An investigation of memory deficits and executive function in adults reporting high checking behaviours.

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Author's Declaration

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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Previously published work

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List of Abbreviations

CANTAB	Cambridge Neuropsychological Test Automated Battery
CBT	Cognitive Behavioural Therapy
DASS	Depression Anxiety and Stress Subscale
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders – 4th ed., text rev.
DSM-5	Diagnostic and Statistical Manual of Mental Disorder– 5th ed.
EVET	Edinburgh Virtual Errands Task
ID/ED	Intra-Dimensional/Extra-Dimensional
MACCS	Memory and Cognitive Confidence Subscale
OCD	Obsessive Compulsive Disorder
PI-R	Padua Inventory Revised
PMQ	Prospective Memory Questionnaire
RAS	Responsibility Attitudes Scale
R/K	Remember/Know
SOC	Stockings of Cambridge
SST	Stop Signal Task
SSRT	Stop Signal Reaction Time
SWM	Spatial Working Memory
TOH	Tower of Hanoi
TOL	Tower of London
WAIS-R	Wechsler Adult Intelligent Scales-Revised
WCST	Wisconsin Card Sorting Task

Y-BOCS	Yale-Brown Obsessive Compulsive Scale

Abstract

Cognitive-behavioural models have been proposed to explain the development and maintenance of Obsessive Compulsive Disorder (OCD) and checking symptoms. Previous research has examined models relating to cognitive dysfunction, including the memory deficits and executive impairments. Evidence to support these models is inconclusive. Researchers suggest that it may be more fruitful to examine memory and executive function as involving several independent processes rather than treating them as unitary processes. It has also been suggested that memory impairments may be secondary to executive dysfunction. Reported work examining this relationship is limited. Studies investigating checking behaviours have highlighted the role of belief and appraisal models. In particular, memory confidence and perceived responsibility has been examined. The relative contribution of these variables, when examining memory deficits and executive dysfunction, is uncertain.

This work programme had the objective of examining the relative contribution of different cognitive-behavioural models to checking symptoms across four different studies. Prospective memory deficits and familiarity biases were found to be related to checking symptom severity. These findings suggest that, when examining memory deficits, independent memory processes should be considered. Inhibitory function was shown to consistently predict checking symptom severity, suggesting that executive dysfunction is related to a specific dimension of cognitive regulation. Inhibitory impairments were not shown to be solely related to the presence of OCD symptoms, with similar inhibition deficits in an OCD and anxiety group. Additionally, inhibition was demonstrated to independently contribute to compulsive but not obsessive

symptoms, when anxiety was taken into account. These findings highlighted the role of anxiety and inhibition in relation to compulsive symptoms. Correlation and mediation analyses across this work demonstrated that there is no relationship between memory impairments and inhibition. It was concluded that both memory deficits and inhibition independently contribute to the checking symptom profile. When memory confidence and perceived responsibility were examined in the same model as memory and inhibition, only perceived responsibility was found to be an independent predictor of checking symptom severity. The results from each of the four studies reported here have potential implications for future research examining cognitive-behavioural models of checking. It is suggested that an integrated model of checking may be useful in helping to develop a better understanding of the onset and maintenance of the disorder.

Chapter 1

Introduction

Obsessive Compulsive Disorder (OCD) is a mental health condition characterised by intrusive thoughts or images (obsessions) and by repetitive behaviours or recurrent mental acts (compulsions) (Stein, 2002). The World Health Organisation has classified OCD as one of the most frequently occurring mental health disorders for individuals aged 15-44 (World Health Organisation, 2001) and it has been shown to have substantial economic and social impacts (DuPont, Rice, Shiraki, & Rowland, 1995; Eisen et al., 2006). It is important to continue developing our understanding of the disorder in the hope that this knowledge can improve treatment options.

This chapter will review checking symptoms, differences in clinical and non-clinical samples and comorbidity in OCD. Following this, we will briefly examine conditioning models of OCD. Focus will then turn to cognitive-behavioural theories of OCD and compulsive checking. Cognitive-behavioural models can be divided into two main areas: cognitive deficit models and belief and appraisal models. The first objective of this thesis will be to examine cognitive deficit models of OCD and checking. This chapter will focus on memory deficits, with particular emphasis on retrospective memory and prospective memory. Executive dysfunction in OCD and checking will then be examined, with specific focus on inhibition. A second aim is to examine a model in which memory deficits are thought to be secondary to deficits in executive function (McDaniel & Einstein, 2000; Omori et al., 2007; Savage et al., 1999). Thirdly, the author will examine belief and appraisal models. Specifically, we will investigate how memory confidence and heightened perceived responsibility combine with other

variables thought to be impaired in checking (memory and executive deficits) to produce checking compulsions.

