Cognitive mechanisms underlying perseveration on the Wisconsin Card Sorting Test

by

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Dedicated to my mum and dad for everything they've given me and everything they've stood for.

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Abstract

Four studies were undertaken with the aim of investigating primarily task conditions associated with perseveration on the Wisconsin Card Sorting Test (WCST). In addition, the last study examined the possibility that perseveration may be associated with a reduced emotional reaction to feedback received during the WCST. The prevalent idea regarding perseveration has been that it is a result of an inability to disengage from a behaviour that is "overlearned" or that has become habitual (Milner, 1963). Following this premise, it was initially hypothesised that perseveration on a particular response would increase as reinforcement of this particular response increases. In the first study, the standard WCST as well as two variations differing in number of correct consecutive trials per category (CCT) (WCST5 and WCST15) were administered to twenty individuals with brain injury and an equal number of healthy participants. The purpose of the study was to examine a possible difference in perseveration when individuals were offered more (15) or less CCTs (5) for each sorting category on the WCST. Contrary to predictions, the healthy group showed significantly fewer perseverative errors and total errors on WCST15 when compared both to WCST10 and to WCST5 although no significant difference was found between WCST10 compared to WCST5. The brain injured group showed significantly more perseveration on WCST15 compared to WCST10 but not compared to WCST5. Also WCST10 and WCST5 were not significantly different in terms of perseveration. However, after the exclusion of individuals who did not complete any categories, the results resembled those of the healthy group. Overall the results indicated that perseveration is not likely to be a result of an inability to inhibit well-learned responses. The second study was an attempt to confirm the findings of the first study whilst eliminating the possibility of a practice effect. Twenty individuals with closed head injury were administered either WCST5 or WCST15. Perseveration was not found to be significantly different between the two groups tested. It was suggested that the results were inconclusive owing to the exceptionally high perseveration scores of the participants. The study highlighted a serious methodological issue, namely that the effect of number of CCT cannot be accurately assessed on individuals with exceptionally high perseveration scores. The third study included sixteen individuals with traumatic brain injury and four individuals with Korsakoff's disease who were tested on either WCST5 or WCST15. Apart from the number of CCT, both versions differed from the original in that ambiguous cards were removed and participants were allowed to determine the sequence of sorting categories. The aim of this study was to confirm earlier data, investigate the effect of ambiguity and alter the task to ensure that at least one sorting category being completed. Data analysis revealed that, as expected, the group that was tested on the WCST15 produced significantly less perseverative errors when compared to the group that was tested on the WCST5. The final study aimed firstly at confirming preceding findings but more importantly at further investigating a possible link between perseveration and an inefficient use of cues. Damasio's idea of the somatic marker (1991) was adapted in an attempt to examine whether perseveration is linked with a decreased emotional reaction to feedback on the WCST. High perseverators (individuals with 20% and above perseveration) were expected to show a lower Skin Conductance Response (SCR) indicating a reduced emotional response to feedback received by the examiner. In addition SCR after negative feedback was expected to be higher than SCR after positive feedback owing to the corrective nature of the negative cue. Twenty-six participants without neurological history were administered either WCST5 or WCST15. As in the third study, the sequence of sorting categories was undetermined and ambiguous cards were removed. The study supported earlier findings showing that perseveration is significantly lower on WCST15 compared to WCST5. No significant differences in SCR were found between high and low perseverators or between negative and positive feedback. In addition, SCR was not proven to be significantly lower for negative feedback compared to positive feedback. Consequently, the idea that perseveration is associated with a decreased emotional reaction to feedback, was not supported. Overall, with the exception of the second study, the findings contradicted the prevalent idea that forming a strong "response set" would increase perseveration. In fact, they indicated that performance on the WCST is facilitated by a stronger response set, and perseveration decreases. This view is inconsistent with the way perseveration is viewed in the current literature but is consistent with early conceptualisations of perseveration (Grant and Berg, 1948, Gormezanno and Grant, 1958 or Pribram, 1961) that suggest that perseveration may be linked to ambiguity or unreliability of feedback. However, the findings of the fourth study did not provide evidence for a decreased emotional reaction to cues among perseverators during the WCST. Further investigation would be helpful in deciphering the relationship between perseveration and the use of external feedback.

Preface

Perseveration refers to the reoccurrence or repetition of a behavioural response that is not called upon by the situation, that is no longer appropriate or that is labelled incorrect, when other options are available. Sandston and Albert (1984) defined perseveration as "any continuation or recurrence of experience or activity without the appropriate stimulus".

Perseveration has, for a long time been associated with impaired frontal lobe function, especially since the work of Brenda Milner (1963, 1964) who found that perseverative errors on the Wisconsin Card Sorting Test (WCST) were more prevalent among patients with frontal lobe lesions. However, literature on the frontal lobe is largely descriptive and has not really successfully identified or explained underlying mechanisms. An obvious problem when it comes to understanding perseveration in particular is that, despite a clear operational definition and standardised quantification, perseveration has lent itself to a circular argument: on the one hand it lacks a reliable description of its underlying cognitive mechanisms, but on the other hand it is taken to be indicative of specific frontal lobe dysfunction. However, a number of studies have shown perseveration among a variety of neurological groups and there has not always been a strong relationship between frontal damage and perseveration (Lombard et al, 1999). The aim of the studies presented here is neither to preclude the frontal lobe as the locus of perseveration nor to underestimate the direct or indirect associations it may have with perseveration. Rather it is to investigate perseveration as a cognitive impairment independently from locus of lesion, and examine possible related cognitive mechanisms.

Perseveration is traditionally thought to reflect an inability to shift attention away from an established mental "set" (Berg, 1948, Flowers and Robertson, 1985). A set is acquired after an individual repeatedly performs the same response. A decrease in errors and an increase in speed of performance usually signify that the response has become automatic, and that the individual has acquired "set" (Brown and Marsden, 1988). Subsequently, as learning of a behaviour (or a rule) increases, the stronger a "set" is established and the stronger the likelihood that this behaviour will be the focus of perseveration. Set shifting or "reactive flexibility" (Eslinger and Grattan, 1993) is defined as switching from an automatic to a novel behaviour, usually as a response to cues (external or internal). Problems in set shifting usually involve frontal lobe or basal ganglia lesions (Brown and Marsden, 1988, Eslinger and Grattan, 1993).

Similar to the notion of inability to disengage from set is the notion of disinhibition. Disinhibition is defined as the inability to inhibit or disengage from previously acquired responses (Dias et al, 1996). Both disinhibition and poor set shifting are intrinsically linked not only to the ability to disengage oneself from a prior behaviour, but also to the utilisation of cues as guides for monitoring and changing behaviour. They are necessary when individuals need to alter their behaviour as a response to new incoming stimuli and is regarded to be associated with frontal lobe. According to Passingham (1992) and Verin et al (1993) the frontal lobe provides the very mechanism by which it is made possible for humans to disengage from a well-learned, automatic, or habitual behaviour in order to respond to a changing external situation. According to Verin et al (1993) this mechanism involves the inhibition of the current behaviour or mental set as well as that of previously established "automatic programmes".

In the studies that follow, perseveration is measured on versions of the Wisconsin Card Sorting Test (Berg, 1948, Grant and Berg, 1948), which include the original version and two variations. The participants are required to sort cards according to three different sorting categories. The versions differ in terms of numbers of times each sorting category is reinforced, and in terms of inclusion or exclusion of ambiguous sorting cards. The investigation that follows is divided into four separate studies, the aim of which is to investigate the underlying cognitive mechanisms involved in perseveration. They are specifically aimed to test current views on perseveration and explore two issues associated with perseveration. Firstly the studies investigate the relationship between perseveration and learning and secondly they explore the possibility that perseveration might be accompanied by an absence of an emotional reaction (measured by Skin Conductance Response) to the feedback provided by the examiner.

Since Milner's work in the 1960's, a relationship between learning and perseveration has consistently underlined the way perseveration is defined, however it has not been directly investigated. A specific aim of the current study therefore, is to investigate this link. Although the initial prediction was that a well-learned set as produced by a high number of Correct Consecutive Trials per sorting category (CCT) on the WCST would be followed by a significant increase in perseveration, what became quite clear from the initial study was that the opposite was occurring. In other words, as the number of CCT increased, and the set became more established, perseveration dropped significantly. One possible reason for this is that fewer CCT would create ambiguity and a situation where learning each sorting category (and subsequently the overall task) would be more difficult and perseveration is more likely to increase. It is proposed therefore that perseveration increases in conditions that give rise to ambiguity and ineffective learning. This idea is consistent with early studies by Grant and Berg (1948) and Grant and Cost (1954) on healthy individuals that showed a decrease in perseveration following an increase in number of reinforced trials on the WCST as well as early studies by Pribram (1961) and Gormezanno and Grant (1958) who thought that perseveration increases under conditions of unreliability. However, it contradicts the very popular idea that perseveration is more likely to occur in situations of "overlearning".

Secondly, the role of emotional reaction to feedback as it pertains to response selection and perseveration, will be more closely examined in the last part of the studies. Damasio's research on the somatic marker hypothesis (1990) has indicated the importance of emotionally reacting to stimuli or cues during cognitive tasks influence performance. The present study measures participants' Skin Conductance Response (SCR) after each cue received by the examiner during the WCST, indicating whether a sort is 'right' or 'wrong'. It investigates whether high perseverators show a significantly lower SCR compared to non-perseverators and also whether there is a difference in SCR between negative ('wrong') and positive ('right') feedback. In the WCST, the cues would be the words 'right' or 'wrong' given by the examiner after every sort. The cues have an instructional but non-directive nature. Their purpose is to prompt the individual to change the way they are sorting. If the participants do not benefit from the instructional nature of the cues, they may continue to sort in the same way regardless of the feedback they receive. Individuals who do not perseverate on the WCST would attempt other sorting ways, often incorrect, or indeed guess upon receiving negative reinforcement, if the alternative categories have not yet been detected, or the overall rule of the task has not been grasped. It is the persistence to the previously correct sorting category, despite negative reinforcement, and the purposefulness of the behaviour, that suggests the idea that somehow the cue may not be utilised effectively. The guiding hypothesis in other words is that perseveration may occur when the cue meant to guide behaviour does not elicit the required emotional response.

Finally methodological issues pertaining to the use of the WCST as an investigative instrument and to the way in which perseveration is measured for these purposes are examined throughout the paper and their influence on the present studies as well as future research on perseveration is taken into account.

CHAPTER 1

Perseveration

In clinical situations perseveration is usually measured with the Wisconsin Card Sorting Test (WCST) or variations of the test like the Modified Card Sorting Test (Nelson, 1976). These tests are thought to assess difficulty in switching mental set. In the past however, a variety of different behaviours have been termed perseveration. The existing classifications of perseveration are many and varied (Sandson and Albert, 1984 and Hotz and Helm-Estabrooks, 1994). There seems to be a main distinction between motor and cognitive (including verbal) perseveration but it remains uncertain whether these two divisions of perseveration share a common anatomical or physiological basis.

Three types of perseveration were identified early in the history of its study. Firstly Liepmann (1905) described an inability to end a motor act, for example to stop drawing after the task is completed. This was identified as a form of perseveration and was labelled tonic (Liepmann, 1905), cortical (Luria, 1966) or impaired switching (Freeman and Gathercole 1966). Goldberg and Tucker (1979) called it perseveration of activities while Sandson and Albert (1984) defined it as "stuck-in-set" perseveration. Secondly, perseveration may involve a continuous repetition of an action (e.g. drawing loops) or a pathological inertia at the motor periphery (Luria, 1966). This was named clonic perseveration (Liepmann, 1905), compulsive repetition (Freeman and Gathercole, 1966), efferent motor perseveration (Luria, 1966) primary rigidity (Goldstein, 1943) or continuous perseveration (Sandson and

Albert, 1984). Finally, a third type was thought to reflect repetition of a previously emitted response when a new response is intended (repetition of behaviour such as blowing a match) when it is no longer appropriate (repeat the blowing motion to subsequent stimuli). This was named intentional perseveration (Liepmann, 1905), ideational perseveration (Freedman and Gathercole, 1966) secondary rigidity (Goldstein, 1943) or recurrent perseveration (Sandson and Albert, 1984).

It seems to stem from the above that the one characteristic that links the different types of perseveration is the repetition of a particular behavioural response. It also becomes clear that perseveration cannot be defined as merely an excessively repetitive behaviour. The repetition is typically needless and does not accommodate changing environmental requirements. As Ridley (1994) pointed out, perseveration reflects a particular mental state, which may be the result of a restriction of choices of action and thus should not be confused with stereotypy. Moreover it may not be necessarily excessive (Gauntlett et al, 1999). Most importantly the notion of repetition in the case of perseveration is one that assumes rigidity either in the sense that the individual seems to be engaged in a routine that was previously successful or because the behaviour remains unchanged despite external reinforcement.

In the last few decades perseveration has been described and defined and its measurement has been standardised. Although simply manifested, perseveration is a complex behaviour. It may involve impairment in cognitive elements such as attention, short-term memory, inhibition, and selection, changing mental sets, sustaining information, responding to and analysing feedback and altering behaviour according to changing reward contingencies as well as creating and following a mental plan. However, understanding why perseveration occurs has proved very difficult. Furthermore, apart from the fact that cognitive factors such as attention and short-term memory are relevant to perseveration, research has identified a number of other possibly related factors that affect perseveration. The main factors that appear to be associated with perseveration are related to the state of the individual as well as the nature of the task.

Allison (1966) and Freeman and Gathercole (1966) found that fatigue and frustration increased perseveration. They reported that patients might show no perseveration on tasks on which they had perseverated earlier. Goldstein (1948) and Sandson and Albert (1987) also observed that perseveration was more likely to occur in conditions of fatigue or decreased attention. Allison (1966) for example claims that anxiety or difficulty of the task significantly affects performance on the WCST. Studies have shown that as the task becomes more difficult, perseveration increases (Jaspers, 1913, Goldstein, 1943, Werner, 1946). However the idea that perseveration is due to tiredness or difficulty, is in other words transient, has been questioned. Sandson et al (1984) claimed that perseveration does not increase with increasing difficulty of the task and many subjects are unaware of their perseverative behaviour.

As mentioned earlier, perseveration is highly represented among patients with frontal lobe injuries. This however does not necessarily facilitate its investigation. The reason for this is threefold. Firstly perseveration does not occur exclusively among frontal lobe patients. Secondly, frontal impairment itself is varied. Perseveration is linked to a variety of different anatomical sites within the frontal lobes themselves and thus has been associated with a number of "frontal" impairments. Lastly, tests such as the WCST that traditionally measure perseveration are multifaceted and multifactorial. It is not surprising therefore that there are many different explanations and a number of inconsistencies in the literature regarding the underlying mechanisms of perseveration. The fact that the WCST is widely used as a standardised assessment instrument in clinical settings creates certain urgency for the attainment of a more accurate understanding of perseveration in terms of its underlying cognitive mechanisms.

As discussed in the introduction, perseveration is mostly viewed as a deficit in changing from a learned and well established to a new behaviour. The relationship between perseveration and learning therefore is a significant one. The majority of studies dealing with perseveration invariably assume the existence of a learning process that more or less precedes perseveration. Perseveration is often thought to reflect an inappropriate or excessive use of a learned behaviour, in a way that disrupts further learning or inhibits the utilisation of alternative solutions or behaviours.

Many investigators have suggested that impairments in short-term memory or attention underlie perseveration and a number of studies have investigated their role in perseveration. In tasks such as the WCST, each cue received by the experimenter as well as the emerging pattern must be kept in short term memory, in order for the feedback to be effectively utilised (Goldman-Rakic, 1993) and for an overall plan to be established and followed. According to Burgess (1996), the WCST is thought to depend upon the utilisation of different memory systems. During the administration of the WCST, individuals must keep in working memory the feedback received from the experimenter, which will help to form a hypothesis on which performance will be based. Discrepancies between feedback and the current hypothesis must be evaluated and new responses attempted as a result. In this sense the task involves maintaining different types of information in working memory and conducting various mental computations on the feedback in order to produce correct responses (Dunbar and Sussman, 1995). The effective management of feedback may in itself be a major contributing factor to successful performance on tests that measure perseveration. This issue is addressed later in the chapter. Dunbar and Sussman examined the relationship between perseveration and memory by simulating frontal-like performance in healthy individuals, using a dual task methodology that resulted in the disruption of the phonological loop. Their hypothesis was that if working memory deficits underlie perseveration then it should be possible to "induce" perseveration in healthy individuals by interfering with working memory functions. The participants were administered the WCST whilst performing a second task at the same time. The main manipulation of their experiment was whether the secondary task loaded the phonological loop (group A) or the central executive (group B). Their results showed that group A achieved the least number of categories and the most perseverative errors and their performance appeared to show the most striking resemblance to frontal lobe patients. However, post hoc analysis as well as a second experiment revealed no significant differences between the central executive and phonological conditions.

In a third experiment a patient with a severe deficit in phonological working memory was tested and showed a deficit in WCST performance with a very high score of perseverative errors and no completed categories. Their research seems to indicate a potential phonological aetiology of perseveration in the WCST, which perhaps might provide an explanation of why non-frontal subjects perseverate on the WCST. Another possible mechanism may be that a central executive deficit may prevent patients from maintaining information in the phonological working memory.

Similarly, Baddeley (1995) investigated one function of the central executive, namely the allocation of attention, among patients with frontal lobe lesions. He suggested that frontal patients do not have a deficit in inhibiting responses, but rather a deficit in attentional allocation. Perseveration therefore may be produced if the central executive system is impaired because individuals are not able to attend to feedback (or loose track of feedback) and so are unable to process the relevant information during the WCST. A successful performance on the WCST would involve both the temporary storage of information in a phonological store and the shifting of attention to move information in and out of this store. Dunbar and Sussman (1995) maintain that the deficits observed among frontal patients during the test occur when the task involves the maintenance of a temporary representation in working memory. It is hypothesised that the central executive or attentional allocation system cannot update information in the temporary stores particularly when there is more than one chunk of information to be maintained in working memory.

Greve (1996) suggested that the WCST primarily reflects an attentional dysfunction. Efficient performance on the WCST would require the ability to attend effectively to feedback as well as utilise the feedback in order to initiate a search for alternative responses. It also may require the creation, sustenance and implementation of a mental plan. This would involve engaging in a series of separate steps. Luria (1964, 1969) thought that what caused perseveration was the inability of frontally impaired patients to tackle problems that involve an "orderly sequence of separate steps".

Perseveration on the WCST may also involve problems in selective attention, inhibition, orienting responses, habituation and sustained attention (Stuss et al, 1994). Shallice (1988) claims that perseveration results from an inability to generate voluntary actions. He sees voluntary action as being on the top of the hierarchy of "higher level" functions and under the control of a supervisory attentional system which continually influences the choice of possible responses an individual can make at any given time. This system is particularly necessary for the choice of options which are not activated by environmental events, like bringing information stored elsewhere in the brain about past experience and predicted outcomes into the decision making area. If this system is defective, then the individual responds only to the immediate environment.

Notwithstanding the variety of interpretations that perseveration lends itself to, it is safe to postulate four, not necessarily mutually exclusive, possible difficulties that individuals may face during the administration of WCST, which may result in perseveration. Firstly they may be unable to perceive alternative response options.

However, anecdotal evidence from past studies (Milner, 1963) as well as clinical observations from the current study suggests that this is unlikely. Individuals who perseverate often claim to be aware of the possible sorting categories either when asked or on their own accord, despite heavily perseverating. In addition many individuals indicate that their responses are wrong as they are making them. Dias et al (1994) also reported that in a visual discrimination task, patients would verbally state that the contingencies have changed but were nevertheless unable to change their behaviour accordingly.

Secondly, individuals may have difficulty disengaging from a particular way of responding, or releasing attention from a particular sorting category. This represents the more prevalent view of perseveration and is heavily influenced by the work of Brenda Milner (1963, 1964, 1984) Stemming from this idea, as discussed previously, is the notion that if a particular response that has been chosen becomes established or 'overlearned', perseveration to that response will increase. In the case of the WCST, this would mean that individuals begin sorting to a particular dimension (e.g. colour) and the more they sort successfully the more difficult they would find it to release their attention from that dimension in order to sort to another.

Thirdly, individuals may be unable to generate new responses or to automatically generate a variety of probable solutions to a problem. In this case also, one would expect that the more a particular response is reinforced, the more difficult it would become for the participant to come up with alternatives. In this case, it is possible that a pattern of feedback by the experimenter might facilitate response generation especially if changes in the feedback are easily identifiable.

Finally, perseveration may be due to an inability to effectively utilise external or internal cues to facilitate performance. Although this has not been directly linked to perseveration, there is a long history of research claiming that frontal lobe patients fail to utilise cues and feedback effectively in order to correct errors and improve performance. In other words cues that signal error and are supposed to trigger a change in responding, whether externally provided or self-directed, do not serve the purpose of behavioural guidance. Alivisatos and Milner (1989) and Alivisatos (1992) found that frontal lobe patients are unable to utilise directive cues to improve their performance when responding to particular target orientations. They found that response time did not improve when information about orientation was provided in advance. Additionally, in 1994, Dias et al found that frontal lobe patients had specific difficulties in modifying responses especially after negative feedback on reversal and visual discrimination tasks.

Earlier, Konorski and Lawicka (1964) conducted delayed alteration experiments on animals (dogs and cats) with frontal ablations. They found that the animals perseverated consistently on a particular choice despite negative reinforcement. They proposed that the cue or "conditioning signal" becomes insignificant as an "unguided release response" takes place that is triggered by the mere presentation of the stimulus (Konorski and Lawicka, 1964). This idea is similar to the more recent concept of environmental dependency or utilisation syndrome. Nauta (1971) also found that monkeys with frontal ablations showed guidance failure on object discrimination tasks. Milner (1964) and Luria (1969, 1973) found that both spatial and nonspatial cues fail to guide response among human frontal lobe patients. Milner (1964) administered the Weigl test (a variation of the WCST) to patients with frontal lobe injuries. The test entails sorting 128 cards on the basis of 3 criteria similar to the WCST. The participants were given no verbal instructions. Although they seemed able to "verbalise the requirements of the test", they still perseverated, as if unable to use this information to guide their behaviour when the criterion changed. Milner also suggested that, in a stylus- maze task, the basic problem among frontal lobe patients was complying with the rules. As in the case of the WCST, she found that they were aware of their mistakes but this awareness did not facilitate their performance (Milner, 1964). Milner also maintained that individuals with frontal lobe injuries especially in the dorsolateral area have difficulty with the standard WCST because of their inability to adjust their responses by use of external cues that are dependent on their performance. This inability to benefit from cues is, according to Milner an example of inhibitory loss, very similar to that characterising utilisation behaviour (Milner, 1984).

Luria (1969) argued that a disturbance in the verbal regulation of behaviour is a distinctive feature of frontal lobe injury in man. Perseveration occurs in individuals or in states in which the past history of responses exerts more influence in guiding behaviour than does the current external cue. Konow and Pribram (1970) distinguished between error recognition and error utilization. When testing a frontal patient on a simple drawing task, they found that while error recognition remained intact, error utilization was disturbed. Their patient did not utilise the knowledge of her mistakes to improve performance. Pribram proposed that evaluative processes rely on the posterior party of brain while utilisation involves frontolimbic regions. The particular patient seemed to register but not utilise errors for subsequent performance.

The differentiation between registering and utilising errors may be related to the fact that utilisation is a function that is more supervisory in nature. It may explain why Stuss et al (1983) found that patients who had undergone frontal lobotomy became more impaired after the sorting categories were disclosed to them. It was claimed that as direct result of being offered additional information, the participants became reflective on their behaviour. This made the task more "supervisory" in nature. Indeed, Benson (1981) found that the performance of schizophrenics on the WCST became worse after they were told about the three sorting categories, whereas the performance of healthy individuals improved. It must be noted, however, that numerous other studies contradict Benson's findings by indicating that at least for patients with schizophrenia, instructions tend to improve performance (Green et al 1992, Bellack et al, 1990, Goldberg et al, 1987, Metz et al, 1994, Vollema et al, 1995) on a variety of cognitive tasks including the WCST.

An additional dimension to understanding the process by which individuals utilise cues to moderate their performance is offered by the work of Damasio (1994, 1996) on the somatic marker. By using a gambling task, Damasio illustrated the importance of a somatic marker i.e. an emotional reaction to an externally provided cue that is needed to guide behaviour in a risk-taking situation and assist decision-making. Damasio (2000) also indicated that when emotions and motivational forces are not controlled, decision making and reasoning is disrupted. Damasio's work is somewhat reminiscent of Rolls (1994) and Dias et al (1996) who noted the importance of emotion in learning and subsequently perseveration. Rolls et al (1991) found that frontal lobe damage was associated with impaired performance on tasks that included changing reward contingencies, the difficulty in modifying behaviour being more noticeable after negative feedback. Dias et al (1996) differentiated between attentional selection (associated with the lateral prefrontal cortex) and affective processing (orbital frontal) (Dias et al, 1996). It would be difficult to determine which type of perseveration best reflects the one present during the WCST.

Two types of perseveration have been proposed depending on whether they represent a disruption of the emotional response described by Damasio (affective perseveration) or a difficulty in changing conceptions (paradigmatic perseveration) (Carlson et al, 1998).

Overall the knowledge gained so far relating to perseveration has provided many clues and propositions as well as a relatively comprehensive understanding of how perseveration is manifested and the various indicators of the cognitive impairments it may reflect. The current research might hopefully shed more light into the circumstances that are more likely to produce it and help achieve an understanding of its relationship to two crucial cognitive processes: emotion and learning.

