1	1	1	1	0	0	0	0	10	**22**	14	9	3	0	3	0	7	1	3	**10**	0	2	3	0
H14	2	1	1	1	0	4	4	0	**11**	4	1	5	2	0	4	4	4	1	**37**	6	3	3	0	0
H15	1	1	1	1	0	4	4	4	1	1	1	1	4	4	4	4	1	1	1	2	4	4	4	4
H16	1	1	1	1	0	1	0	3	1	1	**3**	1	4	4	4	4	1	1	1	2	4	4	4	4
H20	1	2	1	1	1	3	4	1	7	2	6	**7**	4	4	3	3	**18**	2	3	3	4	4	3	3
H21	1	2	1	2	0	0	0	0	**8**	4	3	1	0	3	3	1	**13**	9	4	3	0	1	3	3
L6	2	**4**	1	1	0	0	0	0	**30**	6	16	1	0	1	0	1	9	**19**	7	2	0	0	0	0
Mean	1.2	1.7	1.0	1.1	0.2	1.3	1.3	1.4	8.6	4.7	6.2	3.4	2.6	2.4	3.0	2.7	6.1	4.3	6.4	3.4	2.4	2.7	2.7	2.3
Partially explicit																								
H11	1	2	2	**7**	3	3	3	1	4	1	**12**	1	3	3	0	3	**3**	1	2	2	2	4	3	3
H18	**5**	2	1	1	0	0	1	0	19	1	**22**	4	3	0	0	1	**19**	5	11	12	1	0	2	3
H22	1	2	**5**	1	0	3	3	3	2	2	**6**	4	3	3	3	3	2	1	**9**	3	3	3	3	3
L9	**3**	2	1	1	1	0	4	4	**19**	6	2	6	3	3	3	3	1	1	7	**14**	4	3	3	3
L14	2	**4**	**4**	1	0	0	0	0	9	1	1	**15**	0	0	0	0	1	2	**11**	8	0	0	0	0
L20	**6**	3	5	2	0	1	3	0	**8**	5	1	2	3	1	3	0	1	4	3	**11**	3	3	3	0
Mean	3.0	2.5	3.0	2.2	0.7	1.2	2.3	1.3	10.2	2.7	7.3	5.3	2.5	1.7	1.5	1.7	4.5	2.3	7.2	8.3	2.2	2.2	2.3	2.0
Minimally explicit																								
H2	3	5	**16**	2	3	1	3	0	2	2	**11**	1	3	1	3	1	3	1	1	**14**	3	3	3	3
H4	2	6	2	**9**	1	1	0	0	3	2	**4**	2	3	3	3	3	2	3	5	**6**	3	3	3	3
H6	1	**7**	2	3	0	0	0	0	**13**	6	7	10	0	0	0	0	1	2	**5**	4	3	0	0	0
H7	2	**9**	4	4	0	2	0	3	**11**	6	2	2	1	3	0	0	**19**	5	14	8	3	0	0	0
H8	2	**6**	4	4	0	0	0	0	4	1	1	**7**	0	1	3	0	**8**	**8**	5	2	1	0	3	0
H9	2	2	3	**6**	1	3	3	3	6	5	**8**	2	3	3	3	3	3	1	1	**4**	4	3	3	3
H13	2	5	6	**11**	1	0	1	1	5	**6**	3	1	3	3	3	3	**7**	4	5	4	4	3	3	3
H17	1	1	4	**7**	0	3	0	3	**19**	14	5	2	1	3	3	2	**13**	3	2	7	3	3	3	2
H19	3	6	7	**12**	3	1	2	0	4	1	7	**8**	0	1	0	0	3	4	1	**10**	3	0	0	0
L2	4	2	5	**8**	0	1	0	1	**7**	**7**	5	1	3	0	3	0	**40**	12	8	8	1	1	3	3
L5	4	**17**	1	3	1	0	1	0	**6**	3	**6**	3	1	0	0	0	1	3	3	**4**	0	0	0	0
L7	4	**18**	2	3	0	0	1	0	14	3	5	**19**	1	3	1	1	4	**19**	1	7	1	0	3	1
L12	3	**16**	8	7	0	1	3	3	**27**	7	1	12	0	1	0	1	10	2	2	**17**	1	1	3	3
L13	**36**	11	17	19	3	2	3	0	5	**8**	6	5	3	2	1	3	5	**7**	1	2	3	3	3	0