Approximately 2-3% of the population is thought to be affected by OCD, making it a relatively common disorder (Karno, Golding, Sorenson, & Burnam, 1988; Robins et al., 1984; Ruscio, Stein, Chiu, & Kessler, 2010; Sasson et al., 1997; Weissman et al., 1994). Furthermore, 15% of the general population have been estimated to suffer from sub-clinical[1] OCD symptoms (Stein, Forde, Anderson, & Walker, 1997). Evidence suggests that sub-clinical OCD symptoms are relatively common in non-clinical populations. It can be argued that participants with sub-clinical symptoms share common neurobiological substrates with clinical OCD (Spinella, 2005).

Researchers tend to have treated OCD as a homogeneous disorder. It may be better to treat OCD as a heterogeneous disorder, where subtypes have different etiological pathways and psychological impairments (McKay et al., 2004; Müller & Roberts, 2005). Although it is generally accepted that OCD involves obsessions and/or compulsions, the nature of obsessions and compulsions can vary greatly between individuals. In one of the largest factor-analytical studies of OCD symptoms, four symptom factors were acknowledged: obsessions and checking; symmetry and ordering; cleanliness and washing; and finally hoarding (Leckman et al., 1997). Researchers have suggested that OCD sub-types may exhibit different deficits (Nedeljkovic et al., 2009). The presence of impairments has been suggested to impact treatment outcome (D'Alcante et al., 2012). Consequently, investigating cognitive functioning in specific

[1] Please note that Chapters 3 & 4 used the term sub-clinical according to use of this term by Cuttler & Graf (2007, 2008) and definitions proposed by Black and Gaffney (2008) & Spinella (2005). In chapter 5 & 6, sub-clinical terminology will be used according to the Y-BOCS instrument developers.

sub-types, such as checking, may prove useful. This may help researchers to develop understanding and treatments for this condition. The first three studies in this thesis will proceed on the basis that distinct sub-types exist and will focus on checking symptoms. The final study will specifically investigate whether cognitive functioning impairments predict obsessive and/or compulsive behaviours, whilst considering the role of anxiety.

1.1 Checking compulsions

Checking compulsions are most commonly observed in OCD, with over 50% of patients reporting this subtype (Henderson & Pollard, 1988; Rasmussen & Eisen, 1988; Stein et al., 1997). Individuals with checking compulsions experience doubt in relation to whether or not a task has been completed and repeatedly check to try and obtain certainty. Checking can be viewed as a preventative behaviour, performed to minimise potential risks that one has not harmed oneself or others and to lower anxiety (Rachman, 2002). Common checking compulsions include checking doors, locks, cookers or appliances. Less commonly, individuals may check repeatedly to avoid mistakes, for example, checking a document to ensure all details are correct.

1.2 Clinical and non-clinical samples

Checking compulsions have been frequently reported in non-clinical samples (Sher, Frost, & Otto, 1983). Examination of such samples may help us to further understand the etiology of the disorder. OCD studies vary in the recruitment of clinically diagnosed samples and university recruited samples with a range of OCD and checking symptoms. In university samples, individuals scoring higher on OCD inventories are typically defined as sub-clinical. It has been reported that individuals with sub-clinical OCD show clinical features and personality traits similar to individuals with clinical

OCD (Frost, Steketee, Cohn, & Griess, 1994; Gershuny & Sher, 1995; Mataix-Cols et al., 1999). In particular, checking compulsions have been commonly shown in non-clinical populations (Sher et al.) and the content of checking compulsions does not appear to differ between clinical and non-clinical samples. Individuals experiencing checking compulsions in non-clinical populations, termed sub-clinical, may find it easier to dismiss compulsive tendencies than individuals clinically diagnosed, as they are experienced less frequently and intensely (Gibbs, 1996). Researchers expect that any deficit shown when investigating checking symptoms in a non-clinical sample, that includes participants with sub-clinical symptoms, will be exemplified in a clinical checking sample (Cuttler & Graf, 2007). The use of non-clinical samples appears to be a useful method for examining hypotheses about checking compulsions. This method helps to overcome some of the methodological problems related to the use of clinical samples, for example, medication effects. The current research will predominantly use non-clinical samples.