Chapter 2

A brief historical overview of the theories of frontal lobe function

Although perseveration has not been uniquely observed among frontal lobe patients, the frontal lobes and more particularly the dorsolateral prefrontal cortex have been most associated with perseveration on the WCST. Despite contradicting evidence, one of the more consistent approaches to perseveration in the literature is that it reflects a frontal lobe deficit of some sort. The cognitive characteristics that have been attributed to the frontal lobes often include components that describe or even define perseveration, for example the switch between different conceptual frameworks (Goldstein, 1948). Thus an overview of frontal lobe function is necessary for the understanding of how perception of perseveration has been shaped.

The frontal lobes have been regarded as the seat of the highest intellectual functions and are said to control all capacities uniquely human. It is not surprising that it was suggested that the entire period of human evolutionary existence should be called the "age of the frontal lobe" (Tilney, 1928, in Hotz and Helm-Estabrooks, 1995). This view of the frontal lobe was reinforced by early research showing no life-threatening or obvious specific impairment after damage to the frontal lobe, but rather a change in character, personality, social skills and "intelligent observation" (Ferrier, 1876). Although a number of investigators have demonstrated the existence of specific defects on simple sensorimotor tasks and not on complex problems (e.g.Teuber, 1959 in Hotz and Helm-Estabrooks, 1995), an overwhelming amount of literature especially during the last decades seems to indicate that the frontal lobes are involved in such complex tasks as planning, estimating and reasoning. In any case, the vast literature that has accumulated regarding the frontal lobes and their functions reflects, apart from the bewilderment of early scholars, the multiple and complex ways in which behaviour is affected, but also reveals inconsistencies and generalisations.

The study of the relationship between anatomy and cognition has never been more perplexing and more intriguing than in the case of the frontal lobe. Specific knowledge of frontal lobe functions has remained limited and hypotheses remain controversial. Deficits associated with frontal lobe damage are often classified under the more general heading "frontal lobe syndrome" which itself reflects "an amorphous, varied group of deficits, resulting from diverse aetiologies, different locations, and variable extents of abnormalities" (Stuss and Benson, 1984, p.3). However, despite the diversity of study outcomes, they do paint a picture of the frontal lobe as an integrator of sensory, motor, affective and memory information arriving from a variety of sources outside the frontal lobe.

Historically, research on the frontal lobe started in the beginning of the 19th century. Flourens (1824) was the first to conduct experiments involving the frontal lobe. In 1835, Franz Joseph Gall (1835) studied the frontal lobe in conjunction with social action, foresight and creativity. In addition, in 1861 Broca proposed that impairment of verbal communication skills is related to the posterior-inferior frontal area and adjacent cortex of the left temporal lobe while Fritsch and Hitzig (1870) related the posterior frontal regions to motor movement. At around the same period Hughlings

Jackson (1884) suggested that the frontal lobe represented the "higher centres" which were responsible for controlling the "lower centres". This idea is very similar to the current attribution of executive functions to the frontal lobe.

The story of Phineas Gage in 1848 had already prompted research into the relationship between personality and social conduct and the frontal lobes (Ferrier, 1878). Jastrowitz (1888) and Oppenheim, (1890) observed "inappropriate cheerfulness", lack of concern (or "moria"), sarcasm and aggression among frontal lobe patients. It was noted however that not all patients showed this type of change to their personality. The effects were variable and could be multiply determined. It is quite apparent that earlier research was mostly concerned with the role of the frontal lobes in personality, emotions and social conduct.

Towards the beginning of the 20th century, cognition became a focal point in frontal lobe investigations. Franz (1907) proposed that frontal lobes are important for solving puzzle-box performance in cats and monkeys. Gelb and Goldstein (1925) found that anterior frontal lesions in humans caused deficits in problem solving while Lashley (1929) found an increased decrement in maze-learning ability in rats as larger areas of the frontal cortex were destroyed. Jacobsen and Nissen (1937) and Jacobsen Wolfe and Jackson (1935) showed that animals with prefrontal lesions could not perform delayed response tasks. This was described as a loss of the ability to maintain "mental set". Ackerly (1937) and Ackerly and Benton (1948) proposed that frontal lobe injury produces an inability to attend simultaneously to more than one environmental event. This may be interpreted as an inability to switch between events. Nauta (1971) characterised frontal lobe disorders as "the derangement of behavioural programming". Similarly to Luria (1966, 1973) Nauta (1971) believed that the frontal lobe is the site where major sensory and motor systems connect and integrate with all components of behaviour. Incoming information from both external and internal sources, conscious and unconscious as well as stored memory components and arousal centres are integrated there to produce a behavioural response (Lezac, 1982). Thus as Hecaen and Albert (1978) put it, the frontal lobes "regulate the "active state" of the organism, control the essential elements of the subject's intentions, program complex forms of activity, and constantly monitor all aspects of activity".

Attempts to localise function within the frontal lobe became particularly common in the 1960's. The frontal lobe was seen as holding in separate areas affective, cognitive, motor and verbal abilities. Studies on localisation, although providing an ever-clearer picture of the general capacities linked to the frontal lobe, also reveal a number of inconsistencies that often turn frontal lobe research into an elusive endeavour. For example functions such as conceptual shifting or response-inhibition have been localised in the ventral frontal areas by some studies (Iversen and Mishkin, 1970) and in the dorsal by others (Milner, 1963). Valenstein (1973) distinguished between the cognitive functions of the dorsolateral frontal cortex on the one hand and the affective process of the orbitomedial frontal region on the other. Dias (1996) similarly identified the dorsolateral region as responsible for processes involving attentional shifts and the orbital frontal cortex associated with affective processes. The initial studies of perseveration, as described in the previous chapter were concerned with its localisation within the frontal lobes. Indeed Milner (1963) identified the dorsolateral region as responsible for perseveration on the WCST. On the other hand Luria (1965) identified two specific types of perseveration linked to different sites within the frontal lobe. The first type pertaining particularly to repetitive movement was thought to be located in the premotor area of the frontal lobe, while the second which involved impairment in switching between cognitive tasks was associated with the anterior or basomedial portions of the frontal lobe.

Attempts to summarise the functions of the frontal lobe in the literature almost always include planning, decision-making, judgement, cognitive flexibility, self-perception, social conduct and abstract reasoning. Goldstein (1927, 1936, 1944, 1948) suggested that the frontal lobes are the source of the "abstract attitude". This encompassed not only abstract reasoning but also a variety of elusive functions such as initiative, foresight, self- awareness, flexibility in behaviour, and the capacity to break down complex situations and ideas into their constituent parts. Specific elements of what Goldstein called "abstract attitude" include the ability to shift from one situation to another, to hold in mind simultaneously different aspects of a situation, to grasp the essential of a given whole, to break up a given whole into parts, to isolate and synthesize them, to plan ahead ideationally, to assume an attitude towards the "mere possible" and to think or perform symbolically (Goldstein and Scheerer, 1941). Due to its broadness, the idea of the abstract attitude lost popularity in recent decades.

Overall, more recent views of the frontal lobe include very similar attributions to earlier approaches, especially regarding conceptual shifts and planning. In an attempt to summarise frontal lobe function, Lezac (1983) cited goal formulation, planning and carrying out goal directed plans as well as conceptual functions such as perceptual organisation, the processing of two or more mental events at a time and monitoring and modulating behavioural outputs. She also included the notion of abstract thinking and mental flexibility.

Studies consistently suggest that patients with frontal lobe lesions are impaired on tasks requiring constant shifting of response to meet changing environmental demands or to take account of feedback (Stuss and Benson, 1986) as well as on tasks, which require the inhibition of irrelevant material (Luria, 1976, Milner, 1964, Milner, 1982, Moscovitch, 1982, Squire, 1982, Parkin, 1987). What makes the frontal lobe studies so intriguing is the very nature and variety of cognitive abilities they show the frontal lobe to encompass. As Tranel et al (1994) suggested the capacities attributed to the frontal lobes seem to be at the top of a hierarchy of cognitive functions. Furthermore, they seem to rely on other cognitive components such as memory, perception and linguistic functions, the most important considered by many to be working memory (Goldman-Rakic, 1987, Baddeley, 1992). These cognitive abilities are often described under the umbrella term "executive functions". As useful as this term may be in terms of its descriptive value, it is quite elusive, lacks precise operational definition and relates to many functions that are ambiguously related. In reality, just what executive functions mean escapes the majority of investigators and varies greatly among the rest. The fact that “frontal” and "executive" are often used interchangeably adds to the confusion and can be seen as one of many instances of "trespassing back and forth between psychological constructs and anatomical terms". (Tranel et al, 1994).

To attempt to summarise, in one statement, the role of the frontal lobe may be futile given the complexity of the matter. However, the larger portion of available research seems to indicate that the frontal lobe has the role of linking together ongoing sensory and motor information with appropriate memory resources, placing them in an emotional context and integrating them in such a way as to promote awareness of the self in place and time, making possible the appreciation of the past and the contemplation and planning of the future.

As mentioned earlier the aim of the current research is not to question whether or not perseveration is a frontal lobe function. A number of studies have linked perseveration not only with the frontal lobes, but also with specific sites within the frontal cortex to the exclusion of others (for example Milner, 1963, Mishkin, 1964, Passingham, 1972, Dias, 1996, Lombardi, 1999). It is worth remembering however, firstly that between them these studies offer data that is more conflicting than it is compatible and secondly that a number of studies have also linked perseveration with areas outside the frontal lobe.

Clinical populations such as individuals with Parkinson's disease (Owen et al, 1992, Owen et al, 1993, Brown and Marsden, 1998) schizophrenia (Summerfelt, 1991, Young et al, 1993, Stratta, 1993, Green et al 1992, Bellack et al, 1990, Goldberg et al, 1987, Metz et al, 1994, Vollema et al, 1995, Franke et al, 1992, Abbruzzese et al, 1996), Korsakoff's syndrome (Oscar-Berman, 1980, Joyce and Robbins, 1991) and patients with traumatic brain injury (Hotz and Helm-Estabrooks, 1994, Hotz and Estabrooks, 1995, Parsons, 1975 and Tarter and Parsons, 1971, Delis et al, 1992) have shown in recent literature to display moderate to high levels of perseverative errors. It could be argued that all the above individuals may experience direct or indirect frontal dysfunction.

It is nonetheless taken into consideration in the current research that perseveration has been viewed as a "frontal" deficit for years and that it is likely that its underlying cognitive mechanisms are affected by frontal lobe activity.

However, the present study aims to explore perseveration in the absence of its possible anatomical affiliation to the frontal lobe. On the one hand existing frontal lobe theories may be a useful tool when conceptualising the cognitive mechanisms that underlie perseveration, which is why an account of frontal lobe research was deemed necessary. On the other hand it is possible that the very preoccupation with viewing perseveration as a frontal lobe dysfunction may hinder a better understanding of it. The assumed connection between perseveration and the frontal lobe immediately carries significant implications regarding its underlying cognitive mechanisms and gives rise to a circular argument of which there are many in frontal lobe literature.

Chapter 3

Perseveration and Learning

The association between perseveration and learning has had a long standing, although often merely implied, existence in the literature. As discussed in the previous chapters, perseveration is predominantly thought to reflect a failure to disengage from a well-learned behaviour. The relationship between learning and perseveration however, has not really been explored in the literature. Nonetheless, the tasks that are used to illustrate and measure perseveration are usually simple learning tasks in which behaviour is based on changing reward contingencies, such as reversal and discrimination tasks. According to Oscar-Berman (1980) these tests "provide a measure of original learning" making it possible to "trace development of learning strategies". In clinical settings, perseveration has been measured by sorting tasks such as the Weigl test (Grant, 1948) or the Wisconsin Card Sorting Test (WCST) (Berg, 1948, Grant and Berg, 1948), which are more complex but in which performance again is dependent to a large extent on responding to feedback in order to learn the rule of the test.

The association between learning and perseveration is not a straightforward one. As mentioned above, it is implied in the literature more often than it is explained. Perseveration may suggest a fault in the process by which behaviour is shaped, through trial and error, to adapt to new situations, by means of responding to cues. In this sense, perseveration may reflect an inability in forming new associations or utilising old ones according to the requirements of the situation. In any case there seems to be no doubt of a relationship between the mechanisms by which learning takes place on the one hand and perseveration on the other.

As discussed earlier, Milner (1963) suggested that individuals perseverate because they have difficulty switching tasks after they have repeatedly performed and mastered one particular task. She further proposed that frontal lobe damage (specifically in the dorsolateral prefrontal cortex) causes an inability to inhibit initially successful or reinforced responses, which in turn results in a decreased ability to shift response strategy (Milner, 1964). Perseveration therefore reflects the inability to disengage from a learned response. The idea put forward by Milner seems to suggest a fault in the learning process, in the sense that learning of the overall task is inhibited by a reluctance to 'unlearn' an established association.

Rolls et al (1991) found that frontal lobe patients (with damage at the orbitofrontal cortex) were severely impaired in altering their behaviour in response to changed contingencies in a visual discrimination task (they continued to respond to a previously correct stimulus). Along similar lines as Milner, Rolls maintained that this behaviour reflects a deficit in extinction, or "failure to break or adjust previously learned associations between stimuli and primary reinforcement" (Rolls et al, 1991). In other words the occurrence of a specific behaviour does not decrease after reward is no longer given. Similarly, in 1994, Rolls et al found that in a simple discrimination task, patients (with orbitofrontal lesions) perseverated to a previously rewarded stimulus, despite acknowledging that the odds had changed. Again it was suggested that the difficulty lay in modifying responses especially when followed by negative consequences.

Perseveration in the same study (Rolls, 1994) also correlated highly with inappropriate social behaviour and major changes in emotion. The authors introduced the idea that like perseveration, ineffective social behaviour and emotional changes that result from brain injury are associated with a fault in the learning processes. In particular, they suggested that the deficit lay mainly in the failure to modify responses when followed by negative reinforcement. Frontal lobe injuries have often been associated with inappropriate social conduct, in terms of incongruous communication styles or behaviours or in the sense of engaging in improper social behaviour resulting from the exaggerated use of environmental cues (as in utilisation behaviour). The similarity between these and perseveration may lie in the fact that in a social context, individuals rely on cues (external and internal), to control, moderate and modify the ongoing patterns of their behaviour.

Dias et al (1996) claimed that primates with frontal lobe damage showed an inability to inhibit previously learned responses in a visual task, which were inappropriate for the current situation. Dias et al differentiated between two different types of cognitive shifting (associated with different regions of the prefrontal cortex), namely perceptual and affective shifts. The former requires attentional selection while the later involves changing behaviour as a result of the change of the emotional significance of stimuli. Dias et al found that monkeys with damage to the lateral prefrontal cortex that were trained to maintain an attentional set towards one dimension over a series of discriminations with novel stimuli lost inhibitory control in attentional selection, thereby losing the ability to shift attentional set from one dimension to another (extra dimensional shift). On the other hand, monkeys with damage to the orbitofrontal cortex lost inhibitory control in 'affective' processing and were unable to alter their behaviour in response to changing of the emotional significance of stimuli. In both cases the problem was an inability to shift from previously rewarded responses, because of difficulty in inhibiting those responses.

Deficits on tasks such as pattern reversal and object alteration have also been reported in other populations that are known to perseverate, such as Korsakoff's patients. In a reversal-learning paradigm, Zola-Morgan and Oscar-Berman (1980) found that Korsakoff's patients were impaired on visual and spatial tasks. This was taken to reflect a difficulty in recognising the relevance of cues and forming new associations subsequent to unlearning a related old response. Petrides (1982) found that frontal lobe lesions result in a distinct inability to perform on tasks that are based on associative learning because of the frontal lobe's implication in situations requiring the production of specific responses to stimuli. Robbins and Brown (1990), Owen et al. (1993) and Ridley et al. (1993) emphasised that the history of reinforcement of correct responses affects responding in tasks such as the WCST (and not merely the history of exposure to them). Furthermore, Owen et al (1993) differentiated between two distinct deficits that relate to the pattern of reinforcement on reversal tasks where set shifting was required. Perseveration occurs when individuals fail to disengage from a previously rewarded response (found mostly among frontal patients) whereas learned irrelevance is a result of the inability of patients to switch attention to a response that was previously wrong.

A prevalent view in the literature of perseveration, initially put forward by Milner (1963) is that the better learned a response is, the more it will be perseverated to. In situations, such as during the WCST, in which an individual is exposed to and reinforced for a particular response, he/she would be more likely to provide that response, as the test progresses, regardless of the subsequent cues provided by the experimenter that deem that response inappropriate. This prevailing response would therefore be a reflection of previous experience, and previous learning. In other words, the more instances of reinforcement of particular responses are presented during a task, the stronger the influence of the reinforced responses on performance. A logical conclusion of this idea would be that perseveration is more likely to occur under circumstances where learning of a particular response is facilitated. This idea is compatible with Lezak's suggestion (1983) that the shorter run of six consecutive trials in the Modified Card Sorting Test (MCST, Nelson 1976) as compared to the ten consecutive trials in the standard WCST, would not give individuals an adequate opportunity to develop a strong response set i.e. adequate learning of one particular response. This in turn would be reflected in the lower rate of perseveration than would be expected by patient groups known to perseverate (for example frontal lobe patients or patients with Parkinson's disease). Perseveration then according to this view is highly influenced by the learning process occurring during testing and may even reflect in essence, a learning deficit.

From the above it becomes obvious that for both humans and primates frontal lesions are associated with impairment in changing behaviour according to feedback, which may further be linked to the inability to respond to cues of varying emotional significance. Furthermore, the preceding studies suggest that perseveration on a variety of learning tasks, pertains to an inability to change behavioural responses according to changing cues and that it increases as the old response is reinforced.

Chapter 4

Perseveration and the Wisconsin Card Sorting Test (WCST)

The Wisconsin Card Sorting Test (WCST) was originally developed to assess abstract thinking (Berg, 1948 and Grant and Berg, 1948). Since then its use as a neuropsychological instrument has grown and today it is used mainly to assess frontal lobe impairment. Its association with the frontal lobe, as mentioned earlier, was brought to attention after the work of Brenda Milner (1963) who found that patients with frontal lobe injuries showed significantly more impaired performance on the WCST, when compared to patients with non-frontal injuries.

The WCST requires individuals to sort cards according to three sorting categories, namely colour, form and number (of items depicted on the cards), by following the experimenter's feedback ('right' or 'wrong'). Effective performance on this test would involve the selection of appropriate, feedback-related responses in a situation where a number of options exist. This selection is based on monitoring responses on the basis of feedback, inhibiting irrelevant or incorrect responses and rule learning based on internal representations. In addition, it would involve attention to relevant stimuli (Sandson and Albert, 1984, Goldstein, 1948, Wepman 1972), and short-term memory (Sandson and Albert, 1984, Hudson, 1968, Buckingham et al, 1979, Shidler et al, 1984).

Characteristics of the WCST and Scoring Procedure

The original WCST consists of four stimulus or key cards unique in terms of colour, shape and number of items and two sets of sixty-four response cards comprising of all possible combinations. The cards may be green, blue, yellow or red, the items on the cards may either be stars, circles, crosses, or triangles and finally each card may have from one to four items depicted. According to instructions presented in Heaton's manual (Heaton, 1993), the administration procedure is as follows: The Participant is presented with four key cards, which are placed on the table along with two decks of cards and told from the start that not much will be disclosed about the task. The participant is asked to match each of the cards in the decks to one of the four key cards. He/she is told to take the top card from the deck and place it below the key card he/she thinks it matches. It is made clear to the participant that the experimenter will not disclose how the cards should be matched but will inform the participant whether he/she is right or wrong after every sort. If the participant is wrong, he/she is instructed not to correct the last sort but rather to try to get the next card right. Finally the participant is informed that there is no time limit on the test.

Individuals are required to sort the cards into three categories or sorting dimensions, namely colour, number and shape of items depicted on the card. Furthermore, those dimensions should be selected in a predetermined sequence (colour, then form and then number), which is then repeated. However, the participants are not told what the sorting categories are or how to sort the cards. They are simply told that they will receive positive feedback ('right') upon a correct and negative feedback ('wrong') upon an incorrect response. Positive feedback is initially given when an individual begins to sort the cards according to colour. He/she must sort to colour ten consecutive times before positive reinforcement for that particular category stops and subsequent sorting to colour is given negative feedback ('wrong'). The participant then should sort according to form and then to number for ten consecutive trials each. The same sequence is then repeated. There are no time restrictions for the completion of the test.

The critical features in the administration procedure of the WCST are that no information is given to the participants as to the sorting principles and that these principles change with no prior warning. Measurements obtained from the WCST include number of perseverative errors (PE), number of total errors and number of categories completed, while scores calculated include percent of perseverative errors (%PE) and percent total errors (%TE). The scoring procedure according to Heaton (1981) is as follows: A response is correct if it matches the current sorting principle and it is an error if it doesn't. Many of the cards on the WCST are ambiguous in the sense that they may share a sorting dimension with more than one of the key cards. The issue of ambiguity requires special consideration whilst scoring because it affects whether a response is scored as perseverative or not. An unambiguous response is a response that cannot represent more than one sorting principle. In other words, a response card that matches the stimulus card on only one dimension would provide an unambiguous response. If this response is wrong (i.e. does not follow the current sorting dimension), then it is marked as an unambiguous error. For example placing a card with three yellow stars under the stimulus card with two green stars is an unambiguous response because the response card matches the stimulus card only in terms of form (stars). It would be an unambiguous error if the current sorting principle happened to be number or colour. If however a card with three green stars is placed under the same stimulus card it would be an ambiguous response since the response card would match the stimulus card on two dimensions: both colour and form. A perseverative response that is also incorrect (does not match the current sorting category) is also a perseverative error. The first unambiguous error establishes the perseverated-to principle for the current category. This error will not itself be scored as perseverative but any subsequent unambiguous error that matches this principle will. If ambiguous responses match the same principle, they too are scored as perseverative, but only if they are "sandwiched" between unambiguous ones. Once a category (e.g. colour) is completed, any unambiguous response to the same category (colour) (beginning immediately after the completion of the category i.e. the 11th sort) will be marked as perseverative and will provide the new perseverated-to principle until the new category (form) is completed. As with all perseverative responses, if ambiguous responses matching the perseverated-to principle (colour) occur between unambiguous ones, they will be marked as perseverative. However, the perseverated-to principle may change within a category: If an unambiguous error is found (e.g. to number) that matches neither the current (form) nor the previous category (colour), then the perseverated-to principle changes as long as three unambiguous errors to this new principle (number) are made. These errors do not have to be continuous as long as all ambiguous responses between the first and third unambiguous error match this new principle. Again the first unambiguous error will not itself be marked as perseverative. The second unambiguous error and all subsequent matching responses (ambiguous and unambiguous) will be scored as perseverative as long as ambiguous responses matching the perseverated -to principle are "sandwiched" between unambiguous ones.

The use of the WCST in localising performance

The WCST is used extensively as a neuropsychological assessment instrument and one of its purposes is to identify frontal lobe damage, or to examine whether a particular individual shows "frontal-like" cognitive impairments such as perseveration. A number of studies found significant differences in performance between frontal and non-frontal populations on the WCST (Milner, 1963, 1964, Nelson, 1976 and Robinson et al, 1980). However, the WCST does not always successfully differentiate between frontal and non-frontal damage (Drewe, 1974, Robinson et al, 1980, Mountain and Snow, 1992, Anderson et al, 1991). Nevertheless, a problem that is thought to underlie poor performance on the WCST, namely the inability to change a behavioural response in accordance to varying external cues, is considered to be a characteristically "frontal" problem.

The history of brain localisation of WCST performance has been a subject of debate. Specific localisation within the frontal lobe as well as laterality have also posed problems and given rise to questions. For example, in one of the earliest studies, Teuber, Battersby and Bender (1951) suggested greater perseveration on the WCST to be associated with posterior as opposed to anterior lesions, while McFie and Piercy (1952) thought that the critical factor was laterality with the dominant hemisphere associated with impaired performance. Milner (1963) subsequently identified the frontal lobe as the locus for perseveration on the WCST. She tested seventy-one patients on the WCST before and after unilateral cortical excision for treatment of epilepsy. Patients with lesions located in the dorsolateral prefrontal cortex (DLPC) performed significantly worse than patients with lesions elsewhere. In later studies she also found evidence of laterality with left frontal lesions associated with poor performance on the WCST, irrespective of location of language (Milner, 1975). A number of functional neuroimaging studies since, have reported increases in activation of the left DLPFC during the WCST (Kawasaki et al, 1993, Nagahama et al, 1995, Rezai et al, 1993). On the other hand, Drewe (1974) found that medial frontal lobe lesions affected WCST performance most severely. Similarly to Milner she also found a laterality effect with the left frontal group more impaired. Meanwhile, Stucco et al (1983) suggested that the orbitofrontal region plays the most important role in WCST performance.

Kertesz and Dobrowolski (1981) compared perseveration scores among thirty-seven patients with right hemisphere lesions according to locus of lesion i.e. frontal, central cortical, central deep, parietal and occipital. They found that perseveration was significantly higher for frontal and extensive central groups. Lombard et al (1999), like Milner and Drewe found laterality to be related to WCST performance. Contrary to Milner and Drewe however, they concluded that the right dorsolateral frontal sub-cortical circuit was primarily involved in WCST performance. Stuss et al (2000) argued that if nonfrontal processes involved in the WCST could be taken into account, it may serve as a reasonable index for frontal function. Stuss et al compared prefrontal activation (measured by ERP) during the WCST between early (novel classification) trials and later (repetition) trials. Differences between novel classification and repetition trials appeared early at the left frontotemporal region and later at the parietal areas of both hemispheres. It was suggested that early differences between the trials reflect the activation of the left dorsolateral prefrontal cortex (DLPFC), which is especially active during extradimensional shifts i.e. novel classification trials.