L16	4	**9**	7	8	3	0	0	0	**15**	4	7	14	1	1	1	3	5	5	2	**12**	1	3	3	3
L18	2	**7**	5	5	0	0	3	3	2	4	**12**	10	3	0	0	0	1	4	1	**5**	3	3	3	3
Mean	4.7	7.9	5.8	6.9	1.0	0.9	1.2	1.1	8.9	4.9	5.6	6.2	1.6	1.6	1.5	1.2	7.8	5.2	3.6	7.1	2.3	1.6	2.2	1.7
Implicit																								
H3	2	1	1	**4**	0	0	0	0	4	4	3	**6**	0	0	3	0	1	**16**	1	2	1	0	2	0
H5	1	3	3	**5**	3	0	0	0	**10**	2	2	6	2	0	0	0	**12**	2	1	11	1	0	3	0
L1	**13**	5	2	8	4	1	0	0	5	2	**11**	2	0	0	3	3	9	2	**14**	2	3	0	3	3
L3	2	**16**	1	3	1	0	2	0	**16**	1	4	7	0	2	0	2	5	**9**	1	5	0	0	2	2
L4	6	**10**	1	5	0	3	3	3	**26**	8	7	4	0	3	2	0	**13**	2	1	4	1	3	3	3
L8	**22**	15	5	5	3	0	0	0	12	**19**	12	3	1	3	1	0	11	**16**	5	11	3	0	0	3
L10	36	7	8	**45**	3	1	0	3	6	3	5	**17**	3	3	2	3	5	1	7	**12**	1	1	3	1
L11	4	5	5	**6**	1	0	1	1	5	**10**	4	2	0	0	0	0	4	3	4	**12**	0	0	0	0
L15	**11**	7	**11**	5	0	1	0	1	**19**	4	13	6	2	0	0	0	3	2	**8**	3	0	2	2	2
L17	2	4	**20**	17	0	1	1	3	6	**16**	5	4	0	0	1	1	2	4	**20**	10	1	3	3	1
L19	**36**	13	3	5	0	0	0	0	**29**	4	15	3	0	0	2	3	**18**	2	3	3	1	3	3	3
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 5. Mean number of attempts and explanation level at Times 1, 2 and 3, by parental input style (standard deviations in parentheses).

	Time 1		Time 2		Time 3		Overall	
	Attempts	Exp level	Attempts	Exp level	Attempts	Exp level	Attempts	Exp level
Fully explicit	1.25_a (0.33)	1.08 (1.10)	5.72 (4.66)	2.67_a (1.24)	5.08 (3.99)	2.53 (1.46)	4.02_a (2.57)	2.09 (1.15)
Partially explicit	2.67_{ab} (0.78)	1.37 (1.10)	6.37 (3.07)	1.83_{ab} (1.18)	5.58 (3.31)	2.17 (1.24)	4.87_{ab} (1.97)	1.79 (1.15)
Minimally explicit	6.34_{bc} (4.14)	1.06 (0.75)	6.42 (2.86)	1.48_{ab} (1.02)	5.92 (3.79)	1.97 (1.07)	6.23_{ab} (2.09)	1.50 (0.79)
Implicit	8.84_c (6.27)	0.91 (0.68)	8.00 (3.04)	1.02_b (0.73)	6.41 (1.95)	1.50 (0.78)	7.75_b (2.95)	1.14 (0.57)

Where values within the same column have no different subscripts, they are significantly different at $p < .05$ (Bonferroni).

Figure 1 Performances across time-points by parental support condition