1.3 OCD and co-morbidity

Individuals with OCD frequently have additional comorbid psychiatric disorders. OCD was classified by the Diagnostic and Statistical Manual of Mental Disorders (4th ed., text rev.; DSM-IV-TR; American Psychiatric Association, 2000) as an anxiety disorder. In the recently published Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; American Psychiatric Association, 2013), OCD has been classified under obsessive compulsive and related disorders. Regardless of this change in classification, evidence still suggests that OCD is highly co-morbid with anxiety (Ruscio

et al., 2010) and classic behavioural approaches (for example, cognitive behavioural therapy - CBT) account for anxiety as a psychological component of the disorder.

OCD has been suggested to be highly comorbid with mood disorders and an OCD sub-classification system has been proposed by Nestadt et al. (2009). According to the authors, there are three classifications. These are: an OCD simple class, where major depressive disorder is the most common comorbid disorder; an OCD comorbid affective class, where panic disorder and anxiety are frequently presented, and an OCD comorbid tic-related class, where tics are common but affective conditions are less prominent. The British National Psychiatric Morbidity Survey included 8580 participants and indicated that comorbidity occurred in 62% of OCD cases (Torres et al., 2006).

The fact that OCD appears to be highly comorbid with anxiety and depression suggests that these diagnoses may not be entirely separable. D'Argembeau, Van der Linden, d'Acremont, and Mayers (2006) and Miller and Chapman (2001) have suggested that when there are significant comorbidities, controlling for them may not be realistic as they may not be entirely separable from a disorder. For this reason, the first three studies of this dissertation will not control for anxiety or depression, which are assumed to be common associated conditions in individuals with high levels of OCD symptomatology. In order to assess the impact of anxiety on OCD, chapter 6 will include an anxiety control group and consider the effects of anxiety, whilst examining cognitive functioning.

1.4 Models of OCD

In order to try and understand the onset and maintenance of OCD behaviours, models of OCD have been proposed. Several models of OCD have been developed, for

example, conditioning models and cognitive-behavioural models. Initially, focus in the OCD literature was on conditioning models. Limitations to these models resulted in focus turning to cognitive-behavioural models. Focus in this thesis will be on cognitive-behavioural models.

1.4.1 Conditioning models of OCD.

Initially, conditioning models (e.g. Rachman, 1971; Rachman & Hodgson, 1980; Teasdale, 1974) were used to explain OCD behaviours, based on the Mowrer (1960) two factor model of fear. These models assumed that obsessional fears developed via classical conditioning and obsessions were maintained by operant conditioning. For example, individuals with checking compulsions may have had a frightening experience such as having their home robbed if they had forgotten to lock the front door. Individuals then fear further break-ins and compulsively check to lower distress and anxiety. Checking relieves immediate anxiety but encourages ongoing compulsions in response to continuing obsessions. Conditioning models were key in the development of exposure therapy, considered to be one of the most effective treatments for OCD (March, Frances, Carpenter, & Kahn, 1997). Nonetheless, Taylor, Abramowitz and McKay (2007) stated that there are limitations to these models. For example, they do not account for why compulsions are persistent and repetitive. In addition, it was stated that the models do not explain why some individuals do not report any history of conditioning experiences which could have contributed to their fear (Taylor et al). Due to these shortcomings, researchers began considering cognitive-behavioural formulation models of OCD to explain obsessive and compulsive behaviours.

1.4.2 Cognitive-behavioural models of OCD and compulsive checking.

Cognitive-behavioual models have been proposed in order to explain the onset and maintenance of OCD symptomatology. These models follow two theoretical arguments. Some researchers hypothesise that OCD symptom severity is related to cognitive deficits (cognitive deficit models). For example, researchers have indicated that individuals with OCD show deficits in some forms of memory and executive function (Aydin & Oyekcin, 2013; Kuelz, Hohagen, & Voderholzer, 2004; Müller & Roberts, 2005; Olley, Malhi, & Sachdev, 2007) when compared to control participants.