Indirect support of a frontal lobe involvement in perseveration comes from studies showing that patients with neurological conditions that affect sub-frontal areas like the basal ganglia and the limbic system have been linked to high rates of perseveration on the WCST (Eslinger and Grattan, 1993). Parkinson's disease and other dementias (Bowen, 1975, Bayles, 1985, Cooper, 1991, Owen et al, 1993, Ebersbach et al, 1994, Lamar et al, 1997), Korsakoff's disease (Oscar-Berman, 1980, Joyce and Robbins, 1991), schizophrenia (Franke P et al, 1992. Abbruzzese et al, 1996) and obsessive compulsive disorder (Harvey, N.S., 1986, Abbruzzese et al, 1997) as well as traumatic brain injury (Estabrooks Hotz and Helm-Estabrooks, 1994) which often involves frontal damage (Mattson and Levin, 1990) have all been associated with increased rates of perseveration.

Stratta et al (1993) found significant differences between healthy and schizophrenic participants on the WCST on all indices. Interestingly these differences exclude perseverative errors. On the other hand, Summerfelt et al (1991) suggested that impaired performance on WCST among schizophrenic patients is based primarily on motivational deficits. However, Young et al (1993) and Lysaker and Bell (1994) also linked poor insight in schizophrenic patients to cognitive deficits and subsequent poor performance on the WCST. Similarly, Stratta et al (1994) also maintained that poor insight plays a crucial role in poor performance on the WCST as it relates to poor information processing and organisational skills, including the inability to develop a response set and follow a plan of action. However, when patients are allowed to say the sorting category they are employing at any given time their performance was showed to improve dramatically. Also the performance on schizophrenic patients on the WCST greatly improves with the use of instructional cues (Goldman R et al, 1992). In this case the cue provided was informing the participants that sorting categories may change at any time without informing them about the precise time of the change. This information was given at the onset of the test and after every thirty-two sorts. A study by Cuesta et al (1995) however showed no significant relation between poor insight and impaired performance on the WCST. Crider (1997) maintained that the poor performance of schizophrenic patients on the WCST is a result of an ineffective information-processing system and disinhibition of inappropriate responses while Gold et al (1997) interpreted poor performance on the WCST primarily as a working memory deficit.

As mentioned previously, dementias and especially Parkinson's disease have been associated with perseveration on a variety of tasks including the WCST. Perseveration among Parkinson's disease patients is thought to involve a basic impairment in shifting set (Owen et al, 1992, Owen et al, 1993) or an inability to maintain set (Flowers and Robertson, 1985). Brown and Marsden, (1998) found that although patients showed impairment on the WCST they were not impaired in establishing set or switching between sets on the Brown and Marsden's Reaction Time Task (1998), which involves making right-left decisions under two stimulus conditions. Brown and Marsden proposed that Parkinson's patients perform badly on the WCST because they have to rely on internal control for the regulation of behaviour. Lees and Smith (1983) maintained that instability of cognitive set, perseveration or increased distractibility are the underlying causes for impaired performance of Parkinson's Disease patients on Nelson's modified version of the WCST (MCST, Nelson, 1976) as well as on the Odd-Man-Out Test (Flowers and Robertson, 1985) and Benton's Word Fluency Test.

However an increasing number of researchers have claimed that the WCST may not be as sensitive an indicator of frontal lobe impairment as once thought. A number of studies suggest there is not enough evidence to postulate that frontal patients perform more poorly than non-frontal patients on the WCST (Drewe, 1974, Mountain and Snow, 1992, Anderson et al, 1991). Specifically, Grafman et al (1990) did not find a significant difference between a frontal group and a non-frontal group on the WCST while studies by Anderson, Damasio, Jones and Tranel (1991) also revealed no significant differences between the performance of frontal and nonfrontal populations on the WCST. The later study also found that optimal cut-off scores for frontal and non-frontal patients correctly classified only sixty-two from a total of ninety-one individuals tested. Comparisons between left, right and bilateral frontal damage as well as different areas of damage within the frontal lobes produced no significant differences. In addition, studies have shown that patients with non-frontal lesions (for example lesions in the temporal lobes) also show perseveration on the

WCST (Strauss et al, 1993, Horner et al, 1996). The evidence against an exclusively frontal contribution to performance on the WCST seems to be less strong than initially thought. Indeed there has been doubt as to whether tests do or even could exist that specifically target frontal lobe capacities (Wang, 1987). In any case the evidence seems insufficient to determine a consistent relationship between poor WCST performance and frontal lobe damage (Anderson et al, 1991). As Mountain and Snow (1993) suggested, owing to the fact that the WCST is a complex multifactorial test, engaging therefore a variety of cognitive functions, it is unlikely to be sensitive only to frontal lobe functions. What is more plausible then, is that the WCST taps onto a variety of different skills, managed by different areas of the brain, which would explain why lesions in different areas produce impairment on the test. It may well be the case as Costa (1988) put it that it may be "easy to find tests sensitive to frontal lobe dysfunction and very difficult to find tests that are specific for it".

Variations of the WCST

In the past, different forms of the WCST were utilised not as a way of investigating perseveration but more or less as a means to simplify the administration procedure while maintaining the reliability and validity of the original version. The most popular modification of the WCST is the Modified Card Sorting Test (MCST) introduced by Nelson in 1976, which was developed as a less stressful test for elderly patients, or patients vulnerable to the strain of testing (Hart, 1988, Greve and Smith, 1991). It differs from the original in that ambiguous cards are removed, the number of correct consecutive responses before change of category are changed to six instead of ten, the participants are notified regarding the change of rule and lastly the sequence of sorting categories is not predetermined.

Changes were also implemented in regards to the scoring procedure, whereby perseverative errors were calculated as a percentage of total errors and not total responses as is the case with the original version. This last alteration has largely passed unnoticed in the literature. However it may very well reflect a serious deviation from the original test, firstly because it may provide an inflated estimate of perseveration and secondly because it carries the implication that perseveration is not defined by the overall performance of the task. In any case, the assumption that was made at the time was that the MCST was a less tiresome alternative to the WCST but nonetheless as effective as its counterpart in assessing frontal lobe damage. Since 1976 it has been the most extensively used alternative as a measure of frontal lobe executive functioning (Butler, Retzlaff and Vanderploeg, 1991, Mountain and Snow, 1993). In addition Kwentus, Wade and Taylor (1988) were able to distinguish alcoholics, depressed patients, patients with dementia and healthy elderly on the basis of performance on the MCST. A number of studies have maintained the comparability between the MCST with the original WCST (for example Nelson, 1974, Drewe, 1974). However, it has recently been suggested that the removal of ambiguous cards in the MCST may profoundly alter the test (Robinson et al 1991, Axelrod et al, 1992, Zubicaray, 1996) to the extent that it may be tapping onto different cognitive abilities altogether (Lezac, 1983, Zubicaray et al, 1996). Specifically, it is claimed that the shorter number of reinforced trials per category (six instead of ten) create a difficulty in that the subject is unable to develop a strong response set or may obscure occurrences of loss of response set (Lezac, 1983). In other words it was proposed that perseveration may be difficult to measure as individuals do not have the opportunity to form a strong response set that will then be perseverated to.

Other variations of the WCST have appeared in the literature, with similar objectives as the MCST including the Milwaukee Card Sorting Test (Osmon and Suchy, 1996), and the most recently adopted WCST-64 (Greve, 2001). Variations that are undertaken for investigative purposes are few and far between. As described previously, in the early days of the WCST Grant and Berg (1948) introduced a variety of manipulations of the WCST for the purpose of investigating the effect of varying levels of reinforcement, with results that are pertinent especially today as they contradict more prevalent views of perseveration. Additional studies have attempted alterations of the test such as varying the symbol configurations (Fey, 1951, Teuber et al, 1951, Grany, 1954, Drewe, 1974, Malmo, 1974) or altering the number and order of categories (Berg, 1948, Drewe 1974, Malmo, 1974). A few studies have attempted to randomise the order of cards in the decks (Berg, 1948, Fey, 1951, Robinson et al 1980). The California Card Sorting Test (Delis et al, 1992) was adopted as a means of breaking down performance into a number of cognitive components. Recently, Stuss et al (2000) administered the WCST to patients with posterior and focal frontal brain damage while presenting three different conditions of test administration, which varied in terms of the extent of support given to the participants and how specific the instructions were. In addition to differentiating between the patient groups, Stuss et al maintained that information about the sorting categories brought about a loss of set.

Cognitive components of the WCST

Regardless of whether the functions measured by WCST are strictly frontal there seems to be some consistency in the literature as to which cognitive abilities are required to perform the test. Successful performance on the WCST is predominantly thought to reflect the ability to shift mental set or perceptual dimension (Milner, 1963, Bornstein, 1986, Owen et al 1993) as well as to generate, test, and select alternative hypothesis (Albert and Kaplan, 1980, Milner, 1963). Isolating the cognitive components involved in the WCST is inherently difficult owing to the complexity of the test. However, attempts have been made to emulate the WCST and create separate testing conditions that account for distinct cognitive features.

Dehaene and Changeux (1991) created a neural network and isolated three cognitive components in WCST. These include the ability to change the sorting rule after negative feedback is received, the ability to hold in working memory the previously tested rules and the associated feedback in order to avoid testing them twice and lastly the ability to reject through reasoning. Greve et al (1997) examined the factorial structure of the WCST on healthy individuals and concluded that the WCST measures two distinct functional domains. The first pertains to abstract thinking ability (as described for example by Grant and Berg, 1948), concept formation (e.g. Lees and Smith, 1983) and set shifting (e.g. Mirshky, Anthony, Dunkan, Ahearn, and Kellam, 1991) while the second includes memory (Bowen, Kamienny, Burns, and

Yahr, 1975) and motivation (Fey, 1951). However, according to Greve et al (1997) the tendency to perform badly on one or more aspects of the test might reflect a number of different of cognitive impairments that are not necessarily distinguishable.

Dunbar and Sussman (1995) particularly stress the role that working memory and attention play for a successful performance on the WCST. According to them the WCST primarily involves the temporary storage of information in a phonological store and the shifting of attention needed in order to pass information in and out of this store. Working memory was also shown to play a key role by Barcelo et al (1997) who compared ERPs (P3b waves) between early and late WCST trials. The involvement of working memory was illustrated by the appearance of significantly larger amplitudes during late as opposed to early trials.

Over the years, perseveration on the WCST is traditionally attributed to the inability to shift attention from a previously successful i.e. "learned" category (Milner, 1963). The specific role of use of cues to guide subsequent responses has also been highlighted. For example Donders and Kirsch (1991) maintained that an essential skill required to successfully perform on the WCST is the ability to develop and modify strategies of responses to stimuli on the basis of feedback regarding the accuracy of the responses. In fact it has been known for a while that individuals with frontal lesions show an inability to benefit from instructional cues that are meant to facilitate performance on cognitive tasks (Alivisatos, 1992). The involvement of cue utilisation in successful performance on the WCST is particularly relevant to the studies that will follow.

Anecdotal evidence suggests that individuals who perseverate on the WCST show an awareness of all three sorting criteria regardless of the fact that they perseverate on one (Teuber 1964, Milner 1964, Konow and Pribram, 1970, Luria, 1973, Stucco and Benson, 1984). Although anecdotal, these observations are consistent with the idea that perseveration may reflect an ineffective use of feedback or what Pribram described in 1971 as a "thought-action dissociation" or in other words a disconnection of feedback-feedforward systems, which inhibits individuals from utilising errors (Pribram, 1971) despite being aware both the errors as well as alternative sorting dimensions.

Brown and Marsden (1988) provide some evidence that may suggest that ineffective use of feedback is more likely to be the primary cause for perseveration on the WCST as opposed to set shifting. They observed that patients with Parkinson's disease who perseverate on the WCST show no set shifting impairment on the Brown and Marsden Spatial Reaction Time Task. According to Brown and Marsden, the ambiguity inherent in the WCST can account for this dissociation. For ambiguous stimuli, the cue given by the experimenter is an ambiguous one. Attention to a particular attribute of the card must be given while attention to other attributes of the card must be inhibited which makes it difficult for individuals to decipher the instructional nature of the cue.

The WCST is inherently complex, a fact which creates difficulties for understanding the cognitive mechanisms underlying poor performance and specifically perseveration. The use of the WCST as an investigative tool is fraught with difficulty the most significant being that of separating the different cognitive components needed to perform the task. Therefore in order to investigate perseveration on the test, one would have to identify and manipulate components of the test relating to specific cognitive functions. This may be difficult given that the WCST employs a variety of functions as described above, that cannot be easily isolated and that perseveration may reflect a deficit in any one or more of those functions.

On the other hand, if perseveration is to be understood, it makes sense for this understanding to occur within the context of a test that has defined it. In addition an enhanced understanding of perseveration on the WCST will inadvertently also facilitate a better understanding of the test itself, which is worthwhile since it is commonly used in clinical settings.

Chapter 5

Introduction to studies

Consideration of the accumulating data on perseveration and the relevant literature points towards a few likely scenarios, not necessarily mutually exclusive, regarding the cognitive mechanisms underlying perseveration.

Firstly, perseveration may be due to an inability to actually perceive alternative options and in the case of the WCST, alternative sorting options. This idea is reminiscent of early studies on visual perseveration, in which perseveration is considered as an inability to "see" an ambiguous drawing or picture in more than one ways. However, as mentioned in earlier chapters, clinical observations from previous studies (e.g. Milner, 1963, 1964) have suggested that participants who perseverate when tested on the WCST consistently illustrate awareness of the various sorting categories available. Perseverators have been known, on numerous occasions, to verbally draw attention to at least one other sorting possibility, which invariably was left unexplored.

Secondly, perseveration may reflect primarily an inability to generate alternative solutions. This possibility reflects the idea that repetition of a particular action occurs because of a lack of alternative plans and brings to mind behaviours that occur amongst healthy populations in everyday settings whereby an erroneous application is tried over and over again when the task at hand is unfamiliar (for example when trying out a new piece of software equipment). It remains to be seen whether this kind of behaviour is cognitively similar to perseveration.

Thirdly, perseveration may be the result of an inability to disengage, or release attention, from a particular mode of responding (i.e. sorting to a particular sorting rule) that has been "overlearned". As discussed in earlier chapters, this view is in line with the traditional ideas on perseveration (Milner's 1963), according to which perseveration is seen as being "stuck in a mental set" whereby attention cannot be drawn away from a learned response to a new one. In other words the more habitual a response has become the more difficult it would be for the individual to disengage from it. This notion supports the idea that perseveration is related to frontal damage since the frontal lobe is taken to be responsible for shifting attention away from the habitual (e.g. a task that has received considerable exposure and/or reinforcement) towards the new (Passingham, 1992). If perseveration occurs because of difficulty in shifting attention from a learned response, than it would follow that on the WCST, an increased number of Correct Consecutive Trials per category (i.e. more opportunity to sort to one category and be correct, therefore facilitating learning of that category) would create an increase in perseveration. On the other hand, if little opportunity were given for an individual to sort to, and therefore learn a particular category, perseveration to that category would decrease.

Finally, the problem of perseveration may lie on an inability to effectively utilise feedback or available cues to facilitate performance. Animal studies using delayed response tasks suggested that errors occur because the cues provided undergo a “rapid decay” after every presentation and performance on a task is taken over by an automatic "release response" triggered by the mere presentation of the choice (Konorski and Lawicka, 1964). On the other hand, studies of human patients with frontal lobe damage suggest that often spatial and nonspatial cues fail to guide their actions appropriately (Milner, 1964, Luria, 1969, 1973, Passingham, 1992). Luria (1964) distinguished between identifying an error, and utilising cues to correct it, with frontal injury impairing the later. In other words, although a cue signifying an error is registered, it may not be utilised to correct that error in subsequent behaviour. Konow and Pribram (1970) investigate this distinction further in a frontal lobe patient who showed impairment in “error evaluation”. Evaluation of errors in their study was synonymous with utilisation of available cues to correct errors and was distinguished from error recognition, which referred to the mere acknowledgement, or registration that an error had occurred. The particular patient under study showed intact error recognition and a disturbance in utilisation. In other words, although the particular patient was aware of the error, she was unable to use this knowledge as a guide to correct her behaviour. Konow and Pribram argued that the impairment worsened for instructions that were given verbally but warranted a non-verbal execution. The dissociation between recognising and utilising an error according to Pribram (1957, 1960) is linked to two separate anatomical regions, the posterior parts of the brain and the frontolimbic respectively.

More recently, Passingham (2001) used a choice reaction task with visual stimuli to investigate a similar dissociation and found that while the inferotemporal region is activated when a visual cue is being registered, the ventral prefrontal cortex is active during decision-making and choice selection. Alivisatos (1992) found that frontal lobe patients' performance on a choice reaction time task did not improve with instructional cues. In other words, contrary to healthy participants, they did not benefit from the introduction of informational cues presented in advance. The suggestion is then that there may be particular areas in the brain responsible for facilitating decision-making and choice implementation by utilising available cues. Along similar lines, Damasio's "somatic marker" hypothesis (1994, 1996) suggests that individuals who make erroneous choices in a gambling task do not show a physiological/emotional response (measured as skin conductance response (SCR)). The somatic marker is a physiological mechanism that facilitates cognitive functions such as instrumental decision-making, which it assists "consciously and covertly" (Damasio, 1996). Thus a raised SCR is associated with the awareness of an erroneous selection and serves as a guide and a precursor for action.

Within the context of the ideas presented above, the studies that follow aim to investigate perseveration firstly in terms of the extent to which it is affected by changing reinforcement patterns and secondly in relation to the participants' emotional reaction to feedback. The studies utilise the Wisconsin Card Sorting Test (WCST) along with variations related firstly to the number of correct consecutive trials required per sorting category (CCT), secondly to the presence or not of ambiguous cards and finally to whether or not the sequence of categories is predetermined. With the introduction of these variations perseveration can be measured in situations where the learning of each sorting category is either facilitated or hindered.

Participants that took part in the four studies consisted of three separate groups: firstly, healthy individuals without neurological history, secondly individuals with traumatic brain injury (TBI) and thirdly patients with Korsakoff's disease. The impaired populations were chosen primarily for reasons of accessibility. However, both brain injured and Korsakoff's patients have shown in recent literature to display moderate to high levels of perseverative errors (Oscar-Berman, 1980, Joyce and Robbins, 1991, Janowsky et al, 1989, Leng and Parkin, 1988, Hotz and Estabrooks, 1995, Parsons, 1975 and Tarter and Parsons, 1971, Delis et al, 1992). It is possible that due to direct or indirect dysfunction of the frontal lobe, both brain injured and Korsakoff's patients may show perseveration on the WCST. Eslinger and Grattan (1993) found that neurological conditions affecting sub-frontal areas have been linked to high perseveration on the WCST.

More specifically, traumatic brain injury most often affects orbital frontal and temporal areas (Mattson and Levin, 1990). Therefore, it may produce a variety of cognitive impairments, which often include disruptions in memory and discriminative attention (Arciniegas, et al, 1999), perseveration (Hotz and Estabrooks, 1995) and a number of other cognitive deficits associated in the literature with frontal lobe injury.

On the other hand Korsakoff's disease is associated with lesions either in the medial nuclei of the mammillary body, or nucleus of the thalamus (Mayes et al, 1988). It is characterised primarily by chronic loss of memory and confabulation. In addition, Korsakoff patients have consistently been shown to perform poorly on tests that measure executive function. This may be explained by the fact that Korsakoff's disease may interfere with normal frontal function. Janowsky et al (1989) found that Korsakoff's patients perseverate on the WCST and on the initiation and perseveration subscale of the Dementia Rating Scale. Leng and Parkin (1988) also found that Korsakoff patients perseverated on the WCST but not on a cognitive estimates test. Kopelman (1989, 1991) found significant perseveration among Korsakoff patients on Nelson's Modified Card Sorting Test as well as significant impairment on a FAS verbal fluency test and a cognitive estimates test. In addition, Jacobson et al, 1990 observed impairment on verbal fluency tests for categories and computerised category sorting tests.

The overall goal of the studies that follow is to explore the possibility that perseveration is the result of a faulty learning mechanism, and to gain insight as to whether this in turn is a result of the ineffective use of cues. Therefore, the relationship between the utilisation of cues and learning becomes, by default, an area of consideration. Early studies by Pribram (1961) and Gormezanno and Grant (1958) suggested that perseveration seemed to increase under conditions of unreliability of feedback, specifically when cues were supplied randomly. In addition to the above, the final study also investigates whether the relationship between perseveration and learning is influenced by the absence of an emotional marker that would allow the individual to respond to negative feedback and alter behaviour accordingly.

Chapter 6

STUDY 1

The effect on perseveration of varying the number of correct consecutive trials (CCT) per sorting category on the WCST on healthy and brain-injured individuals

As discussed in previous chapters, the most prevalent view of perseveration is that it reflects an inability to abandon an established (or previously successful) response strategy that is inappropriate, in order to engage in a new one that is appropriate for the current situation (Milner, 1963, Passingham, 1992, Verin, 1993). Perseveration is thought to reflect an inability to abandon a well-learned or habitual behaviour in order to respond to new stimuli or to changing reward contingencies and to adjust behaviour accordingly (Goldstein, 1944, Halstead, 1940, Rolls, 1991, Dias, 1996, Robbins and Brown, 1990, Owen, 1993). Within this context, perseveration is described as an inability to shift "response set". It can be argued that on the WCST, positive feedback received when individuals sort correctly to a particular category would facilitate the learning of that particular category thus establishing a response set. According to the view presented above, the stronger this response set is, the more likely it is to be perseverated to.

The present study aimed to investigate this idea by examining whether perseveration would increase when individuals were given more chance to learn each sorting category on the WCST. Thus two variations of the WCST were created which differed on the number of Correct Consecutive Trials (CCT) per sorting category. The study therefore addressed the relationship between perseveration and level of reinforcement received on the WCST for each sorting category. The prediction that was made was that as the number of CCT increased, perseveration would increase as a result. This prediction was made for both the brain injured and the healthy group. In other words perseveration would be significantly higher for version WCST15 compared to both WCST10 and WCST5 and for WCST10 compared to WCST5.

Participants

Two different populations took part in this study, the first comprising of 20 individuals who had sustained traumatic brain injury and the second comprising of 20 healthy individuals with no neurological history. The mean age was 35 years for the brain injured group and 26 years for the healthy participants. The majority of the brain-injured group were male (14) while the majority of healthy participants were female (13). Most of the healthy participants were undergraduate students while the patient group was recruited from a brain injury vocational centre. Their injuries were sustained 3 years (on average) prior to testing. Two of the brain-injured individuals were also being treated for epilepsy.

Method

Twenty healthy adults and twenty brain individuals with brain injury were given the WCST along with two additional versions in which the number of Correct Consecutive Trials (CCT) per category was manipulated. WCST5 required five consecutive correct trials per category whereas WCST15 required 15 correct consecutive trials per category. All other aspects of the test administration as well as the scoring procedure were carried out as described by Heaton (1993). All participants were initially given the original WCST, which was followed by the two versions (in counterbalanced order) with an interval of at least three weeks between testing sessions.

The testing of the healthy population took place in university facilities while the brain- injured group was tested in a brain injury vocational centre. The participants were instructed to sort the cards to the four key cards and they were informed that they would not be told how to sort the cards but that they would be told whether they were right or wrong after every sort. They were also made aware that there was no time constraint on the test. Measurements calculated from the WCST included percent of perseverative errors, percent perseverative errors per category, percent of total errors (perseverative and non-perseverative errors) while number of categories completed was also obtained. Scoring and administration followed the procedure proposed by Heaton (1981) for all three versions.

Results

Healthy Group

The majority of healthy participants (17) showed less than 20% perseveration on all three versions. A Friedman non-parametric analysis showed a significant difference in percent of perseverative errors (%PE) between the three tests ($p < 0.001$, Chi Square = 18.14) (figure 1). Number of PE was not taken into account as the versions differed in terms of total trials necessary to complete the categories. Furthermore, a Wilcoxon Signed Ranks test revealed a significant difference in %PE in between WCST 5 and WCST 15 ($p = .001$, $Z = -3.3$) as well as between WCSR10 and

WCST15 (p= .001, Z= -3.36), but not between WCST5 and WCST10 (p= .943, Z= -.071). Percent total errors (%TE) (perseverative plus non-perseverative errors) followed the same pattern as percent perseverative errors (figure 2). In other words a significant difference was found between the WCST5 and WCST15 (p= .001, Z= -3.2) as well as between WCST10 and WCST15 (p< .000, Z= -3.5), with version WCST15 eliciting less total errors. However no difference was shown between WCST5 and WCST10 (p= .811, Z= -.24) in terms of total errors. CCT consistently yielded a smaller percentage of total errors than the version with less CCT.

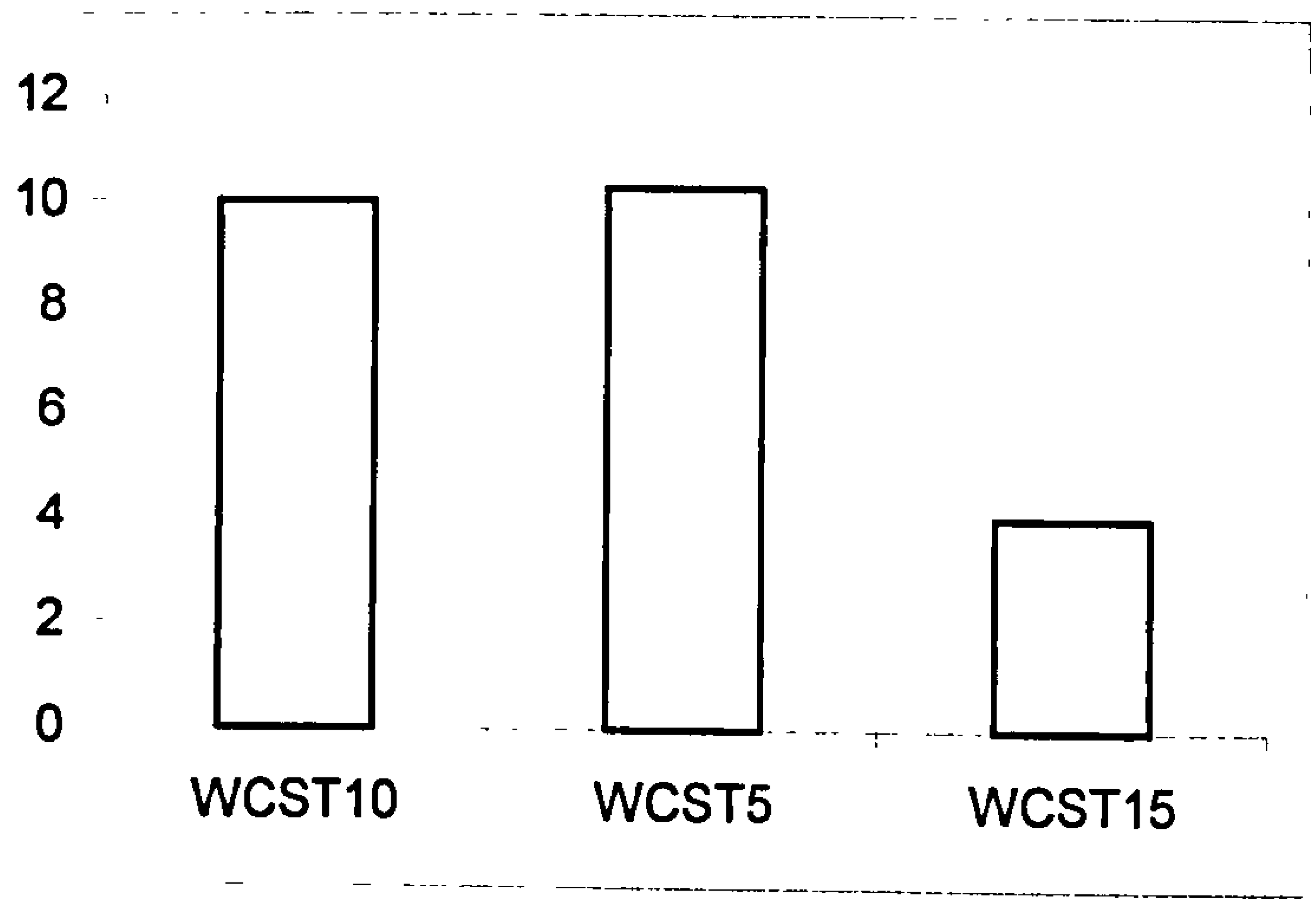

Figure1 Percent perseverative errors on the three versions of WCST (median) among healthy individuals

Table 1 First, second (median) and third quartile scores for percent perseverative errors (healthy group)

	1ST	MEDIAN	3RD
WCST10	7.12	10	16.75
WCST5	8	10.25	12
WCST15	3	4	5

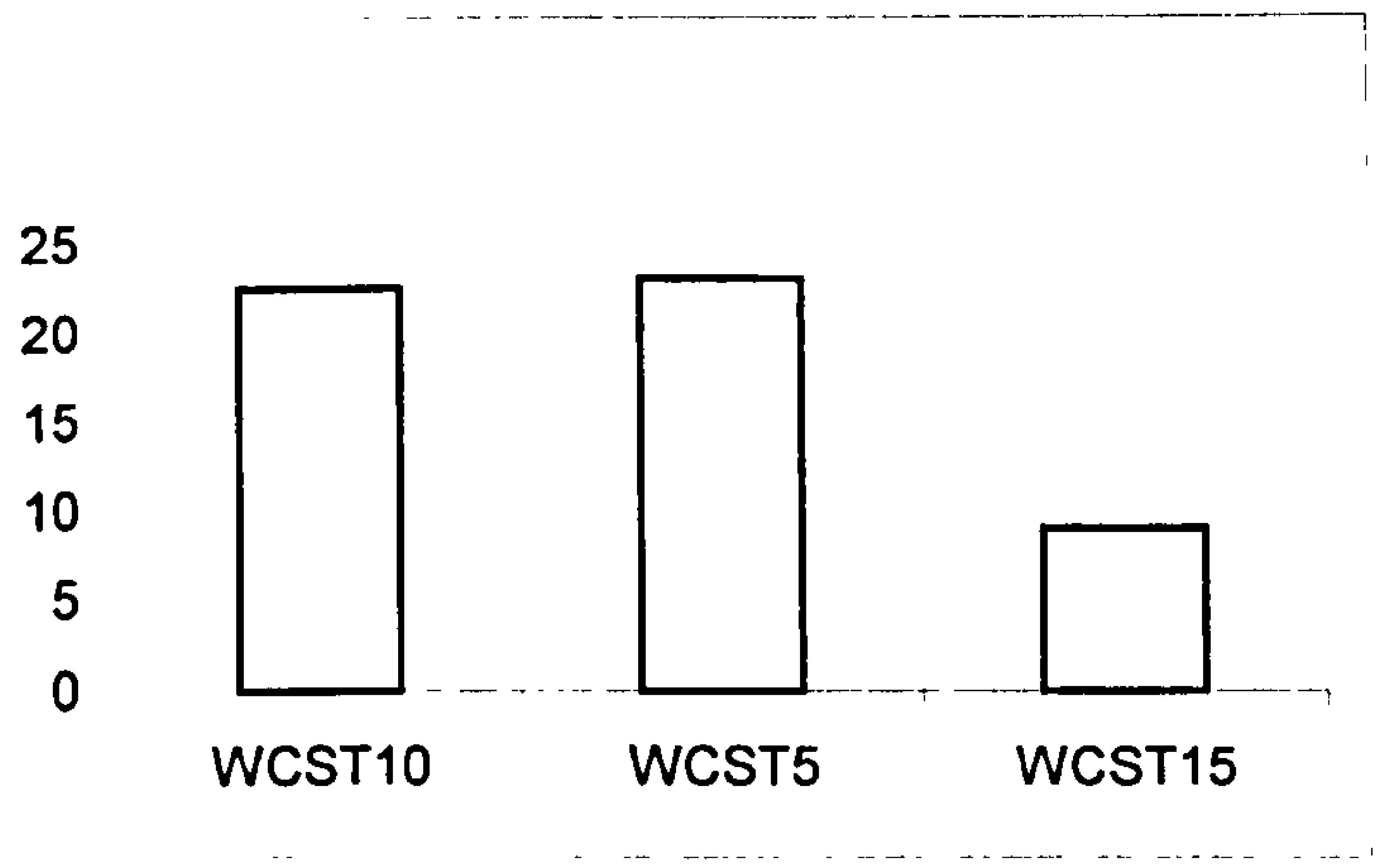

Figure 2 Percent total errors on the three versions of WCST (median) among healthy individuals

Brain injured group

Results for this group were comparable with from those elicited from the healthy participants to an extent. A Freedman Test revealed an overall significant difference between the three versions (p= .005, Chi Square = 10.64) (figure 3). However, a closer inspection using a Wilcoxon signed ranks analysis revealed no significant difference in perseveration between WCST5 and WCST10 (p= .191, Z= -1.30) or between WCST5 and WCST15 (p= .131, Z= -1.51). A significant difference however was found between WCST10 and WCST15 (p= .006, Z= -2.73) with WCST10 yielding more perseveration. However it was found that four individuals that showed severe perseveration did not manage to complete any categories on the initial test (WCST10). When those individuals were excluded from the analysis, the results were similar to those for the healthy group (figure 4). In other words a significant difference in perseveration was found between WCST5 and WCST15 (p= .023) as well as between WCST 10 and WCST15 (p= .017).

The results showed the same pattern for total errors (TE) (figure 5). In other words, before excluding participants who did not achieve any categories the only significant difference was found between WCST10 and WCST15. After exclusion of those individuals, results were similar to perseverative scores, namely a significant difference was found both between WCST5 and WCST15 ($p = .035$) and between WCST10 and WCST15 ($p = .011$) (figure 6). In other words, the brain injured group made significantly more total errors on WCST15 when compared with both WCST5 and WCST10.

The data was subsequently split into two groups depending on the level of perseveration that the participants showed when initially tested on the standard version of the test (WCST10). The high perseveration group comprised of individuals showing 20% PE and over, while the low perseveration group included individuals who scored under 20% PE). It was found that the significant decrease in %PE as presented above was only evident among the low perseverators.

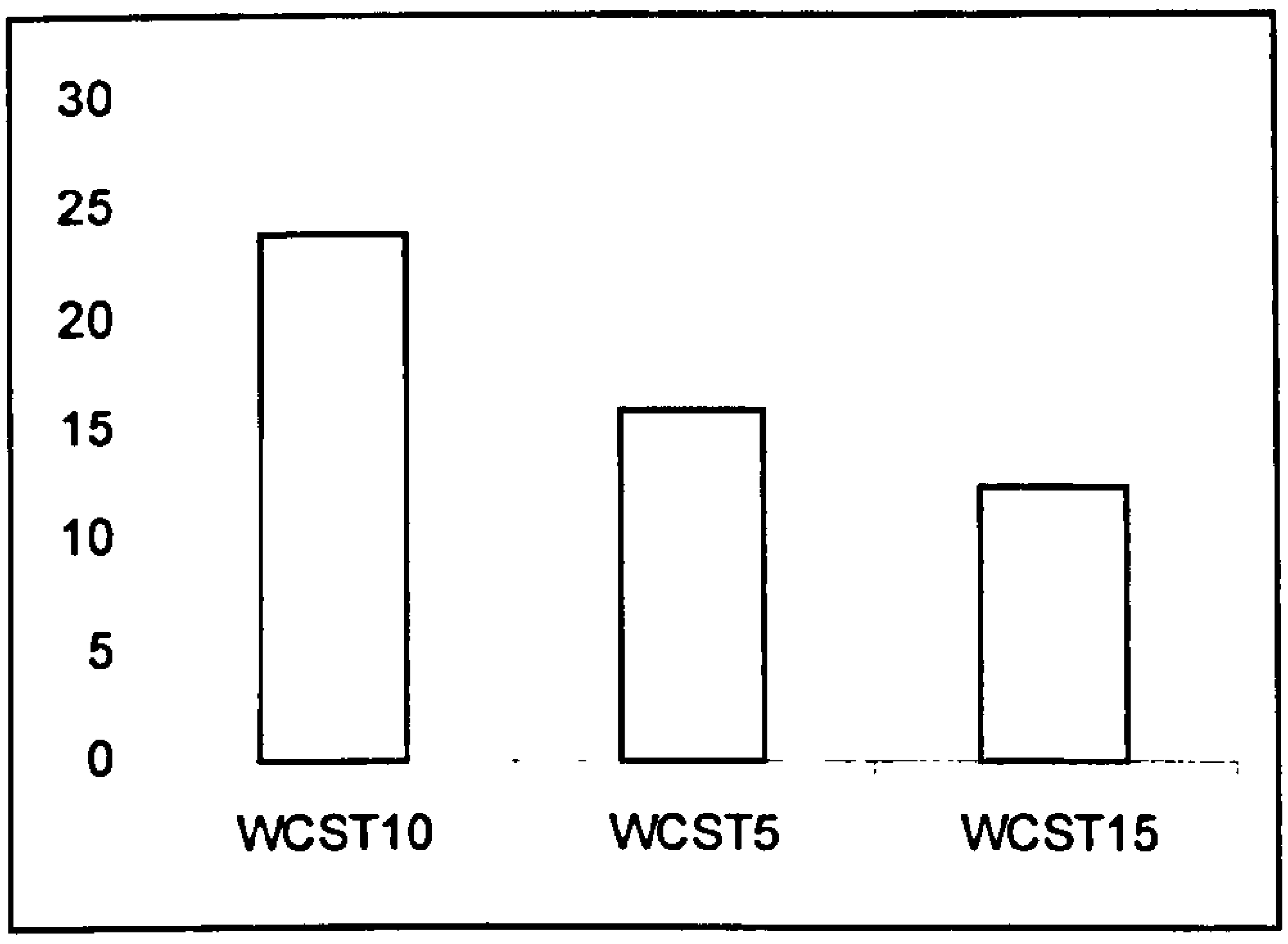

Figure 3 Percent perseveration on the three versions among brain injured individuals

Table 2 First, second (median) and third quartile scores for percent perseverative errors (brain injured group)

	1st	median	3rd
WCST10	10	24	33
WCST5	10	16	26.5
WCST15	4.5	12.5	26.5

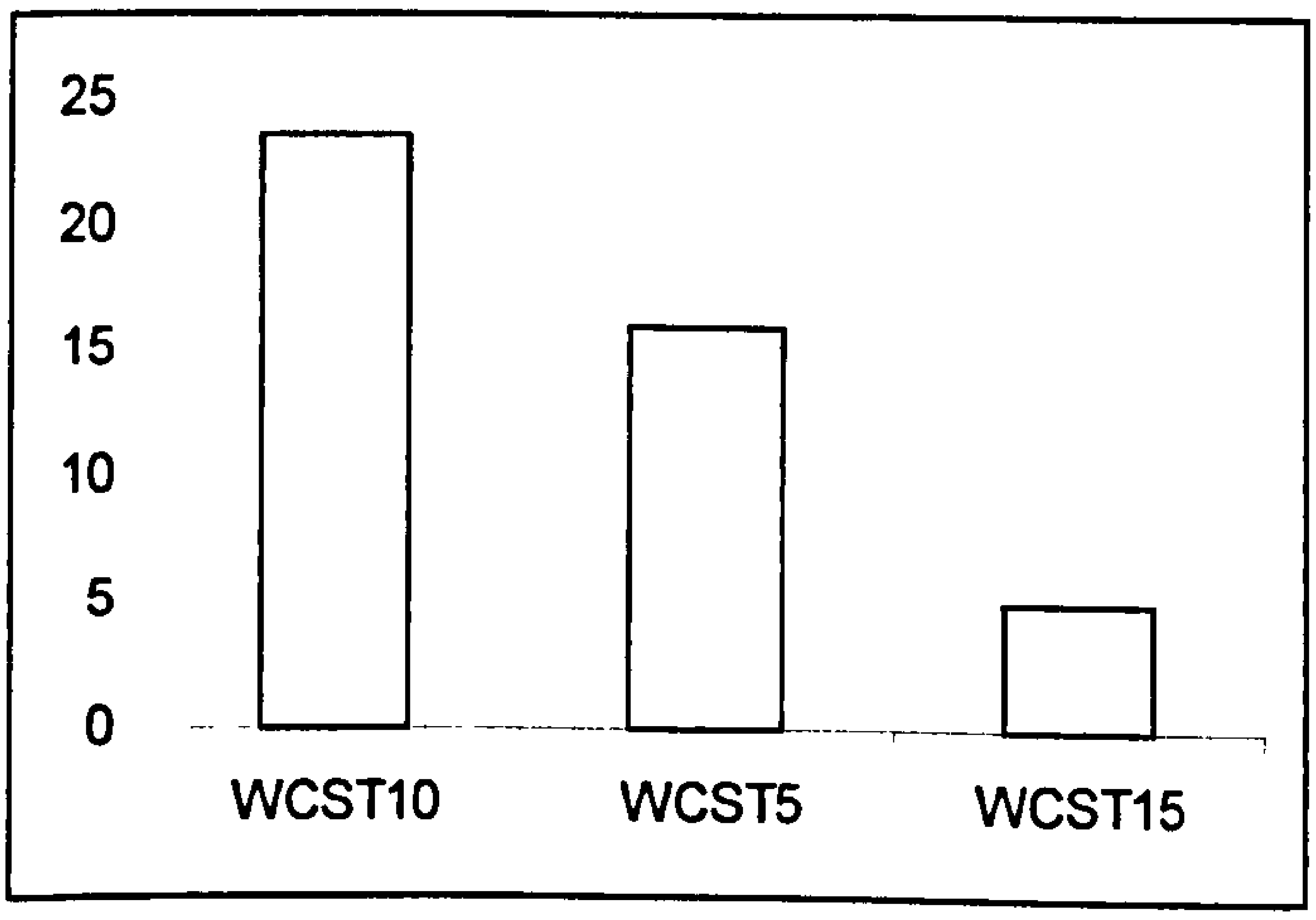

Figure 4 Percent perseveration on the three versions among brain injured participants that have completed at least one category

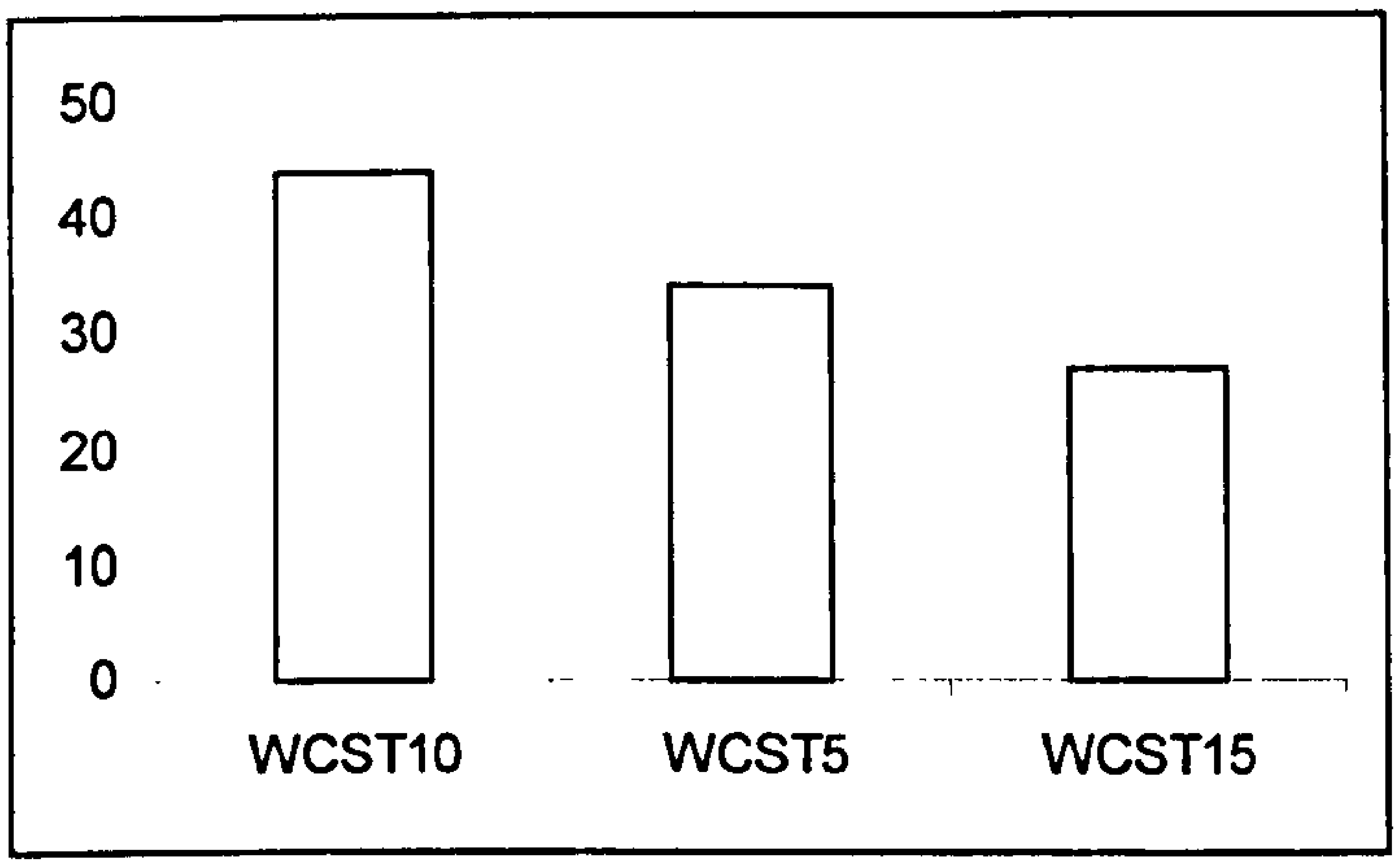

Figure 5 Percent total errors on the three versions among brain injured individuals

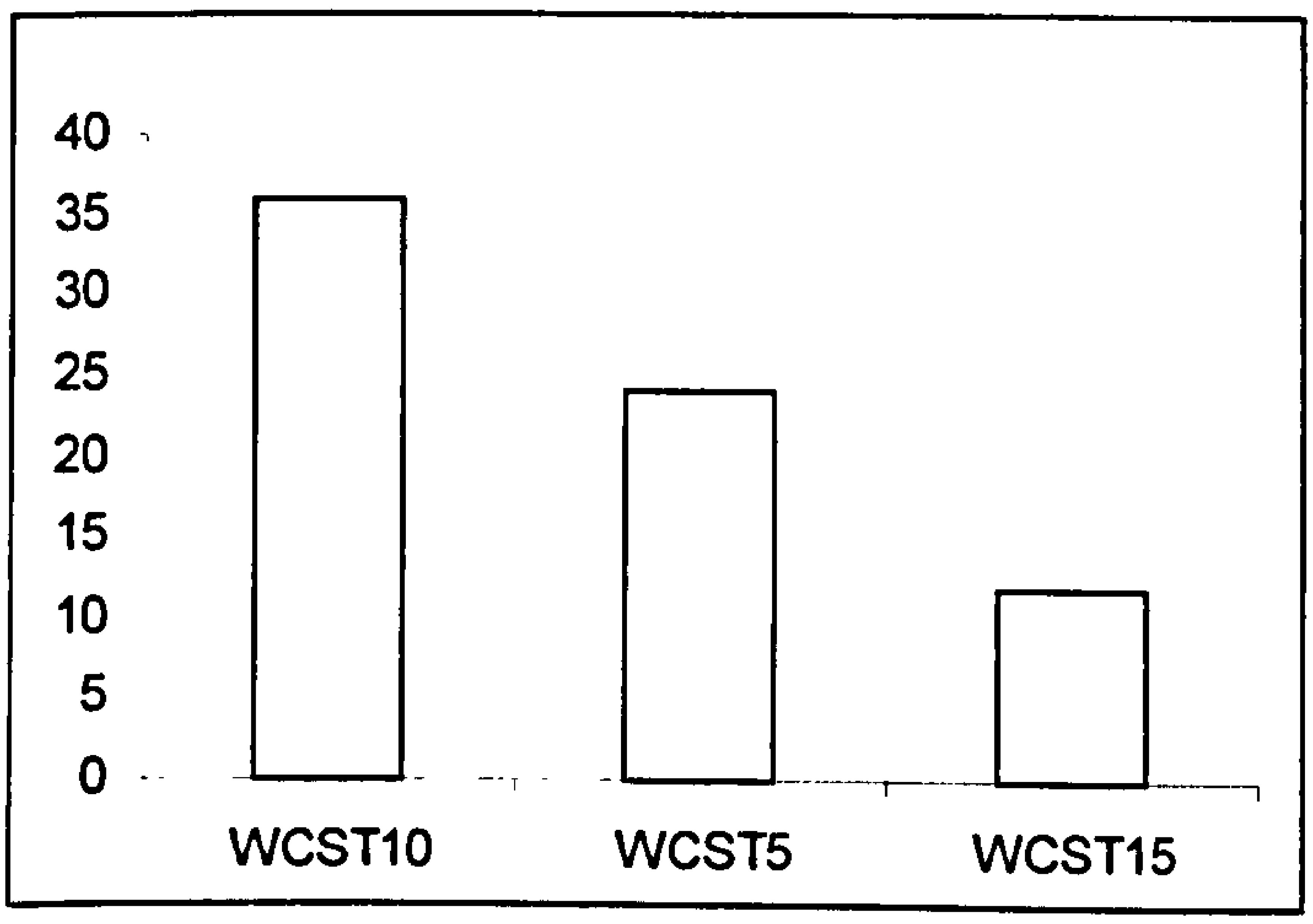

Figure 6 Percent total errors among brain injured participants that have completed at least one category

Percentages of perseveration (PE) and total errors (TE) were taken into account instead of number of PE and number of TE due to the variability in length between the three versions. Although a significant difference in perseveration was revealed between the three versions for both groups, upon closer inspection it was found that, for the healthy group, there was no significant difference between WCST5 and WCST10 in terms of percent perseverative errors and percent total errors. However there was a significant difference between WCST10 and WCST15 as well as between WCST5 and WCST15, with WCST15 eliciting a lower percentage of PE and TE on both occasions. The brain-injured group showed significantly less perseveration and TE on WCST15 when compared to WCST10 but not compared to WCST5 and also similarly to the healthy group there was no significant difference between WCST5 and WCST10 in both PE and TE. However upon excluding four participants whose perseveration prevented them from completing any categories (which meant that the variations imposed would have no effect), findings results were similar to those of the healthy group.