Other researchers have focused on belief and appraisal models. These models of OCD share a central idea that the beliefs held by individuals regarding their OCD symptoms play a key role in the development of the disorder. One such model suggests a role for meta-cognitive beliefs and thought processes that control and monitor cognition. In relation to memory performance in OCD, two constructs of meta-cognitive processing have been proposed. Firstly, individuals with OCD tend to focus their attention on their mental processes. This is known as cognitive self consciousness. Secondly, individuals with OCD tend to report low confidence in their memory performance (Wells, 2008). Diminished confidence in memory in particular has been linked to checking compulsions (Radomsky, Gilchrist, & Dussault, 2006; van den Hout & Kindt, 2003a, 2003b, 2004) and will be focused on in the current work. Low memory confidence has been hypothesised to lead to pathological doubt and may contribute to and maintain checking symptoms (Tolin et al., 2001).

In addition to memory confidence, another extensively researched model involves the role of responsibility as a core element in the appraisal process (Salkovskis,

1985). Responsibility can be defined as 'the belief that one has power which is pivotal to bring about or prevent subjectively crucial negative outcomes' (Salkovskis, Richards, & Forrester, 1995, p. 285).

Rachman (2002) developed Salkovskis (1985) theory in order to account for checking compulsions. Rachman proposed a cognitive theory of compulsive checking which suggested that behaviours arise when a sense of perceived responsibility for harm is heightened, particularly when related to harming others. To lower this heightened responsibility, and to confirm that the threat has been removed, individuals compulsively check to ensure their safety and/or the safety of others. Rachman proposed that repetitive checking can negatively impact on memory and result in diminished confidence.

Evidence to support cognitive deficit models is inconsistent in the checking literature and will be reviewed below. Findings to support belief and appraisal models relating to low memory confidence and heightened perceived responsibility in checkers is slightly more convincing. Rachman (2002) suggests that repetitive checking may occur when individuals feel responsible and uncertain, this then leads to doubt about memory, which results in more uncertainty and checking. Muller & Roberts (2005) on the other hand suggest that checking is driven by memory deficits and biases. Researchers examining cognitive-behavioural models, therefore place slightly different emphasis on the contribution of different variables thought to be implicated in checking. Following a recommendation by Muller and Roberts (2005), interrelations among several variables will be examined in the same study in order to try and explain the development of checking symptoms. This thesis will focus on assessing evidence for and

against these models in the OCD and checking literature. Predictions proposed by these models will be empirically tested.

1.5 Memory deficits in OCD and checking.

It is hypothesised that memory impairments lead to difficulty in remembering whether a task has been completed (Sher et al., 1983). Memory impairments may then encourage compulsive symptoms. Tallis, Pratt, and Jamani (1999) originally proposed that memory deficits may be unique to checkers, as there was no logical reason as to why memory problems would relate to other symptoms, particularly obsessions. Checkers tend to express a feeling of poor memory for checked events (Sher, Frost, Kushner, Crews, & Alexander, 1989; Sher et al., 1983; Sher, Mann, & Frost, 1984). Impairments in memory have been suggested as an explanation for the maintenance of checking behaviours. If checkers do experience memory impairments, then researchers would expect deficits in memory when using objective and subjective tasks. Objective tasks (for example, experimental paradigms) tend to involve impartial measurements and are not based on opinions or beliefs. Subjective measurements rely on personal opinions and beliefs, for example questionnaire measures.

Researchers have supported memory deficits in compulsive checkers. In a meta-analytic review of 22 studies, results showed that memory performance was poorer for individuals with checking symptoms when compared to non-checkers (Woods, Vevea, Chambless, & Bayen, 2002). Specifically, memory deficits were highlighted on tasks measuring short-term memory and episodic memory.

In a review of the literature, Müller and Roberts (2005) argued that memory should be treated as involving several independent processes and should not be classed

as a unitary process when examining deficits in OCD. In a summary of memory processes in rats, monkeys and humans, it was reported that different memory processes may be related to different brain regions, thus supporting separate processes (Squire, 1992). Furthermore, Cuttler and Graf (2009) suggested that investigations of the memory deficit theory may be too general, with few researchers designing studies to focus on specific sub-types such as checking. It was suggested that focus should turn to specific domains of memory when examining checking. The current thesis aims to do this.