Discussion

Although the prevalent view of perseveration as presented in preceding chapters would predict an increase in perseveration on the version offering more CCT (i.e. WCST15), this study revealed that for both healthy and brain injured participants, by increasing reinforcement for each sorting category, perseveration decreased significantly. A strong response set in other words, far from being conducive to perseveration, decreased it. Moreover this pattern was repeated for total errors, suggesting not only that perseveration drops as learning of the sorting categories is facilitated but also that this drop happens along with an overall improvement in test performance. This in itself is interesting as it may be an indication that perseveration is not a distinct deficit but may improve as a result of overall improvement in task performance.

Most importantly the results of the current study provide evidence that perseveration is not, as often suggested, the result of the inability to disengage from an overlearned response. However precisely why perseveration drops as number of CCT increase is less than clear.

A likely interpretation is that the more positive feedback the participant receives, the easier it becomes to respond to subsequent negative feedback. In other words it may be the case that an increased number of CCT renders the feedback more effective. This idea implies that perseveration may be a deficit in utilising feedback. Although there is plentiful evidence in the literature, as presented in previous chapters, that links frontal lobe injuries with the inability to benefit from and utilise feedback, there is no concrete evidence that this inability may be the underlying cause for perseveration.

The findings were similar for both groups that took part, as long as the analysis excluded individuals who did not attain any categories. The results seem to show that both perseveration and total errors (perseverative and non-perseverative errors) significantly dropped when the number of CCT increased from ten to fifteen and from five to fifteen, but not from five to ten. The reason for the later may be a possible practice effect, as WCST10 was administered first to all participants who then received WCST5 and WCST15 in alternate sequence. Alternatively, ten consecutive trials may not be enough for a response set to be established and therefore have no effect on perseveration.

It was discovered after the completion of this study that an early study by Grant and Berg (1948) who originally developed the WCST had actually yielded similar results to the current study using a healthy population. When examining the effect of different reinforcing patterns on perseveration on the WSCT, Grant and Berg found that increasing the number of reinforced trials per category in the WCST in a healthy population resulted in a decrease in perseverative errors. They conducted a study that involved the manipulation of the number of times that a particular sorting category was reinforced in the WCST before the participant was required to change to a new sorting category. Their data indicated that perseverative errors actually decrease as reinforced trials increased. Perseveration was reduced with increasing reinforcement especially after the fourth shift. These findings completely contradict the prevalent idea that enhanced learning of a particular sorting category on the WCST would produce increased perseveration to that category. However their results seem to be compatible with present findings.

Grant and Berg (1948) interpreted what they called greater “flexibility” in shifting from one dimension of the stimulus to another in terms of the decrease in the ambiguity of the situation offered by the "confirming" function of reinforcement. In other words, the greater the number of confirming trials (trials that were accompanied by the cue ‘right’), the better the performance on the task. According to Grant and Berg, the decrease in perseveration indicated greater flexibility in shifting from one sorting dimension to another as the individual receives more reinforcement. This flexibility was in turn interpreted as a result of a decrease in the ambiguity of the situation offered by the "confirming" function of the reinforcement.

In other words, the greater the amount of positive cues for a particular stimulus dimension, the more readily one would react to a change in the reinforcement pattern (Guthrie, 1935). It had been observed in early experiments such as the temporal maze (Hunter, W.S., 1920), conditioning (Humphreys, 1939) and maze running (Brunswick, 1939) that reinforcement of single responses caused selective responses to the overall sequential characteristics of the situation.

The WCST is similar to these tasks in the sense that it involves learning to respond to sequences of stimuli rather than any single stimuli. In this sense an overall rule must be established in order to successfully complete the task. According to Grant and Berg (1948) learning each part of a complex task to an optimum degree would facilitate the learning of the whole task i.e. the sequential characteristics of that task. In other words, reinforcement of single responses facilitates the learning of the "overall sequential characteristics" of the task, in the case of the WCST the overall sorting rule. Moreover as the number of reinforced trails increased, participants were able to reach alternative correct solutions more readily and abandon the previously correct solution. Non-perseverative errors were also reduced as the number of reinforced trials increased, which was attributed to the fact that participants acquired a better understanding of the test.

In addition, it has been argued that a large amount of reinforced trials makes the particular stimulus dimension stand out so that the subject may easily react to a change in the reinforcement pattern (Guthrie, 1935). In other words, reacting to a change in reinforcement is facilitated if it is discriminated from the experimenter's previous feedback. This discriminability increased as the number of the reinforced trials per category increased. It was noted that the greatest improvement in performance takes place as the reinforced trials increase from 5 to 10 and little improvement occurs when they are increased from 10 to 40 (Grant and Bergs, 1946, Grant et al, 1952). This notion was in line with Harlow's idea of the "learning set" (Harlow, 1949). Previous studies on the temporal maze (Hunter, W.S., 1920), conditioning (Humphreys, 1939) and maze running (Brunswick, 1939) indicated that when learning a task, reinforcing single responses facilitates the learning of the overall sequential characteristics of the task.

Pribram (1961) and Gormezanno and Grant (1958) maintained that perseveration increases under conditions of unreliability. Pribram found that on a modified WCST, the performance of monkeys with frontal lesions was not affected by an increase in the number of alternatives, but was affected when the relationship between feedback and response became unreliable. In the same study, Pribram (1961) found that when the number of reinforced trials decreased gradually from ten to two, frontally impaired monkeys did not make use of the cue that signalled that reversal had taken place. Again he found that an increased number of choice alternatives had little effect on task performance. Pribram maintained that ineffective performance was related to the ambiguity produced by changes in the reliability of the cues. In other words, the difficulty occurred where there was relative unreliability in the presence of stimuli that serve as guides. Low reliability could certainly provide a plausible explanation for the current findings. A greater number of CCT would increase reliability between response and feedback, which would then, in Pribram's view, render the feedback more effective.

The context in which the Grant and Berg studies were conducted long before perseveration and the WCST became popular themes in neuropsychological research. Their investigation was mainly exploratory and their work was heavily influenced by learning theories of the time. Consequently and quite naturally, the interpretation of their findings was naturally bound by the knowledge constraints of the time. However the implications that their studies carry for furthering understanding of perseveration today should by no means be overlooked or indeed underestimated. It is particularly interesting that these studies present the notion of cue effectiveness in relation to perseveration, since this idea is now undeniably linked with frontal lobe injury and perseveration.

In particular, the data from Grant and Bergs' study on the effect of increasing the number of reinforced trials in the WCST provides important, albeit largely overlooked information on perseveration. In view of current knowledge and accumulated data these early findings should at the least raise doubts regarding the way in which perseveration is currently viewed in the literature and should be regarded as a source of valuable information.

Clinical observations and limitations

Clinical observation showed that impaired performance on the test was not due to inability to understand instructions. In addition, the majority of participants seemed to be aware of the existing sorting categories, as they would often describe the cards in terms of the three sorting dimensions in a manner which seemed purposeful and related to the task. For example, one individual with high perseveration scores described every card he picked in terms of all three characteristics (e.g. "..now... these are triangles, they are two and they are blue"). This may suggest that perseveration does not occur because of failure to acknowledge the sorting options.

Many individuals (especially high perseverators) appeared oblivious to negative feedback. They did not seem distracted or anxious about receiving negative feedback, even when it followed the majority of their responses. Few individuals perseverated despite obvious distress. Moreover, many perseverators when asked why they did not attempt a different sorting choice upon receiving negative feedback responded that their response "is correct sometimes, so I kept doing the same thing". This may indicate that positive feedback, however sparse, served to reinforce their initial choice, while negative feedback was not used as a cue to correct a wrong response.

It was also observed during testing that in a number of cases perseverators were not only aware of the fact that their selections were wrong, but were also able to predict with astonishing accuracy whether their subsequent sorts would be wrong or right. This may indicate either that perseveration reflects an inability to correct behaviour (by use of feedback) rather than a lack of awareness of the need to change response, or alternatively that perseveration results from an inability to generate alternative responses.

A possible limitation with the WCST as a tool for studying perseveration could be the presence of ambiguous cards, which may affect performance. An ambiguous card shares more than one characteristic with the key card under which it is placed. Consequently, a subject who is perseverating to the wrong dimension may nonetheless, from time to time receive positive reinforcement. For example an individual perseverating to colour may receive positive feedback from the experimenter for a sorting choice, which happens to conform also to the "form" or "number" principle. The process of learning the correct responses via feedback may be greatly undermined under such cases, as the directional attribute of the feedback is not easily deciphered. For investigative purposes at least, a clearer understanding of the relationship between performance on the WCST and the effect of feedback may be attained if ambiguous cards were removed from the WCST in future studies.

An additional limitation pertaining particularly to the present study regards the number of response cards per version. The tests would better serve the study if the total number of trials were adjusted to accommodate the different number of cards needed to complete a category. In other words WCST15, which requires fifteen cards per category, should contain a larger number of cards to allow an equal chance of erroneous selections between categories.

In addition, the design of the study, which entailed administering all three versions to each participant, may have created a practice effect, a possibility that warrants a subsequent confirmation of the results using independent groups.

Finally, the data clearly highlights the fact that individuals who perseverate severely, to the extent of not completing a category would not benefit from the variations imposed by the different versions, so in this case a comparison between the versions becomes meaningless.

It is clear that perseveration although simply manifested, is a complex behaviour. Any attempt to understand it may involve analysis of many cognitive elements such as attention, short-term memory, inhibition, selection, sustaining information, analysing feedback and altering behaviour according to changing reward contingencies. However, current theories suggesting the perseveration is more likely to occur when a response is well learned provide an insufficient explanation for a complex behaviour. It is apparent from these findings that perseveration is not due to an inability to inhibit well learned responses or due to the inability to disengage oneself from an established response set. On the contrary, perseveration seems to increase with the absence of a strong set. A stronger response set (established by more reinforced trials) seems to enhance performance reflected by a decrease in both perseverative and total errors.

Further investigation is needed to establish the factors that determine these findings. However, their implications are important in the sense that they obligate a shift in the way perseveration is perceived and studied in the past decades as well as shedding new light on the use of perseveration as an indicator of frontal lobe damage.

Chapter 7

STUDIES 2 AND 3

STUDY 2

A further investigation of the effect on perseveration of varying the number of correct consecutive trials (CCT) on the WCST

In the preceding study perseveration was shown to decrease with an increase in Correct Consecutive Trials per sorting category. As mentioned in the previous chapter, this was a surprising outcome, since it contradicts prevalent views that perseveration reflects an inability to switch to a different response once a particular response is learned (Milner, 1963, 1964). The implications therefore of the first study were deemed important enough to prompt the present one, which was undertaken primarily to confirm those initial results but also to rectify previous limitations and possibly provide additional insight. In the present study a different group of patients with traumatic brain injury was used. Unlike the previous study, each participant was only administered one test, either version WCST5 (5 CCT) or WCSR15 (15 CCT). This was aimed at eliminating a possible practice effect that may have occurred previously. The aim for this study was to investigate the effect on the number of perseverative errors of an increase in number of CCT. Following the rationale described in the previous chapter, the underlying idea that prompted this investigation is that there may be a different relationship between perseveration and learning than that suggested by the literature so far. In other words, perseveration might not be a case of an inability to switch away form a well-learned behavioural response. Rather it may be associated with an impairment in learning the task. If, as the previous study showed, a situation that facilitates the learning of each sorting category, rather than hinders it, is followed by a significant decrease in perseveration, it is an indication that perseveration does not occur due to overlearning. However, this does not provide an explanation as to why perseveration does occur. This in turn may be understood if a different question is asked, namely what is it that an increase in the number of CCT provides that would result in less perseveration? The creators of the WCST, Grant and Berg (1948) in a very early study suggested that a longer sequence of positively reinforced trials would make the negative reinforcement "stand out" more. Grant and Berg were working in an era highly influenced by emerging theories of learning by reinforcement. However their idea is also consistent with more recent ideas on the effectiveness of external cues.

It is possible that the problem of perseveration may be related to the way in which individuals are affected by and utilise external cues to guide their performance. More recent research outlined in preceding chapters suggesting that some neurological patients fail to effectively utilise cues has given ammunition for the present research and is especially relevant to the final study that will be presented in a later chapter. The specific aim of the present study however, is to confirm that the group of participants given the WCST version that offers more correct consecutive trials per sorting category, namely WCST15, will show significantly less perseveration. For this reason the design of the study is similar with the exception of the use of independent groups and the exclusion of WCST10, which was deemed unnecessary.

Method

Participants

Twenty adult patients, seventeen male and three female, of varying age between 30-60 with traumatic brain injury participated in the study. The patients were residents of a rehabilitation clinic and had received their injuries at least six months prior to testing. Their injuries were diverse, varying in terms of size, location and severity.

Procedure

The participants were administered one of two versions of the WCST in counterbalanced order. The first group was administered the WCST5, which requires five Correct Consecutive Trials (CCT) per category, while the second group was tested on the WCST15, which requires fifteen CCT per sorting category. In addition, thirty cards were removed from WCST5 and the same number was added in WCST15 to allow for the varying number of cards used per category on the two versions. In other words, the total number of sorting cards was adjusted to accommodate the different number of cards needed to complete each category. The cards that were removed and added were identical to the last thirty and the first thirty cards of the standard WCST respectively. Therefore the total number of cards for WCST5 was 98 while for WCST15 it was 158. Apart from the total number of card and the difference in number of CCT, the tests were administered and instructions were given according to Heaton's manual (1981) and have been described in detail in chapter four. Given that there are no time constraints for the tests, administration lasted from ten to forty five minutes per participant depending on the version and on individual performance.

Results

Percent perseveration was calculated to provide a more accurate picture of the extent of perseveration. A Mann-Whitney non-parametric analysis showed that there was no significant difference between the two groups in percent perseverative errors (p= .656, U= 43.500) (figure 7). In other words the study showed that increasing the number of CCT from five to fifteen made no significant difference in terms of perseveration. A closer look at the data however, showed that more then half of the total number of participants (11) perseverated more than 50% while eighteen individuals perseverated more than 20%. It was suggested therefore that in a situation where perseveration was very high the manipulation of number of CCT would have very little or no effect on performance. Individuals that were given the WCST5 completed an average of three categories, while those given WCST15 completed an average of two. Two participants did not complete a category while nine participants completed only one. The difference in % total errors between the versions was not significant (p= .941, U= 48.500) (figure 8).

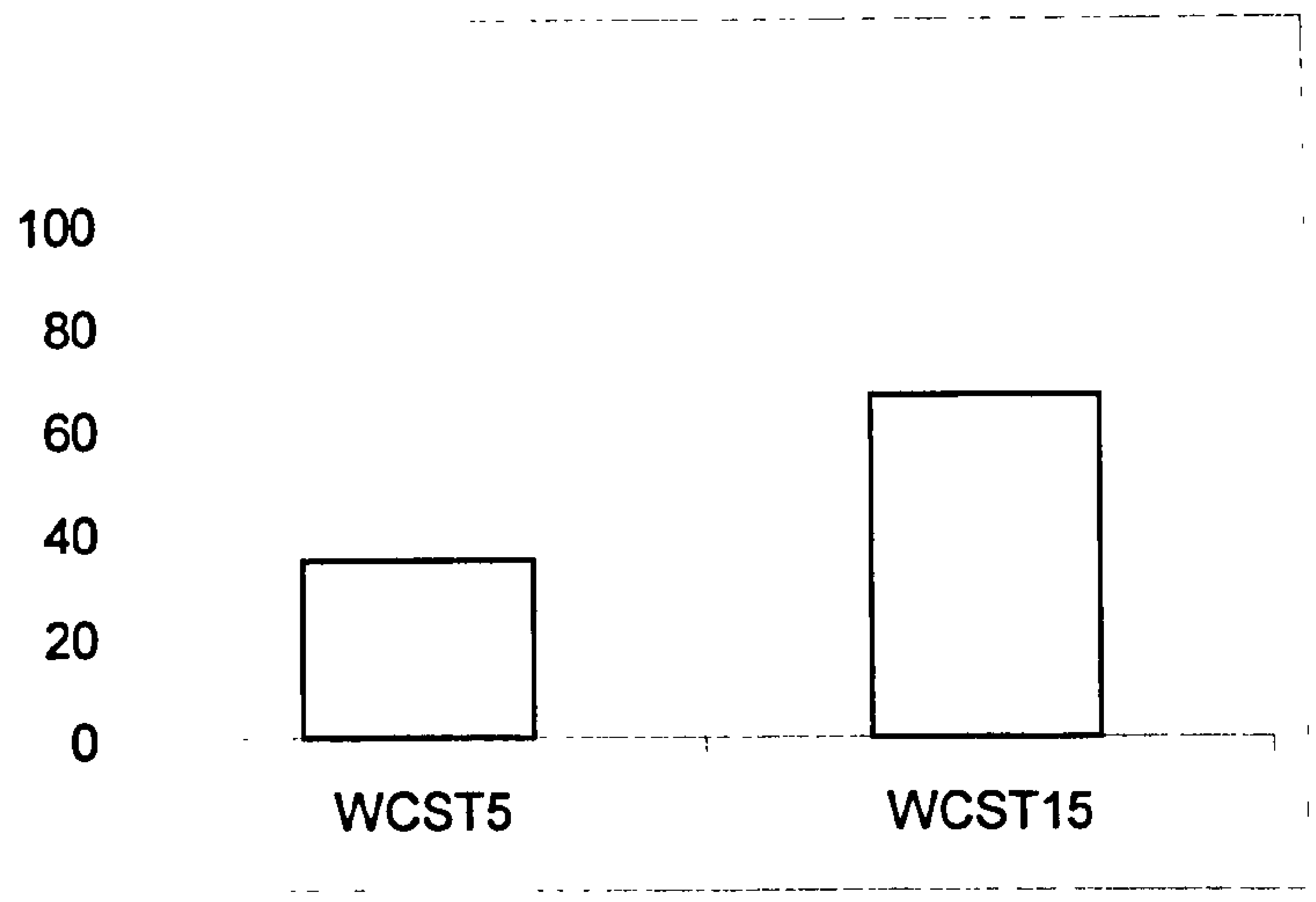

Figure 7 Percent perseverative errors on WCST5 and WCST15

Table 3 First, second (median) and third quartiles for percent perseverative errors

	1st	Median	3rd
WCST5	31.25	34	67
WCST15	23	52	68

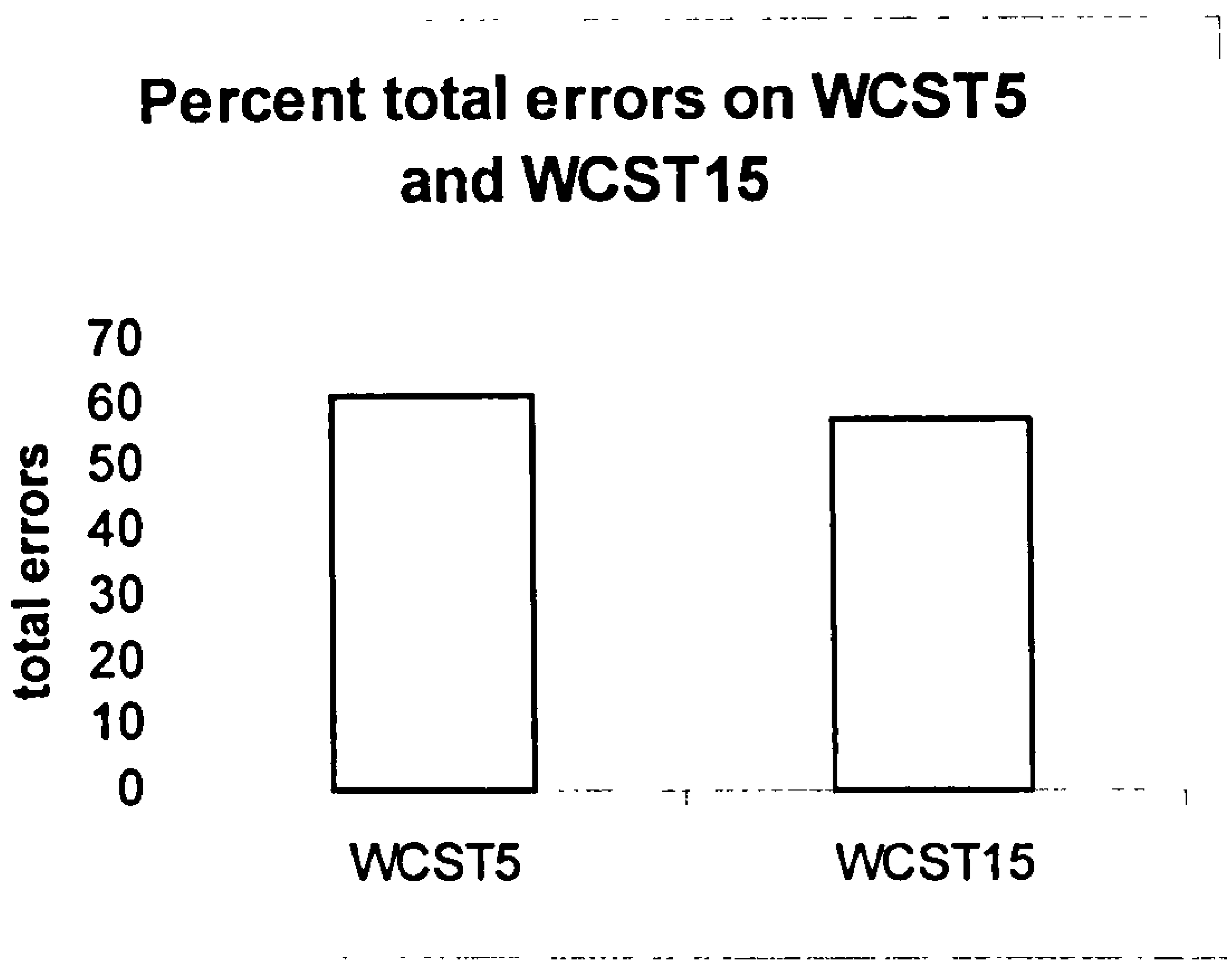

Figure 8 Percent total errors on WCST5 and WCST15

Discussion

The results that this study produced were non-significant. The reason for this may be that the severity of perseveration among the population that participated played a key role in the findings. In other words the levels of perseveration were too high in the majority of cases for the variations of the tests to have a significant effect. Participants who perseverate severely cannot benefit from the difference in CCT between the versions, simply because they do not complete enough, if any, sorting categories. For this reason only it is not surprising that the results were non-significant. The overall idea that given the opportunity to learn each category better individuals will perseverate less, need not be discarded.

A second important finding was that individuals who were administered the WCST5 completed on average three categories in contrast to those who were given the

WCST15 who completed an average of two categories. This also seemed to contradict the main premise. However, because of the variations imposed on the tests, number of categories achieved does not necessarily correlate with severity of perseveration. The very nature of the variations of the tests makes it more likely for categories to be completed on the WCST5, which requires only five sorts per category than on the WCST15, which requires fifteen sorts per category. Therefore, the number of categories should not be taken as an indication of performance when comparing tests that differ in number of CCT.

This study provided insight regarding a number of issues, despite the fact that the results proved inconclusive. Firstly the role that ambiguous cards may play in performance was highlighted again. The presence of ambiguous cards may create a problem when using the WCST as a tool for studying perseveration, as they may affect performance. In fact, Nelson (1976) removed ambiguous cards from the WCST to alleviate difficulties especially among elderly patients. An ambiguous card shares more than one characteristic with he key card under which it is placed. Consequently, a subject who is perseverating to the wrong dimension may nonetheless, from time to time receive positive reinforcement. For example an individual perseverating to colour may receive positive feedback from the experimenter for a sorting choice, which happens to conform also to the "form" or "number" principle. The process of learning the correct responses via feedback may be greatly undermined under such cases, as the directional attribute of the feedback is not easily deciphered. For investigative purposes at least, a clearer understanding of the relationship between performance on the WCST and the effect of feedback should be attained, which would also render the overall manipulation of number of CCT more effective. The removal of ambiguous cards from the WCST in future studies would therefore be recommended.

A second issue warranting attention is that of the role that a predetermined sequence of sorting categories may play on the performance of participants on these tests. On the standard WCST as well as on the two variations presented here the sequence in which cards are sorted into categories is predetermined. Individuals are required to sort the cards according to colour, then form and then number. The test thus restricts individual's sorting choices and increases the likelihood that the first category would not be completed. This in turn creates a situation whereby the manipulation of number of CCT becomes less effective.

The present study also offered additional support for the previous observations that perseveration occurs even when individuals are fully aware of the sorting categories. Clinical observation again showed clearly that individuals were often aware of at least one other sorting category other than the one that was perseverated to. A particular individual with an overall perseveration score of 33% showed complete awareness of the categories and frequently described the sorting cards by all three dimensions (e.g. "this is a star, it is blue and it is just one") despite heavily perseverating to one sorting dimension throughout the test.

Overall, the present study provided a lot of information on methodological issues. A subsequent study was needed in order to implement the necessary adjustments and to further explore the indications of the first study as well as the questions arising from the present one.

STUDY 3

Removing ambiguity: an analysis of the relationship between feedback and perseveration on variations of the Wisconsin Card Sorting Test (WCST)

The first study found that increasing the number of reinforced trials per category in the WCST in healthy and brain injured participants resulted in a decrease in perseverative errors. As discussed in earlier chapters this data indicated that perseveration could not be a result of overlearning of a response, as it clearly indicated that when the learning of a response is facilitated, perseveration to that response decreases. According to Grant and Berg (1948) a decrease in perseveration with increasing CCT is an indication of greater "flexibility" in shifting from one sorting dimension to another. This flexibility occurs as the individual receives more reinforcement, or as a result of a decrease in the ambiguity of the situation offered by the "confirming" function of the reinforcement. This is compatible with early learning theories stating that the greater the amount of positive cues for a particular stimulus dimension, the more readily one would react to a change in the reinforcement pattern (Guthrie, 1935). The important issue for the present study is that of the use of external cues for learning, and whether the ineffective use of cues promotes perseveration.