1.5.1 Evidence for memory deficits.

Research examining the relationship between memory deficits and checking compulsions has tended to focus on retrospective memory, memory for previously learned information, facts or events (Cuttler & Graf, 2009). Evidence suggests that retrospective memory is impaired in checkers when compared to non-checkers (Cuttler & Graf, 2007, 2008, 2009), although this deficit may not be specific to individuals with checking symptoms. A further distinction in the retrospective memory literature has been made between episodic memory, semantic memory and procedural memory (Grusec, Lockhart, & Walters, 1990 as cited in Müller & Roberts, 2005). Episodic memory is related to memory for past events, semantic memory is related to general knowledge, and procedural memory relates to memories for automatic actions. Distinguishing between different memory processes is important, particularly with some aspects of memory appearing much more closely linked to compulsive checking behaviours. Episodic memory appears most closely related to checking compulsions, with checkers unsure whether a task has been completed successfully or not (Exner,

Martin, & Rief, 2009). The episodic memory literature will be examined below in sections 1.5.1.2 and 1.5.1.3.

More recently, the importance of investigating prospective memory in checkers has been proposed (Cuttler & Graf, 2007, 2008). Prospective memory relates to the ability to remember to perform actions in the future, for example, remembering to turn off the cooker after making dinner. Relatively few researchers have specifically examined prospective memory in checkers. The memory literature relating to prospective memory will be reviewed below in section 1.5.1.4. Deficits in both retrospective and prospective memory would provide support for the memory-deficit theory and it is possible that these aspects of memory work together to maintain checking symptoms.

1.5.1.1 The role of retrospective memory in OCD and checking.

Retrospective memory refers to memory for information from past experiences (Harris & Cranney, 2012). Cuttler and Graf (2007, 2008) examined self-reports of retrospective memory failures in sub-clinical checkers compared to non-checkers. It was reported that individuals with higher checking symptoms experienced more retrospective memory failures. Subsequently, Cuttler and Graf (2009) conducted a review of the retrospective memory literature in order to examine the memory deficits in checkers. The review by Cuttler & Graf showed that several researchers have examined retrospective memory in the domains of verbal memory, visual memory (non-verbal), action memory (difficulty remembering intended actions) and source memory (remembering the source where information is obtained). In contrast to previous reviews (e.g. Woods et al, 2002), emphasis was placed on examining whether memory deficits were unique to checkers.

Memory performance was compared between OCD checkers and OCD non-checkers. In support of Woods et al (2002), memory performance deficits were commonly shown in OCD checkers. When comparing memory performance between OCD checkers and OCD non-checkers in all memory domains, few researchers reported deficits in OCD checkers. It was concluded from this review that retrospective memory deficits may not independently contribute or be specific to compulsive checking. It appears that relatively few studies have compared OCD checkers and non-checkers and only in limited retrospective memory domains (see Cuttler & Graf, 2009 for review).

1.5.1.2 The role of episodic memory in OCD and checking.

The memory deficit theory in OCD has been supported by several empirical investigations in which episodic memory has been measured. Müller and Roberts (2005) made a distinction between verbal and non-verbal episodic memory. In order to fully understand the nature of the relationship between compulsive behaviours and memory, the literature for both verbal and non-verbal memory will be examined below.

Evidence to support verbal episodic memory deficits in OCD is contradictory and not yet conclusive. It appears that most research examining verbal episodic memory is in relation to OCD in general, rather than checkers specifically. Using a variety of different measures of verbal memory performance, researchers have reported that OCD participants show a significant deficit in verbal episodic memory performance compared to controls (Exner, Kohl, et al., 2009; Tükel et al., 2012; Zitterl et al., 2001). Furthermore, Deckersbach, Otto, Savage, Baer, and Jenike (2000) made a distinction between verbal episodic recall and recognition memory. Results from this study demonstrated that individuals with OCD scored lower than expected for verbal recall,

but verbal recognition appeared intact. This result suggests that certain aspects of verbal memory are impaired (recall) whilst other aspects are intact (recognition). Other researchers have reported that both verbal recall and recognition memory are intact (Ceschi, Van der Linden, Dunker, Perroud, & Bredart, 2003; Segalas et al., 2010). Evidence for verbal episodic memory impairments is not persuasive. Sample and task differences are likely to have contributed to these conflicting findings.

In contrast to verbal memory, support for non-verbal episodic memory impairments in checkers is convincing. In an attempt to summarise the literature pertaining to several cognitive impairments in OCD, Abramovitch, Abramowitz, and Mittelman (2013) conducted a meta-analysis. When comparing OCD participants to controls, a large effect size was reported for non-verbal memory, in comparison to a small effect size for verbal memory.