The second study failed to support the findings of the first. A possible reason for this may be that participants were perseverating severely, rendering the conditions ineffective. Also, as mentioned in chapter 4 the WCST includes a number of "ambiguous" cards (i.e. cards that have more than one characteristic in common with the key card under which it is placed). These cards, which have been included in the versions used the studies presented above, may create difficulties for the investigation of perseveration. The feedback received by the experimenter for these cards is unclear both in terms of its reinforcing value as well as in the direction that it provides. Two very important alterations in the methodology were therefore implemented in the third study. Firstly ambiguous cards were removed. Secondly, the sequence of cards was left undetermined in order to allow participants to choose the order in which they sort to the different dimensions. This meant that the very first sort was invariably correct (unless the card was placed under a key card with which it did not share any dimension) and so was more likely for the first sorting category to be completed even for participants who perseverated severely.

The present study did not introduce a novel idea as such but was created primarily to rectify possible drawbacks that were presented earlier. The overall aim of this study is therefore the same as for the preceding studies. In other words it investigate whether perseveration levels decline when individuals are given more opportunities to sort to each sorting category. In addition it is predicted that the later half (late trials) of the tests will show a decrease in perseveration and furthermore that this difference will be more evident on WCST15, indicating a superior learning process.

Method

Participants

Participants comprised of sixteen adults with traumatic brain injury (TBI) and four adults with Korsakoff's disease aged between 30 and 60 years. Fourteen of the brain patients were male and two were female while three Korsakoff's patients were male and one was female. The TBI patients were clients at a brain injury vocational day centre. The patients with Korsakoff's disease were seen at an alcohol rehabilitation unit, which was part of a psychiatric hospital.

Procedure

Each subject was randomly administered one of the two WCST versions. WCST5 required five correct consecutive sorts to each category while WCST15 required fifteen. In this study ambiguous cards were removed and the sequence of categories was undetermined. All other instructions and administration followed Heaton's manual (1981). The test lasted from 10 to 30 min per participant depending on performance and version. Similarly to the previous study, the number of cards was adjusted so that variation in number CCT was taken in to account. WCST5 contained 49 cards and WCST15 contained 117 cards.

Results

A Mann-Whitney non-parametric analysis revealed a significant difference in percent perseverative errors between the two groups, with the WCST5 group showing significantly more %perseveration ($p= .016$, $U= 18.000$) (figure 9, table 1). The data was then split in half to measure perseveration separately for the first and second half of the tests. The data did not confirm the hypothesis in this respect. There was no significant difference between early and later trials for WCST15 (p= .919, Z= -1.021). However perseveration significantly increased from early to late trials during WCST5 (p= .014, Z= -2.449) (figure 10).

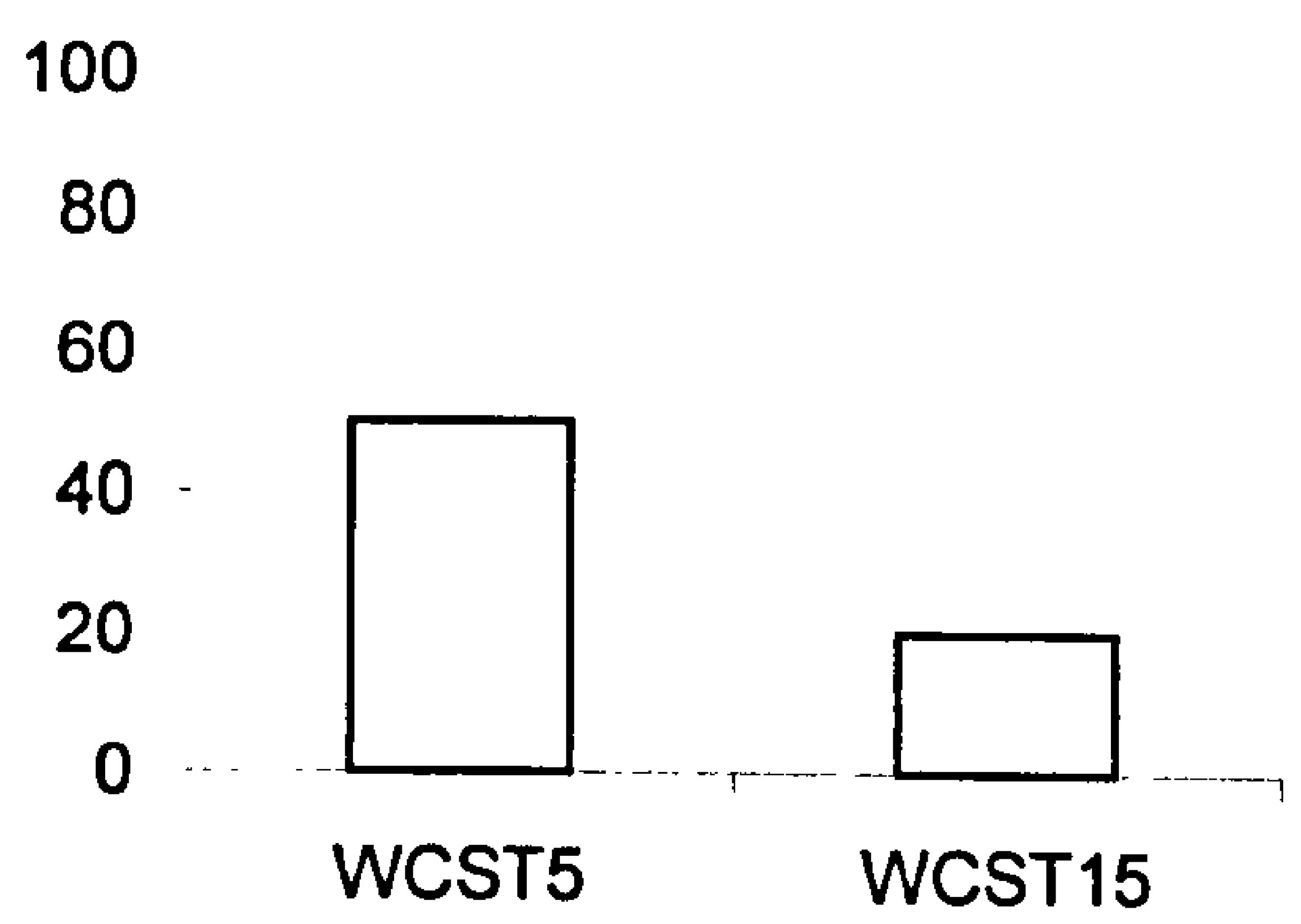

Figure 9 Percent perseverative errors on WCST5 and WCST15

Table 4. First, second (median) and third quartiles for percent perseverative errors

	1^{st}	median	3^{rd}
WCST5	35	50	79
WCST15	8.75	20	33

Table 5 Percent perseverative errors on WCST5 and WCST15 (median)

	Early trials	Late trials
WCST5	9	14
WCST15	13.5	10

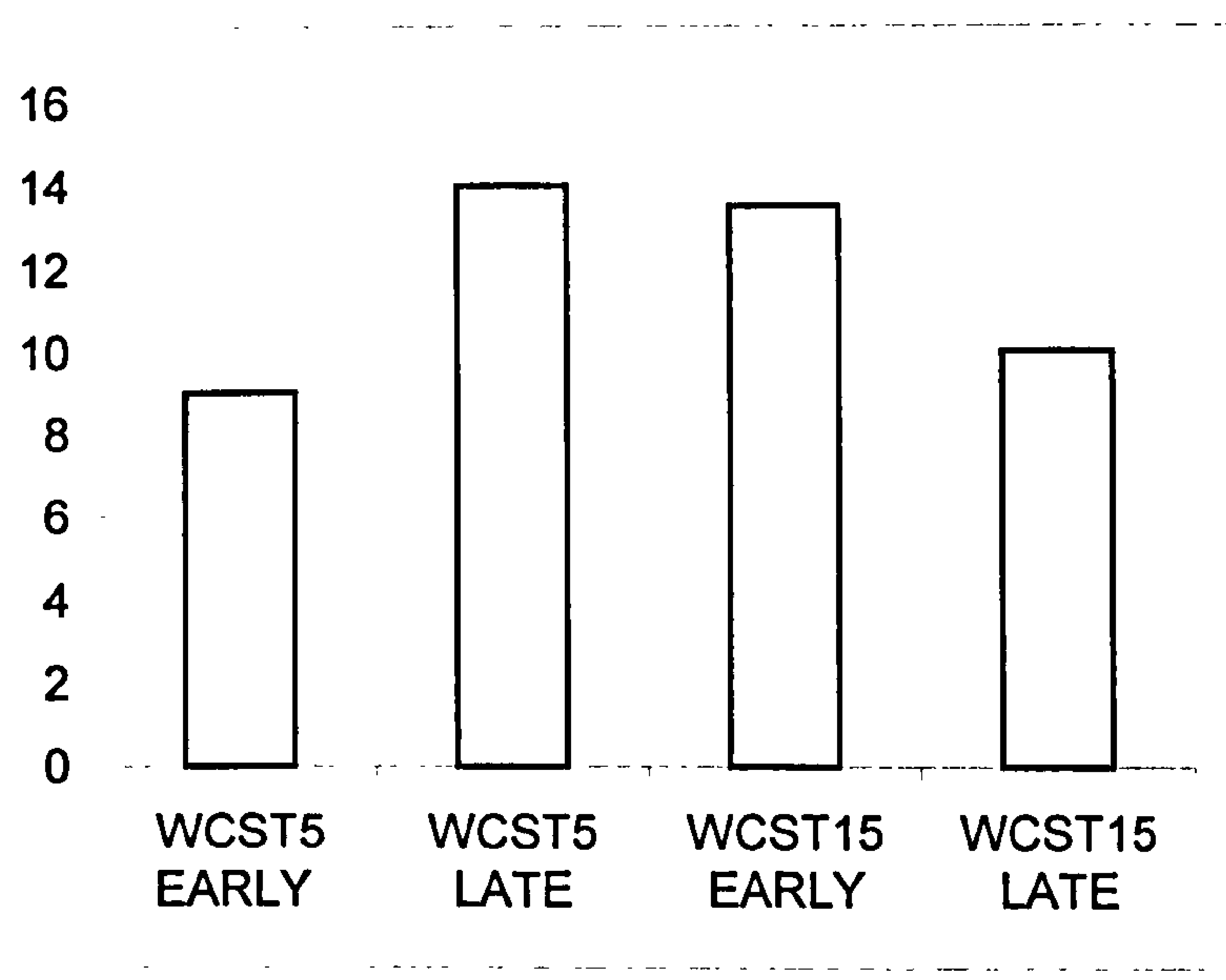

Figure 10 Percent perseverative errors in early and late trials on WCST5 and WCST15

Discussion

The data confirmed the results of the first study showing that individuals perseverated less on WCST15. Therefore when individuals, in this case with brain injury and Korsakoff's disease, are given more opportunity to sort to a particular category, overall perseveration decreases. The implications of this finding are important as they contradict the idea that perseveration is due to overlearning of a particular response.

The alterations to the tests that were undertaken in this study, namely the removal of ambiguous cards and the introduction of a free sequence of sorting categories may have provided a clearer picture of the mechanisms underlying perseveration.

There is an indication from both the findings of the first study as well as the findings of the current one that perseveration may be related to the use of external cues. In other words perseveration may be due to inefficient utilisation of external cues. The suggestion is therefore that the problem may lie in how feedback is utilised to modify responses. A subsequent question that arises is whether this inefficiency is specific to negative reinforcement or occurs for both positive and negative cues. In any case the removal of ambiguous cards allows the a more straightforward relationship between feedback and choice of response, as the participants experimenter are more likely to be aware of the exact sorting choice the feedback relates to.

Surprising results came into light when tests were separated into early and late trials. In the case of the WCST5, not only did perseveration not decrease during the later part of the test, it actually significantly increased ($p= .014$). Two of the three individuals that perseverated more during the late trials of the WCST5 showed very high perseveration scores (over 80% perseveration) and did not complete a category. Four individuals from a total of ten perseverated more during the second half of WCST15 compared to the first half. Two of those only completed the first category and perseverated to the same category throughout the test. Again, as in the preceding study, it becomes evident that in cases of severe perseveration such as these, the manipulation of number CCT cannot have an effect. This poses a real problem for studies of perseveration that utilise the WCST or variations thereof. In this case excluding the scores of the four individuals mentioned above from the data analysis did not affect the overall results. The difference between early and late trials on WCST5 was still significant (p= .042) while the difference between early and late trials on WCST15 was not (p= .233). The reason for these results is not very clear. The main problem with this analysis was that measuring differences in performance between first half and second half was not as straightforward as initially thought. The mere fact that the very first category was almost always completed (due to the fact that participants were allowed to choose the sequence of categories) meant that the first half of the test would contain at least one series of correct responses. Therefore even if a participant perseverated severely the first choices he/she made were likely to be correct. The second half of the test however would not necessarily contain a correct category. The nature of the test produces a bias in favour of the first half of the test in terms of perseverative errors.

Overall, the main finding of this study was as predicted. In addition, with the removal of ambiguous cards, feedback given by the experimenter was less ambiguous to the participants while, on the other hand, the intentions of the participants were more explicit to the experimenter. This in turn meant that the results painted a clearer picture of perseverative performance.

What the findings suggest overall is that on the WCST, perseveration to each sorting category seems to significantly decrease when individuals are given the version that offers more opportunities to become accustomed to and subsequently learn each particular category. Switching into the next category seems to be facilitated as the preceding category becomes more familiar. These studies provide surprising and valuable insight into the relationship between perseveration and learning. Similarly, these studies change an established perception of the association between perseveration and the concept or set formation. It becomes surprisingly clear, that in situations where a stronger set is formed, in this case a particular sorting category, a shift to a different sorting category is not hindered but rather facilitated.

Chapter 8

STUDY 4

An investigation into the relationship between perseveration and a weakened emotional response to external feedback

Studies 1 and 3 showed that individuals perseverated less on the Wisconsin Card Sorting Test (WCST) when there were more Correct Consecutive Trials (CCT) per sorting category. These results suggest that perseveration may not be the result of overlearning of a particular response as has often been suggested. Rather, as the number of CCT increases and the learning of each sorting category is facilitated, perseveration seems to decrease. The reason for this however is less than clear.

Successful performance on the tests entails relying on cues ('right' or 'wrong') provided by the experimenter. Following the cue 'wrong', non-perseverators would attempt other sorting ways, often incorrect, or indeed guess if they are not aware of the correct choice. It is the persistence to a specific sorting category (often the previously correct category but not necessarily), despite negative reinforcement, that suggests the idea that somehow the cue provided does not serve its purpose. However, despite the considerable research especially with frontal lobe patients regarding cue utilisation, this notion has never been directly associated with perseveration.

Evidence from early studies however has suggested that unreliability of feedback increases perseveration. Gormezano and Grant (1958) found that conditions of unreliability regarding the feedback given by the experimenter during the WCST lead to an increase in perseveration. When individuals could not predict feedback and reinforcement was random, perseveration increased. On the other hand Berg and Grant (1948) had suggested that a negative cue received by the experimenter after a longer sequence of positive cues would make the negative cue "stand out" more. It is possible that in such situations the negative cue becomes more effective. It may be safe to postulate that perhaps in the case of perseveration, the external cues provided by the experimenter somehow do not serve their instructive purpose, or are not utilised by the individual to correct behaviour and update an ongoing strategy. The predominant idea behind the previous and the present study is that perseveration is somehow linked with an ineffective or non-existent utilisation of external cues. A specific avenue by which to pursue this idea is by measuring autonomic responses by way of skin conductance response (SCR) during administration of the WCST, an idea influenced by earlier works of Damasio (1991, 1994, 1996, 2000) and Bechara et al (1996) on the somatic marker.

Damasio (1991) first introduced the idea that an emotional reaction to an external cue serves as a guide to decision-making and subsequent actions. According to Damasio, certain external cues are meant to trigger an autonomic response that in turn reflects an emotional arousal, which guides individuals to the most beneficial course of action. This autonomic response he called a "somatic marker".

The prefrontal cortex is thought to mediate the effect of the somatic marker on behaviour (Damasio 1996). The somatic marker is needed in situations where choices have to be made regarding the choice of options and scenarios for the future (Saver and Damasio, 1991), particularly in situations that carry social significance (Damasio, 1990). The range of behaviours that are considered possible for a given situation or the repertoire of responses available to a given stimulus is the result of learning. In other words, punishments and rewards received in social situations give range to a variety of possible acceptable or unacceptable behaviours that could be performed at any given time.

An internal representation of the punishment or reward associated with a given stimulus or situation is essentially at the basis of a somatic marker (Bechara et al, 1996). A potential response with a consequence carrying a negative representation would be avoided while one with a positive representation would be selected.

Thus the somatic marker, which can be measured by skin conductance response when a cue is presented, prompts the individual to alter or adjust a behavioural response to fit the particular situation. Studies by Bechara et al (1994, 1996) and Damasio (1996) found that the absence of a somatic marker among frontal lobe patients was related to erroneous or non-beneficial selections in a gambling situation (Bechara et al, 1994, Bechara et al 1996, Damasio et al, 1996). In other words, for frontal lobe patients at least, negative cues do not seem to trigger the emotional response needed to facilitate response selection when necessary.

The mock gambling game devised by Bechara et al (1994, 1996) involved selecting from one of two decks of cards that represented high and low financial rewards respectively, during which SCR measurements were taken. The aim of the task was to accumulate the most money or lose the least. The deck that contained cards that consistently offered higher rewards also offered higher penalties (which meant loss of money). On the other hand the deck containing cards that offered less money, also offered smaller penalties. In the long run, to perform the task successfully individuals had to learn that it was more advantageous to choose cards from the deck offering less money and smaller penalties. SCRs were measured just before a selection was made (anticipatory SCRs) and just after a selection was made (after the 'reward' or 'punishment' was known).

The studies showed that although both frontal and healthy individuals generated SCRs in response to the punishments and rewards, frontal participants did not produce anticipatory SCRs. Furthermore frontal patients made more disadvantageous selections than healthy participants.

In an earlier study Damasio (1990) compared SCR between three groups of individuals, namely individuals with bifrontal lesions, with lesions outside the ventromedial regions and healthy individuals and measured three types of SCR Firstly "orienting" SCR was measured following stimuli such as an unexpected noise. Secondly "target" SCR was measured following negative images (such as depicting a disaster) and finally following nontarget pictures (e.g. pictures depicting neutral scenes). SCR was measured one to five seconds after the presentation of the stimulus. The study showed that the three groups of participants showed no difference in orienting SCR. However, whereas the healthy participants and those with lesions outside the ventromedial areas showed a larger SCR after the target pictures than after the nontarget pictures, individuals with bifrontal lesions did not show a difference in SCR between the two.

Most importantly in line with Bechara et al (1996) and Damasio's (1996) findings, the absence of a somatic marker hinders an individual from responding advantageously i.e. according to the consequences of his/her actions, even when the individuals retain the knowledge of these consequences. Indeed, studies by Saver and Damasio (1991) have shown that frontal lobe patients do have knowledge of the variety of options that they can select in order to improve performance. According to Damasio therefore, erroneous selections at the tasks described above could not be due to lack of understanding of the options. Rather they could be the result of a working memory or attentional deficit that would preclude knowledge representations from being integrated in the decision process and response selection. Alternatively, they could be the result of an absence of an emotional tag to those representations.

Damasio and his colleagues were referring particularly to situations with social significance. According to Bechara et al (1996), the gambling test simulates a "real-life" situation, where social decisions have to be made. They believe that the impairment that their participants showed in the gambling task pertained specifically to social judgement and was not accompanied by other cognitive or intellectual impairment. In fact Damasio (1996) stated that individuals showed normal performance on a variety of cognitive tasks including the WCST.

Nevertheless performance on the gambling tasks that they described involves selecting responses on the basis of a reward or punishment even when individuals were aware of the long- term effect of the selection (in relation to the entirety of the task). These conditions are present in a situation like the WCST. Moreover it is a theoretical consideration of the present study (in line with Grant and Berg's early conceptualisations) that, on the WCST, perseveration may decrease as the result of an increased understanding of the sequential characteristics of the task in its entirety (i.e. the overall rule). This understanding is in turn facilitated by the learning of each sorting category. In this sense the gambling task devised by Bechara et al (1994, 1996) is not dissimilar to the WCST, notwithstanding the qualitative differences in the rewards and punishments, which are more social in terms of context in the gambling test.

Clinical observation has indicated on a number of occasions in past studies (Milner, 1963) as well as in the present studies that frontal lobe patients and non-frontal perseverators show evidence that they are aware both that their response is erroneous (before receiving feedback) as well as being aware of alternative ways to perform the test, but still perseverate.

How successfully the somatic marker hypothesis can be applied to the investigation of perseveration is not certain. The WCST provides a situation where a choice must be made based on cues provided by the experimenter, from a number of available options and where successful performance depends on understanding the "bigger picture", namely the sequential characteristics of the WCST. In this sense, the somatic marker hypothesis may be applicable. Perseveration may indeed reflect the absence of a somatic marker, which in turn may signify that the cue provided by the experimenter is not utilised.

It was considered a worthwhile endeavour to apply the approach used to investigate the somatic marker hypothesis to the investigation of perseveration on the WCST. The reason for this is rather straightforward: The explanation put forward regarding the role of the somatic marker is one that befits the theoretical standpoint of this study regarding perseveration, namely that that perseveration reflects an impairment in utilising external cues to adjust behaviour. If indeed the somatic marker serves as the precursor of a decision-making process, then it would be useful to examine whether a similar process is active during choice selection on the WCST.

The incorporation of SCR measurements to the study of perseveration, given the theoretical considerations of this study, may be a promising method by which to examine the emotional response to the cues provided by the examiner during the WCST could have on card sorting and perseveration. This investigation may shed light on two related questions: firstly, whether perseveration is associated with an altered response to cues during the WCST, and secondly whether this altered emotional response is different during the shorter or longer sequences of CCTs.

There is at least one report of an association between perseveration with SCR. Perry et al (1998) found that skin conductance hyporesponding of the orienting function

(SCOR-HR) at least among schizophrenic patients, is associated with perseveration on a Rorschach test and also correlated with the negative symptoms scale. According to Perry et al, SCOR-HR occurs at the same levels and for the same percentage of patients regardless of whether the stimuli are meaningful or not. Although this data is not directly relevant to the present study it does suggest a relationship between perseveration, albeit in a different context, and the relative lack of skin conductance response.

In the present study the emotional reaction to cues received during the WCST is investigated among healthy participants by measuring the SCR two seconds after each cue presentation. The specific question asked is whether SCR levels would be greater after a negative cue received by the examiner ('wrong') than they would be after a positive cue ('right'). The idea behind this hypothesis is that non-perseverators (or low perseverators) should show a greater SCR in both versions and for both positive and negative cues compared to perseverators. In addition, they should show a greater SCR response to the negative cue than to the positive cue, as the negative cue is meant to be corrective and directive. Moreover this difference should be more pronounced for WCST15, indicating the increased effectiveness of the negative cue after a longer sequence of positive cues. However, for high perseverators this should not be the case. The participants were divided post administration into high and low perseverators in order to examine a possible dissociation. Given the fact that data so far indicates a decrease in perseveration on WCST15, a higher SCR for negative cues in the WCST15 may provide additional support to the notion that perseveration may be associated with an ineffective use of cues.

Specifically, the hypotheses that were formulated for the present study relate firstly to the number of perseverative errors and secondly to the SCR. The WCST5 group is expected to score more percent perseverative errors than the WCST15 group. This would confirm data acquired from the first and third studies. A difference is also expected in terms of percent perseverative errors between early and late trials of WCST5, as reported in Study 3, with the later trials showing an increase in perseveration.

Secondly, skin conductance response is expected among low perseverators (below 20%) to be greater after a 'wrong' cue than after a 'right' cue in both WCST15 and WCST5. Such a result would indicate that low perseverators react emotionally to the "wrong cue" and modify their behaviour accordingly. Consequently they are low perseverators. For high perseverators, no difference is expected: the negative cues do not elicit an emotional response and these individuals do not alter their sorting behaviour in response to such a cue, hence they are high perseverators. Finally, the negative cues during the WCST15 should yield an overall higher SCR than do the negative cues during the WCST5, because individuals perseverate less during WCST15 than during WCST5 (Studies 1 and 3), and therefore may respond more to the negative cue during WCST15 than during WCST5.

Method

Participants, Materials and Procedure

Participants were twenty-six healthy individuals aged 20–30, with no known neurological history. Two versions of the WCST, as described in previous chapters were administered whilst their SCR was measured. The versions differed from each other in terms of number of correct consecutive responses (CCT). Twelve participants were administered the first version (WCST5) which required 5 CCT per sorting category, while nine participants were given the second version (WCST15) which required 15 CCT per sorting category. The SCR measurements were taken from the index and third fingers of the non-dominant hand, which the participants were told to keep in a resting position during the task. They were also told to avoid any unnecessary movement of the body or deep breathing to minimise the possibility of a movement artefact. A minimum of ten seconds was allowed between each card sort, to obtain a measurable SCR. SCR measurements were taken in the eight-second period between two and ten seconds after the cue ("Right" or "Wrong") was given to the participant. The SCR was measured by taking the difference between the maximum and minimum values (peak to peak measurement) in the eight-second period. The SCR data were analysed using Acknowledge 3.5 software.

The measurements taken comprised of SCR (p-p) measurements, percent perseverative errors and number of perseverative errors. Apart from the variations of the test that were also implemented in Study 3 including the removal of ambiguous cards and the undetermined sequence of sorting categories all other aspects of scoring and administration of WCST5 and WCST15 followed Heaton's manual (1993).

Results

One individual was excluded from the study because he was sorting to the response cards instead of the key cards, while ten of the twenty-six remaining participants had to be excluded from SCR data due to difficulties encountered in data collection. Therefore perseveration scores were taken from twenty-six individuals while SCR scores were taken from sixteen.

1. Perseveration data

A Mann-Whitney non-parametric analysis revealed that there was a significant difference (p= .005, U= 31.500) between the two groups in terms of overall percent perseverative errors, with group WCST5 showing more perseveration (figure 11).

Perseveration was measured separately during early trials (first half of total responses) and late trials (second half) for both versions. A significant difference was observed between the early and late trials of WCST5 (p= .015, Z= -1.069), with late trials showing less perseveration. The difference between early and late trials on WCST15 was not significant (p= .285, Z= -2.437). When perseveration scores were compared between early trials on the WCST5 and early trials on the WCST15, no significant difference (p= .31) was found. The same was the case between late trials on WCST5 and late trials on WCST15 (.920) (table 2).

Twelve individuals scored highly in perseveration (20% and above) while fourteen individuals scored low (below 20%). Their perseverative scores are presented in table 3. Among high perseverators there was no significant difference in perseveration between WCST5 and WCST15 ($p = .683$, $U = 13.500$). On the other hand among low perseverators there was a significant difference in perseveration between the versions, with less perseveration observed on WCST15 ($p = .002$, $U = 1.000$) (table 4). Furthermore, a significant difference in perseveration was found between high and low perseverators only during early trials on the WCST5 ($p = .007$, $U = 3.500$) but not during late trials ($p = .060$, $U = 8.000$). The opposite result was found for WCST15. In other words a significant difference was present during late trials ($p = .009$, $U = .500$) but not during early trials ($p = .209$, $U = 6.500$). In addition, high perseverators that were administered the WCST5 showed a significant difference in perseveration between the first and second half of the test, with more perseveration during the first half ($p = .027$, $Z = -2.214$), whereas high perseverators that were administered the WCST15 showed no difference n perseveration between the first and second half of the test ($p = 1.00$, $Z = .000$). Low perseverators showed no difference between early and late trials on either the WCST5 ($p = .109$, $Z = -1.604$) or WCST15 ($p = .588$, $Z = -.542$).

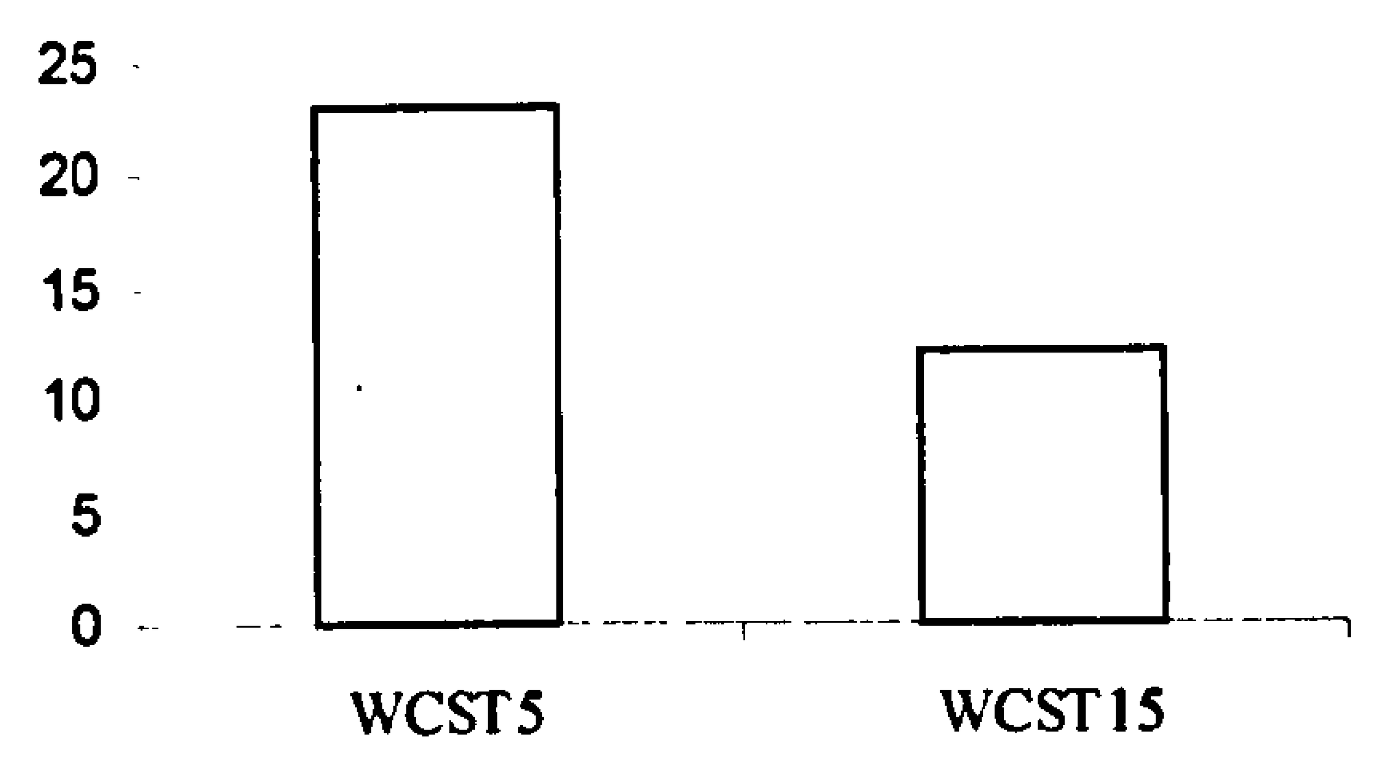

Figure 11 Percent perseverative errors on WCST5 and WCST15 among healthy individuals

Table 6. First, second (median) and third quartiles for percent perseverative errors

	1st	median	3rd
WCST5	18	23	33
WCST15	6.5	12	22

Table 7
Percent Perseveration in early and late trials on WCST5 and WCST15 (median)

	Early Trials	Late Trials
WCST5	11	5
WCST15	5.5	4

Table 3
Mean and median percent perseveration for high and low perseverators on both versions

	Mean	Median
HP*	29	30.5
LP*	11.5	12.5

Table 4
Percent Perseveration between high and low perseverators on WCSR5 and WCST15 (median)

	HP*	LP*
WCST5	32	16.5
WCST15	26.5	6.5

Table 5
Percent perseveration on early and late trials among high and low perseverators on WCST5 and WCST5 (median)

	Early Trials		Late Trials	
	HP*	LP*	HP*	LP*
WCST5	14	4	7	3
WCST15	19	5	14	2

* HP= High Perseverators (PE 20% and above)
LP= Low perseverators (PE below 20%)

2. SCR data

The data was divided into two groups of high and low perseverators, and the results are shown in Table 6. A perseverative score of 20% and over was considered high, while a score under 20% was considered low. No significance difference was found between high and low perseverators in terms of SCR (for both versions) either after a "right" cue (p= .174, U= 18.500) or after a "wrong" cue (p= .142, U= 17.500). When the different versions were taken into account, high perseverators (HP) did not show a significant decrease in SCR after negative cues ('wrong') compared to low perseverators (LP) on the WCST5 (p= .095, U= .000). Also no significant difference was established in SCR after negative cues between high and low perseverators on WCST15 (.889). The same results were obtained for positive cues ('right'). Finally, there was no difference in SCR response among HP between wrong and right cues (p= .500, Z= -.674). The same was found for LP (.932, Z= -.085).

Table 6
Median skin conductance response (micromhos) to "right" and "wrong" cues from high and low perseverators in WCST5 and WCST15.

	LP		HP	
	Right	Wrong	Right	Wrong
WCST5	0.025	0.015	1.100	1.800
WCST15	0.800	1.100	0.435	0.420

Discussion

The present study had a dual purpose. The first was to confirm previous findings that perseveration is significantly lower in WCST15 which offers more CCT compared to WCST5. The second purpose of the study was to investigate a possible association between a deficient emotional response to feedback (measured by SCR) and perseveration. This was tackled by comparing SCR levels between positive and negative cues and between high and low perseverators.

For the first part results were as expected. Once again, it was proven that individuals perseverate more in the version that offers less CCT. Furthermore, when comparing perseverative errors between early and late trials, results were quite unexpected. Perseveration was expected to be less in later trials for both WCST15 and WCST5, indicating an improvement in learning. In addition, this difference was expected to be greater for WCST15. Results showed that this difference occurred only for WCST5. In addition, neither high perseverators nor low perseverators when tested independently showed a difference in perseveration between early and late trials on WCST15. It should be remembered that when number of participants that comprised the HP and LP groups for the respective versions was quite small (between 3 and 7 individuals per group) and thus their data should be considered with caution. Apart from that, one of the factors that may affect performance differences between the first and second half of the test lies in the nature of the test administration, which allows free choice of category sequence. This means that it is more likely for a participant, including those who perseverate severely, to complete the first category and thus score less perseverative errors at the initial stages of the test. This however does not explain why an improvement in performance in terms of perseveration was observed on WCST5 but not on WCST15.

The predictions regarding SCR data were not supported overall. The expectation was to observe an increased SCR for negative feedback among the participants suggesting that negative feedback which is supposed to be corrective as well as directional, creates a stronger emotional response especially when following a series of positive feedback. However this hypothesis was based on the fact that the population that took part in the study was healthy and was expected to show overall low perseveration. This did not prove to be the case. In fact twelve out of twenty-eight participants scored an average of 29% perseveration. Thus the prediction that SCR to negative cues would be greater than SCR to positive cues would not be sensible for this particular population.

Moreover, it was expected that low perseverators (LP) would show a greater SCR than high perseverators (HP) to support the idea mentioned above that perseveration may occur as a result of a weakened response to cues. Overall, on both versions, there was no difference in SCR between HP and LP. The same pattern emerged for positive feedback. These results seem to contradict the idea that perseveration is associated with a weakened SCR. A possible explanation may simply be that perseverators are more worried because of failure to perform well and experience a generally elevated emotional state during the test, which may be unrelated to feedback utilisation. In this case, SCR measurements may be inappropriate for use during the WCST or have been used ineffectively for the purposes of this study. Further investigation may prove enlightening in terms of pinpointing limitations and finding more efficient ways to measure emotional response to cues during this test.

Although the SCR data was non-significant, the overall results confirmed again that perseveration does decrease with more CCT. It is possible that perseveration is not directly related to lack of emotional response to cues but may be associated with faulty learning. Perseverators seem to know when they are wrong, react emotionally to negative feedback but are yet unable to correct their errors. However what does seem to improve their performance and decrease perseveration is a stronger connection between a correct response and positive feedback. In effect, the preceding studies showed that the more opportunity individuals have of getting a sorting response correct, the less they perseverate.

Further investigation would perhaps benefit from measuring SCR after the completion of each category. This may give a clearer indication of the difference in SCR a variation of CCT would have. In addition a study such as the present would be facilitated by a larger sample. In the present study only the data from sixteen participants could be used for SCR analysis. A further limitation of this study that should be addressed in the future is that the administration of the test was greatly affected by the necessity of a ten second delay between selections. This may have had a serious effect on the concentration of participants and lengthens the duration of the test enormously.

Moreover, it is possible that the study would have benefited from the use of different sets of SCR measurements taken comprising of a shorter anticipatory SCR and an additional SCR measurement taken one to five seconds after each cue was received by the experimenter. The current study utilised a single SCR measurement after each sort, the duration of which was long enough to include an anticipatory response to the next sort. Although this measurement was taken to ensure the complete inclusion of the SCR recovery limb, it may perhaps have been too long and may have contaminated the results by merging post feedback SCR with anticipatory SCR. In the study by Bechara et al (1996) SCR measurements were taken both after the participants made a selection and prior to a selection. It was found that it was the anticipatory SCR that differentiates frontal participants who make the non-beneficial choices in the gambling test from non-frontal individuals who choose advantageously. It may be considered, in retrospect, a serious limitation that it was not taken into account that, as learning progresses and individuals understand the overall rule of the task, which would lead to a decrease in perseveration, than the anticipatory SCR should be focused on. However despite aforementioned similarities, the WCST is different from the gambling task in the sense that the feedback is required to indicate to the participant whether the same or different sorting category should be selected.

This investigation can be viewed as a stepping-stone toward future research that could reveal a possible association between perseveration and the lack of emotional response to feedback, or prove conclusively the absence of such a connection. Either way measuring SCR may prove to be a useful investigative approach to resolving at least in part, the puzzle of perseveration.

Chapter 9

An examination of possible limitations arising from standard measurements (the last-forty-trials solution)

An evaluation of the methodology used in preceding chapters brought to attention, apart from the limitations described in the relevant sections, the possibility that by measuring and comparing percentages of perseverative errors and total errors between WCST5 and WCST15, may create a bias in the data, especially for individuals that show limited perseveration. Specifically, owing to the way perseverative errors (PE) are scored (according to Heaton, 1981, 1989) a "perfect" score on the WCST (regardless of version) would allow for 5 perseverative errors at the end of completion of each category. Two non-perseverators who produce a score of 5 PE on the WCST5 and WCST15 respectively, will achieve very different percentage scores owing to the difference in total trials between WCST5 and WCST15. This would produce an unwanted bias in the sense that the individual who was administered WCST5 will score a higher percentage of PE. Consequently, the comparison of PE between the two versions might produce an inaccurate picture of both perseveration and total errors, albeit to a minimum extent. It was nevertheless deemed necessary to find a way to determine the accuracy of the results in the preceding studies and to provide a way around this methodological limitation. It was obvious that the alternative solution could not be to simply replace percentage scores with nominal scores, as the later could not be taken into account owing to the variability in length of the tests.

An alternative way of calculating PE is as a function of total errors, proposed by Nelson (1976). This however would not serve the purposes of these particular studies. The reason for this is that one of main premises of the studies is that perseveration decreases because of facilitated learning. Improved learning is likely to bring about not only a decrease in perseverative errors but also in non-perseverative errors. Thus, the function of PE over total number of errors would not facilitate the observation of changes in perseveration between versions. For example a perseverative score of 50 according to Nelson could be achieved by someone with 20 PE over a total of 40 errors, or by someone with 3 PE over 6 total errors. The improved performance of the later individual would be concealed by a PE score of 20.

Finally a solution to the problem was reached by including in the analysis of data only scores from the last forty trials of both WCST5 and WCST15. This would provide an equal number of trials for both versions, therefore rendering the calculation of percentage obsolete. Moreover, by including the last part of the tests, the comparison would more accurately reflect a difference in learning achieved and on the effect that the variations imposed would have had on performance.

The decision to include forty trials (as opposed to any other number) was taken on the basis that there were a small number of participants who completed the test in just over forty trials (with the exception of a few healthy participants in study one who required just under forty trials). To accommodate this data a figure of forty was deemed appropriate for all studies precluding the first part of the first study, where the total number of trials included in the analysis was thirty-five.

Results

The results in this section pertain only to number of perseverative errors.

Study 1

A Friedman nonparametric test revealed that there was a significant difference in perseveration among healthy individuals between WCST10, WCST5 and WCST15 (p= .001) (figure 12). Also in similarity to the findings of Study 1, a Wilcoxon Signed Ranks nonparametric test revealed that there was no significant difference between WCST5 and WCST10 (p= .189, Z= -1.314) but there was a significant difference between WCST10 and WCST15 (p= .007, Z= -2.683) as well as between WCST5 and WCST15 (p= .001, Z= 13.219).

Among the brain-injured group, the results were similar as those stated in Study 1. Although a Friedman nonparametric test showed that there was a significant difference between the versions (p= .022) (figure 13), a Wilcoxon Signed Ranks nonparametric analysis found that there was no significant difference between WCST5 and WCST10 (p= .191, Z= -1.309) or between WCST5 and WCST15 (p= .131, Z= -1.510). A significant difference was found only between WCST10 and WCST15 (p= .006, Z= -2.738).

Table 13. First, second (median) and third quartile scores for number of perseverative errors among healthy participants.

	1st	Median	3rd
WCST10	1.25	2.5	6.5
WCST5	3	4	5
WCST15	1	1.5	2

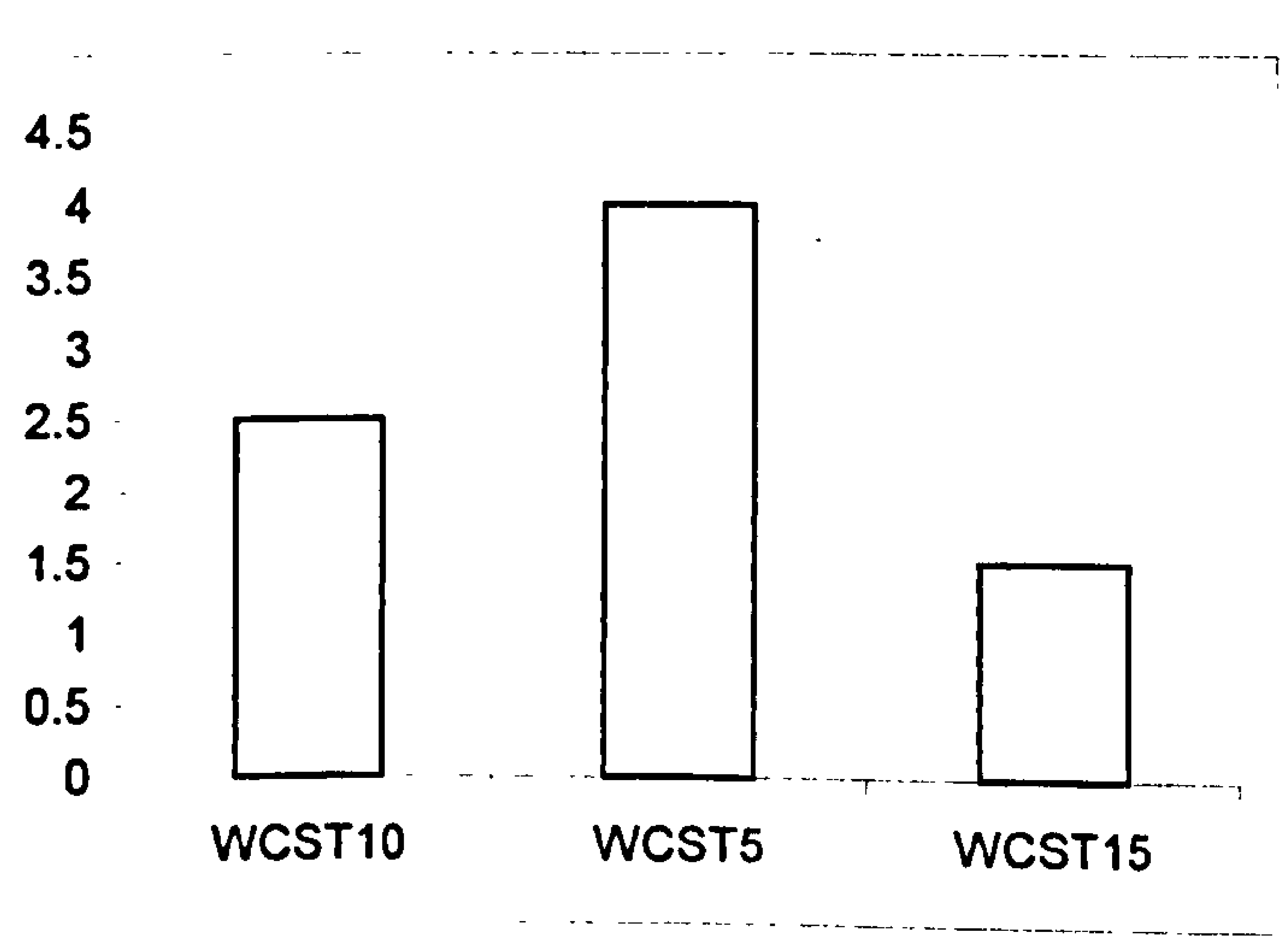

Figure 12 Number of perseverative errors during the last 35 trials among healthy participants (study 1)

Table 14. First, second (median) and third quartile scores for number of perseverative errors among brain-injured participants.

	1st	Median	3rd
WCST10	3	5	12
WCST5	4	6	9
WCST15	2	2	10

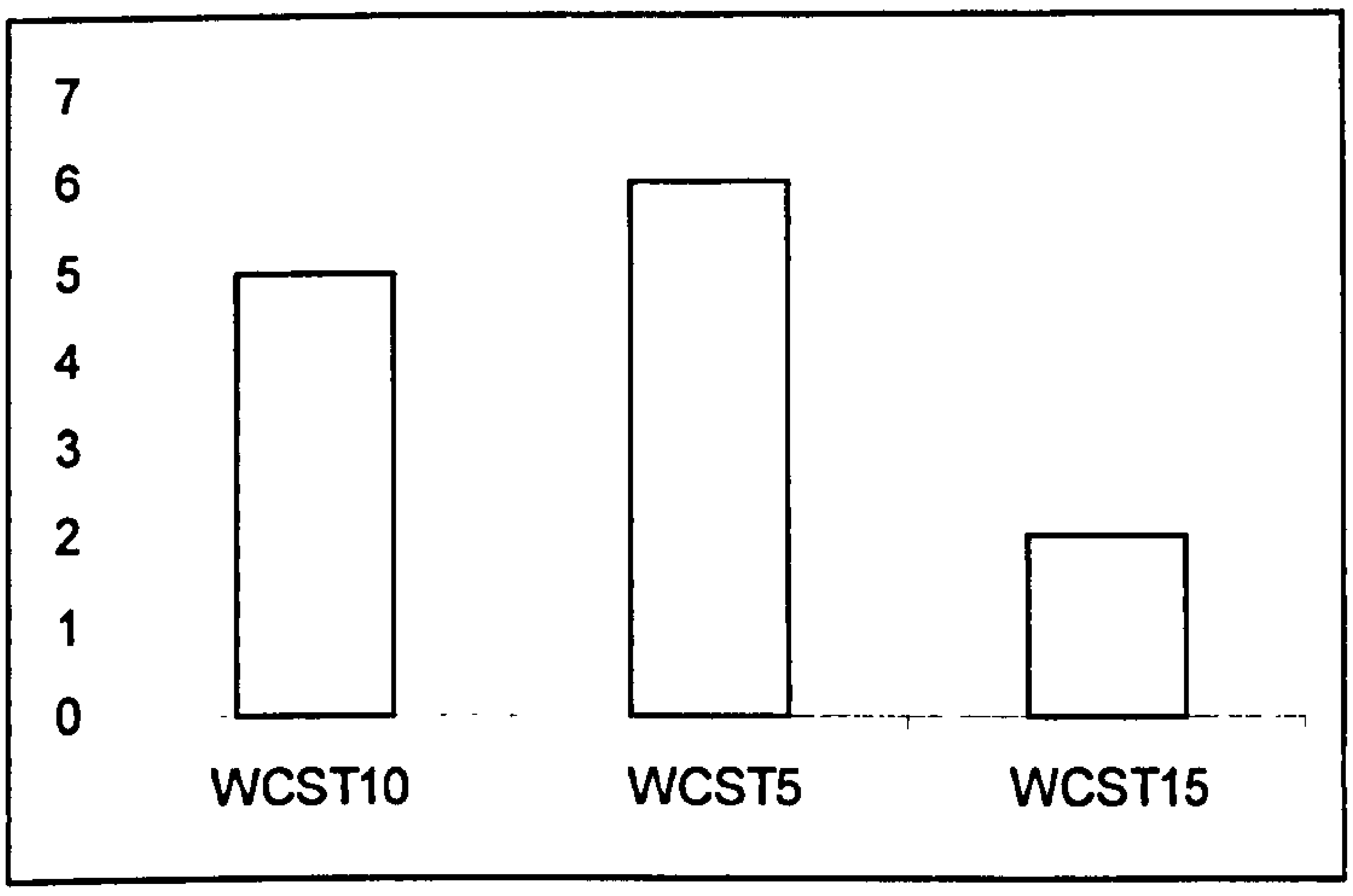

Figure 13 Number of perseverative errors during last 40 trials among brain-injured participants (study 1)

Study 2

Similarly to the data from Study 2, described in Chapter 6, a Mann-Whitney nonparametric test revealed that there was no significant difference in perseveration between WCST5 and WCST15 among brain-injured patients (p= .824, U= 46.500) (figure 14).

Table 15. First, second (median) and third quartile scores for number of perseverative errors.

	1st	Median	3rd
WCST5	11.50	20	25.50
WCST15	6	17	31

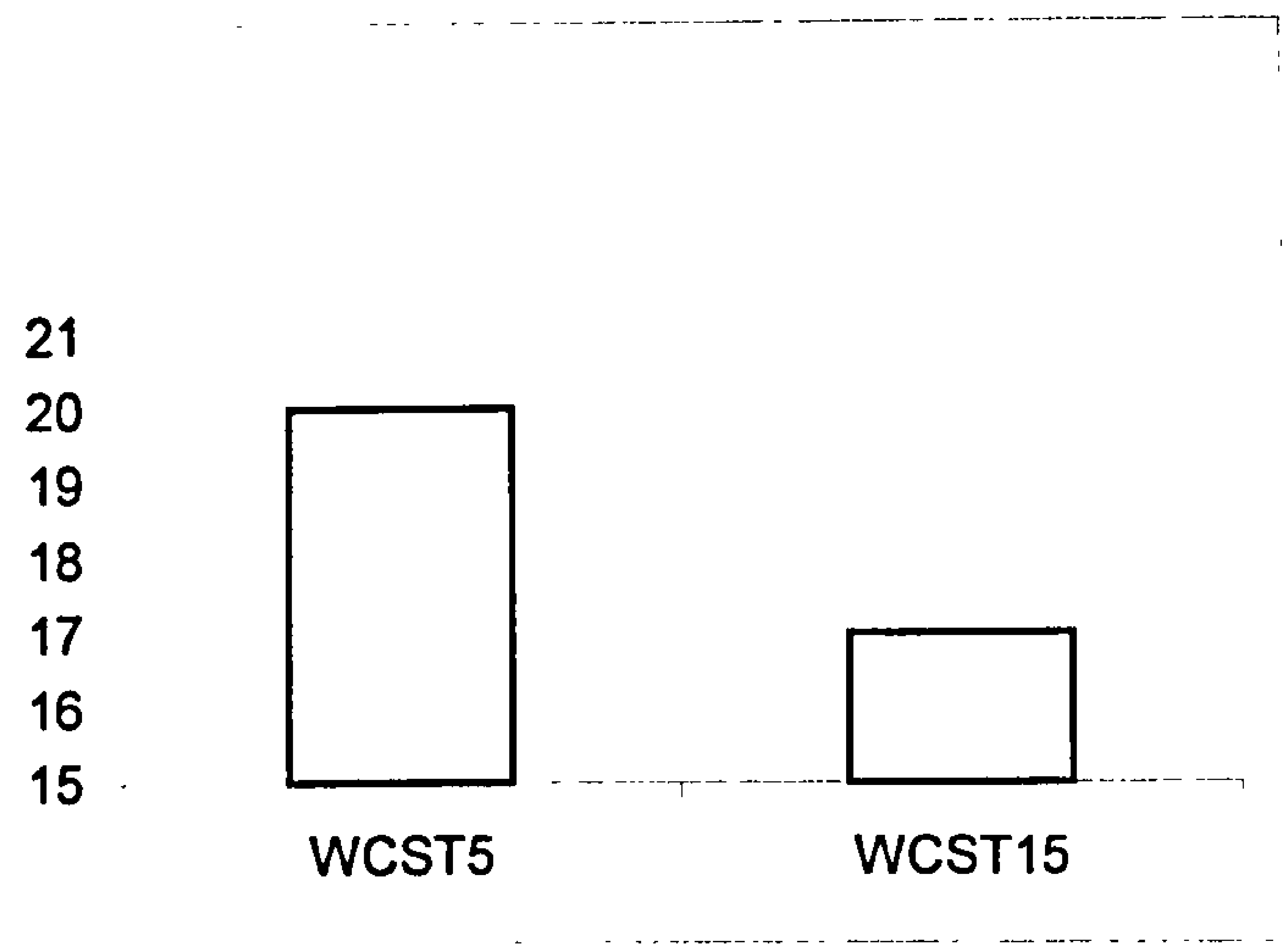

Figure 14 Number of perseverative errors during last 40 trials among brain-injured participants (study 2)

Study 3

The findings for this study were similar to those reported in Chapter 7. A Mann-Whitney nonparametric test showed that there was a significant difference between WCST5 and WCST15 ($p= .029$, $U= 24.000$) (figure 15).

Table 16. First, second (median) and third quartile scores for number of perseverative errors.

	1st	median	3rd
WCST5	15	23	35
WCST15	3.75	6	23.5

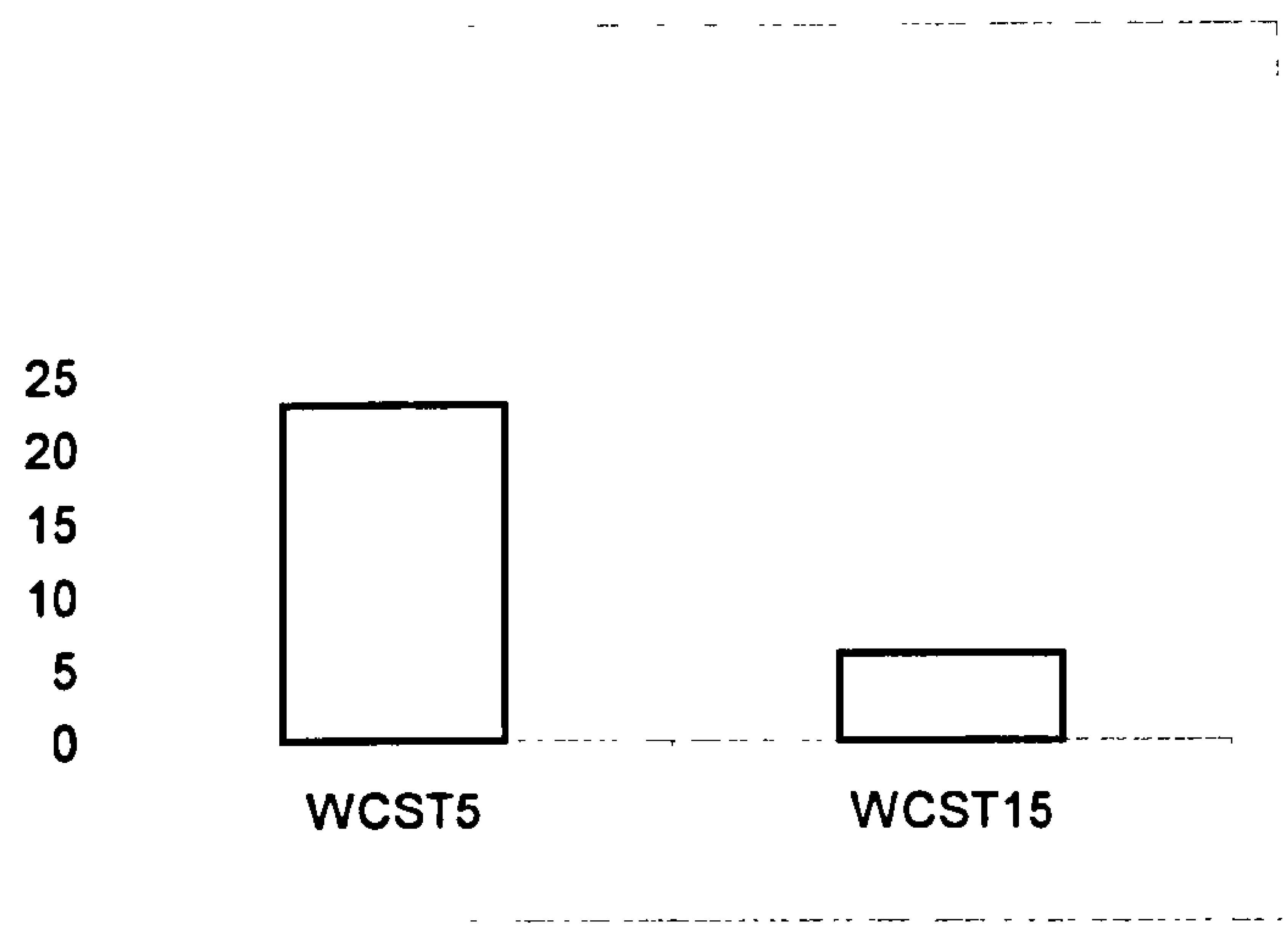

Figure 15 Number of perseverative errors during the last 40 trials among brain-injured and Korsakoff's patients (study 3)

Study 4

A Mann-Whitney nonparametric test confirmed the findings described in Chapter 8. A significant difference was found between WCST5 and WCST15, among healthy participants (p= .034, U= 43.500) (figure 16).

Table 17. First, second (median) and third quartile scores for number of perseverative errors.

	1st	median	3rd
WCST5	6	9.5	14
WCST15	2	3	10

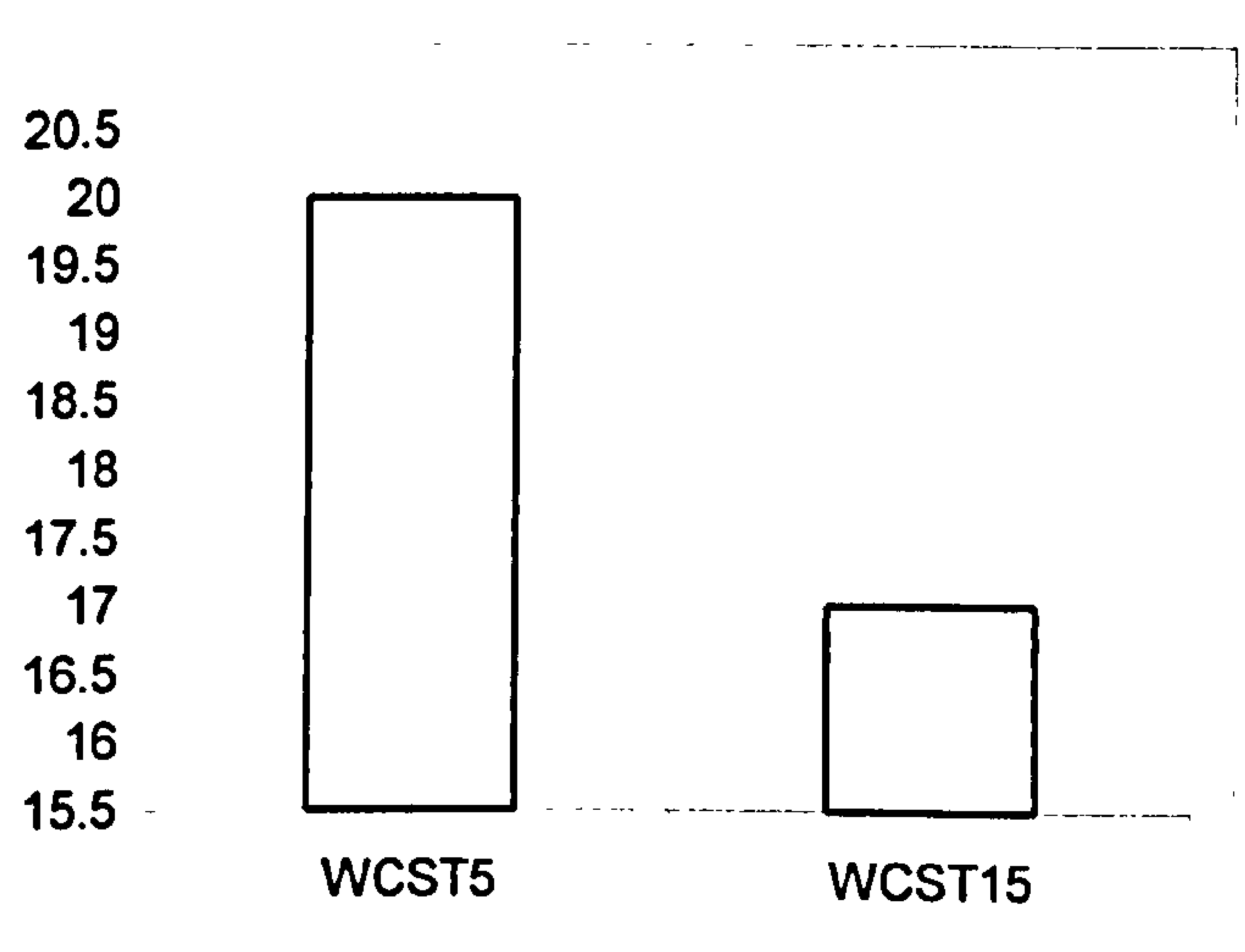

Figure 16 Number of perseverative errors during the last 40 trials among healthy participants (study 4)

Discussion

The results confirmed all the data accumulated in the preceding studies, with the exception of data from the brain injured group in Study 1. Overall these findings indicated that firstly that the findings so far were unaffected by bias but most importantly that perseveration can be measured reliably by including in the analysis only the last portion of the test, namely the lat 35 to 40 trials.

By measuring perseveration during the last forty trials a picture may be painted as to performance of individuals on the WCST which is unaffected by the initial correct sorts and which is may not be biased by percentages of errors, in cases where variations of the WCST are used which differ total number of trials. Above all this measurement may give a more accurate comparison of the learning that has taken place between different versions.

Chapter 10

General Discussion

At the onset of these studies the general consensus among theorists regarding perseveration was that it is more or less a frontal deficit reflecting an inability to disengage from a set of responses that are either learned or have become habitual (Milner, 1963, 1964). In other words, as discussed in previous chapters, inherent in the popular definitions of perseveration was the idea of overlearning, in the sense that when a particular response becomes established, by repeated reinforcement, perseveration to that response increases. This view is compatible with early ideas on perseveration. For example Flowers and Robertson (1985) and Brown and Marsden (1988) described perseveration as an inability to shift attention from an established mental "set". Similarly, the notion of disinhibition was linked to perseveration and was defined by Dias et al (1996) as an impairment in disengaging from previously acquired responses.

The Wisconsin Card Sorting Test (WCST) was found to be an effective tool for measuring perseveration as the later could be operationally defined and measured in a precise way. On the WCST, individuals are asked to sort cards without being informed of the sorting criteria. Participants are required to establish or modify a sorting pattern by relying solely on feedback given by the experimenter ("right" or "wrong"). Under these conditions perseveration is observed as a failure on the part of the participant to adjust his/her responses to the experimenter's feedback. The inability of some individuals to change their sorting behaviour after persistently receiving negative feedback led many researchers to conclude that perseveration is related to an inability to disengage from a chosen conceptual set or similarly to view perseverators as being "stuck in set".

Milner (1963) was the first to show a difference in performance between individuals with frontal (dorsolateral) and non-frontal lesions on the WCST. Subsequent studies have showed a difference in perseveration between frontal and non-frontal populations on the WCST (Nelson, 1976, Robinson et al. 1980). On the other hand a number of studies have failed to show such a difference (Drewe, 1974, Grafman et al 1990, Mountain and Snow, 1992, Anderson et al, 1991). Although undoubtedly informative, these findings achieved little in terms of offering a concrete understanding of the cognitive impairment involved in perseveration itself.

Perseveration has almost exclusively been defined and understood through its implied link to frontal lobe dysfunction. Specifically, the frontal lobe is considered to play a key role in facilitating a switch from a habitual response that is no longer appropriate, to an alternative behavioural response that is more suitable for a particular situation (Passingham, 2001). This behavioural switch presupposes a shift in attention and takes place as a response to changing external cues. Perseveration is thought to reflect more or less the situation where this shift does not take place. It is defined as an inability to disengage from a particular behavioural response despite the existence of cues indicating that a change is necessary. Furthermore as this particular response becomes more habitual or "better learned", perseveration is thought to increase.

The present investigation did not start with the specific aim of disproving these notions, but rather to establish their validity and to further explore perseveration by introducing purposeful variations on the WCST. However, it was discovered at an early stage during the first study that contrary to expectations, individuals perseverated less on a version of the WCST that offered more correct consecutive trials per category (CCT) and therefore facilitated learning for each sorting category. It was subsequently unveiled that in early studies, Grant and Berg (1948) and Grant and Cost (1954) had yielded similar results although the implications did not carry similar weight at the time and were not taken into account in more recent conceptualisations of perseveration. Indeed the central theme in those early studies was influenced by concurrent learning theories such as Harlow's learning set (1949). Their aim was to identify a possible relationship between increased reinforcement and the attainment of set.

In complete contrast to more recent views on perseveration on the WCST, Grant, Berg and Cost thought that the attainment of set would actually facilitate shifts from one sorting dimension to another. The idea behind this prediction was that efficient learning of each section of a task, in the case of the WCST each sorting dimension would enhance learning of the overall task. In addition if each sorting dimension were encouraged adequately, negative reinforcement signalling the need for a change in responding would "stand out" more. This idea was perhaps one of the earlier indications of the effect of external cues on behaviour, an idea particularly relevant to the current research.

The present studies utilised the WCST and varied the number of correct consecutive trials adding a number of purposeful variations, with the aim of unveiling the mechanisms underlying perseveration. In particular the studies presented here attempted firstly to establish a significant relationship between number of CCT and perseveration and secondly to address the role that utilisation of external cues plays on perseveration on the WCST. Both aspects of the studies pertain fundamentally to the relationship of perseveration with learning and emotion.

The first study tested both healthy and brain injured adults and utilised the standard WCST as well as two variations that differed only in terms of number of CCT, namely WSCT5 and WCST15. The findings suggested that perseveration significantly decreased on WCST15 when compared to both WCST5 and WCST10. Overall the indications of this study were that a longer series of trials significantly reduced perseveration for both healthy and brain injured adults. These findings contradicted the initial hypothesis, which reflected prevalent ideas on perseveration, and set the tone for subsequent work.

The second study was conducted to confirm the initial findings while avoiding the likelihood of a practice effect and introducing a number of additional variations to the design. This study tested twenty individuals with traumatic brain injury and each individual was only administered one of two versions, either WCST5 or WCST15. The total number of trials per version was adapted to accommodate the varying number of CCT. Results were not found to be significant in this case. It was indicated however that this was likely to have been a result of very high perseveration rates among participants, which hindered them from completing any categories, a fact that together with other methodological constraints such as a predetermined sequence of sorting categories, rendered the manipulation of the number of CCT ineffective.

The third study attempted to address the above and other methodological issues. Again twenty individuals with traumatic head injury were recruited. A number of alterations were introduced to the test versions. Ambiguous cards were removed to facilitate clarity regarding the feedback received by the experimenter and the sequence of categories was left undetermined to encourage the completion of at least the first category. This meant that the variation in number of CCT was more likely to have an effect. The findings this time confirmed those of the first study indicating clearly that perseveration was significantly lower for the group that was administered WCST15 compared to either WCST5 or WCST10.

The overall suggestion from the first and third studies was that perseveration decreased when individuals were given more opportunity to learn each sorting category. The findings showed rather conclusively that perseveration is not due to the inability to disengage from a mental set or a behaviour that is well learned, which has been the most prominent view during the last decades. This idea alone is an important contribution to the study of perseveration.

Moreover the present data contradicted the idea that perseveration reflects a failure to shift attention to a new stimulus or in the case of the WCST, new feedback. It was showed that such a shift is more likely to occur in situations where the new feedback is preceded by an increased occurrence of the original feedback.

Undoubtedly, these findings shed new light to the relationship between learning and perseveration. It seems that as the learning of each sorting category is facilitated through feedback, participants are able to abandon a sorting response more readily, in favour of a more appropriate one. The information gathered so far pointed to the fact that use of feedback may be central to the investigation of perseveration.

The idea for the fourth study was influenced by previous research on a deficit among frontal lobe patients in utilising cues to direct their behaviour and correct or avoid inappropriate responses. Alivisatos (1989, 1992) for example showed that frontal lobe patients were unable to benefit from the instructional nature of cues in a choice reaction time task. Dias et al (1994) found that frontal lobe patients had difficulty in modifying responses especially after negative feedback on reversal and visual discrimination tasks. Furthermore, quite early in the study of frontal damage, Luria (1964) described a patient with a frontal lesion who could not carry out a sequence of instructions, and who seemed to be impaired in "error evaluation" despite being aware of making the error. The awareness of the error, to the point of being able to predict that a response will be erroneous and will receive negative feedback is well documented through clinical observation in the present studies. However, similarly to Luria's patient, participants in the present study were unable to use the knowledge of the error as a guide to appropriate behaviour.

The accumulated knowledge of research such as the above, although pertaining particularly to frontal lobe patients, may provide an avenue of research on perseveration. Although it is a fact that perseveration is not unique to frontally impaired individuals, the later certainly represent a population that scores relatively high in perseveration on the WCST. There is, at least as yet, no reason why a deficit that has been linked to frontal lobe damage, such as the inability to benefit from cues, may not also occur in other populations that perseverate.

Successful performance on the WCST undoubtedly requires the utilisation of feedback provided by the experimenter in order to make the correct sorting choices and amend errors. Although the importance of utilising feedback for successful performance on the WCST has been suggested in the past (Greve, 1996), the inability to do so has never been specifically investigated as an underlying cause of perseveration. However, the very nature of perseveration (the repetition of a behavioural response despite negative feedback) and the fact that populations with high perseverative scores on the WCST such as frontal lobe patients show a deficit in benefiting from cues point towards the idea that inefficient utilisation of cues may be the central deficit underlying perseveration on the WCST. Thus the fourth study was undertaken as a first step to investigating this idea.

Damasio's work on the somatic marker provided the study with a particular avenue for inquiry. Damasio (1991) introduced the idea of the role in decision making that is played by the physiological reaction that occurs when a wrong choice is about to be made. This reaction serves as a somatic marker or guide, which enables the individual to adjust subsequent behaviour. This idea influenced the final study, which measures Skin Conductance Response (SCR) after positive and negative feedback during the WCST5 and WCST15 among healthy individuals.

The aim of the study was firstly to compare SCR rates between the two versions and between high and low perseverators. It was expected that high perseverators would show a weaker SCR than low perseverators and that WCST5 would be characterised by overall lower SCR levels compared to WCST15 reflecting a weakened ability to benefit from cues. Additionally, it was expected that SCT would be higher for negative cues, which are meant to have a corrective role, compared to positive cues, which have the role of reinforcing a particular selection. Finally the study also aimed at confirming the finding of the previous studies, namely that WCST15 would yield less perseveration than WCST5.

Although the later was indeed confirmed, SCR data did not overall support the predictions. Interestingly, the data although not significant, seemed to be consistently pointing towards a direction opposite from predictions. High perseverators seemed to produce a stronger SCR than low perseverators on both versions. This was important given that the main premise of the study was that individuals who perseverate less do so because they utilise cues better which in turn is indicated by a stronger SCR. The data clearly warrants further investigation on the use of SCR data to investigate utilisation of cues and indeed perseveration.

The role of cue utilisation in perseveration has not been firmly established by the preceding studies. However, the information provided by the last study beckons the question of whether registering cues and utilising cues are separate mechanisms and that the former does not necessarily generate the later. In the case of the WCST, registering the feedback received by the experimenter as indicated by an increased SCR, may not presuppose an efficient utilisation of that feedback, a suggestion that contradicts Damasio's somatic marker hypothesis, at least in the context of perseveration. The difference between the registration and the utilisation of cues may be a central issue in the study of perseveration. The distinction between the two was made clear by Konow and Pribram (1970). Pribram in particular, not only believed in the dissociation between recognising and utilising an error but also linked them to two separate anatomical regions, namely the posterior parts of the brain and the frontolimbic (Pribram 1957, 1960).

The dichotomy between error registration and error utilisation is consistent with more recent findings by Rolls (1991, 1994) who linked perseveration to a disturbance (associated with the orbitofrontal cortex), which occurs between what individuals know and express verbally (e.g. that contingencies have changed) and whether they act on that knowledge (Rolls, 1991, 1994). This disturbance, observed on visual discrimination tasks that include changing reward contingencies, is according to Rolls, primarily the result of a faulty relationship between emotion and learning. Rolls found perseveration to be particularly associated with inability to benefit from negative feedback. This idea ties in with the main finding of the current studies which postulate that the more opportunity individuals have to be correct, the less they perseverate, as well as clinical observation that seemed to indicate that positive cues determined choices more than negative cues did. It is likely that for perseverators, positive feedback may play a confirming role but negative feedback may not play a corrective role.

Errorless learning principles have been used with success to promote long-term improved performance on the standard WCST (Kern et al, 1996). The errorless learning principle is based on creating a training situation that promotes the minimal amount of errors. According to this principal, learning in any particular performance related situation is inhibited by errors. According to this line of thought perseveration on the WCST may not occur despite negative reinforcement, but perhaps because of it. A question that stands out then is whether WCST15 by its very nature provides in some sense a situation of errorless learning and whether in fact improved performance (measured as the decrease in perseverative errors and total errors) reflects errorless learning. This would certainly be a viable avenue for further study.

The limitations pertaining to these studies were numerous and the flaws very difficult to predict and avoid. Apart form those limitations discussed in previous chapters one particular flaw in the design of the studies seems to stand out, namely the adequacy of the WCST as a tool to investigate perseveration. Specifically, it should be questioned whether or not varying the number of CCT is an ideal means to investigate perseveration, as this variation can only be used effectively on individuals with moderate perseveration. In other words, as perseveration becomes more severe, the manipulation of CCT becomes less effective. Although the findings of the studies were arguably, given this limitation, consistent and quite overwhelming, further research on perseveration using the WCST would nonetheless benefit from a less precarious manipulation of the test.

Whether perseveration is a result of impairment in specific brain regions remains under question and is beyond the scope of these studies. It is also not clear precisely what happens on a cognitive level when cues fail to be utilised and why past responses prevail even when no longer appropriate. The non-facilitation of behaviour by instructional cues may result in a failure to learn by trial and error, which in turn may be associated with increased perseveration. The present findings seem to indicate the need for future research in the area of perseveration, along these lines.

The overall outcome of the preceding studies was that they provided a first step for the understanding of perseveration. They also provided valuable insight into the WCST as an investigative tool. It became apparent that perseveration is not associated with an inability to inhibit well-learned responses, as is so often suggested in the literature. Also the final study indicated that a higher emotional response to feedback is not associated with a decrease in perseveration, as was initially predicted. However, further research is needed to determine whether a higher SCR is associated with facilitated utilisation of feedback. Above all the studies provide a stepping-stone for further investigation into the relationship between perseveration, learning and emotion via the utilisation of external cues.

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