Findings presented by Sher et al. (1989) and Tallis et al. (1999) are illustrative of the general patterns of results in the literature and will be detailed below. Sher et al. compared non-verbal episodic memory between a healthy control group and a group that consisted of clinical OCD participants with checking as their prominent symptom. Results indicated significant non-verbal recall and recognition memory deficits for checkers when compared to controls. Tallis et al. compared non-verbal immediate and delayed recall and recognition memory between clinical OCD participants with predominant checking symptoms and healthy controls. Researchers reported performance differences in recall and recognition on non-verbal memory tests, with significant impairments in the OCD group. Nonetheless, no correlations were shown between test deficits and checking. The latter finding could be interpreted as showing

that there is no relationship between non-verbal memory performance and checking. Nonetheless, the individuals recruited had checking as their primary symptom, and significant impairments were shown in the OCD checking group. This suggests that higher symptom severity is related to greater memory deficits. Findings of significant non-verbal memory deficits have been supported in several other investigations using checking samples (Cha et al., 2008; Segalas et al., 2010; Zitterl et al., 2001). It appears that non-verbal memory has been shown consistently to be impaired in individuals with checking symptoms and those with OCD. Focus consequently will be on non-verbal tasks when investigating episodic memory.

1.5.1.3 The role of recognition memory in OCD and checking – dual-process theories.

Most researchers investigating episodic memory recollection in OCD and checking samples have examined it as a single-process. Single-process theories make the assumption that episodic recognition ranges from weak to strong memories of the event. Limited OCD research has examined dual-process theories of episodic memory, in which a distinction is made between two different recognition processes, familiarity and recollection. The dual-process theory of episodic memory seems particularly relevant to checking behaviours and will be further discussed below.

Episodic memory recognition involves two distinct processes: familiarity and recollection (for reviews see Aggleton & Brown, 2006; Diana, Yonelinas, & Ranganath, 2007; Yonelinas, 2002). 'Familiarity' involves a feeling of knowing that you have encountered something before in the absence of a specific recollection. 'Recollection' involves remembering detailed qualitative information about studied events (Yonelinas,

2002). Most OCD studies have focused on retrieval measures that reflect recollection only (Cha et al., 2008; Segalas et al., 2010; Sher et al., 1989; Tallis et al., 1999; Zitterl et al., 2001). There is evidence for impairments in episodic memory recollection in those with checking behaviours in a small number of recent studies which will be reviewed below. These studies examined both familiarity and recollection, but further research is necessary in checkers. It has been argued that checking may, at least in part, reflect an over-reliance on familiarity. For example, individuals who feel the need to check whether a door is locked may focus on familiarity for that event rather than recollection. Familiarity based remembering relies merely on a feeling that an action (or more generally an event) has been encountered before and does not involve contextual processing. Less detailed and vivid memories may encourage individuals to continue checking in order to gain a more concrete memory of having completed an action.

Familiarity has been implicated in checking in a limited number of studies (Coles, Radomsky, & Horng, 2006; van den Hout & Kindt, 2003a, 2003b, 2004). To measure recollection (remember responses) and familiarity (know responses), researchers have used tasks such as the Remember/Know (R/K) paradigm. The R/K paradigm, originally developed by Tulving (1985), requires introspection for memory judgments, whereby individuals are required to report items that are recognised in terms of 'remembering' (e.g. recalling episodic information about a specific event) or 'knowing' (e.g. an event is familiar but information about the event cannot be fully recollected). This task assumes that recollection and familiarity are independent, which is consistent with dual-process models of episodic memory. The R/K task is a subjective measure and one advantage of this is that recollection can include all associative

information about a specific event. A criticism is that some individuals may lack introspection in to underlying processes. Recollections of R/K responses have been shown to be similar to responses from other, non subjective measures of recollection and familiarity, suggesting that individuals are aware of underlying memory processes (Yonelinas, 2001) and subjective tasks are suitable measures of recollection and familiarity. For further discussion of recollection and familiarity and the R/K task see chapter 5.

Familiarity and recollection were examined by van den Hout and Kindt (2003a, 2003b, 2004) in healthy student samples using threat-relevant (tasks that are related to OCD obsessions/compulsions – e.g. leaving the cooker turned on) simulation tasks (performing checking rituals on a virtual kitchen cooker). An experimental group who engaged in 'relevant' checking (i.e. checking a virtual kitchen cooker pre-test and post-test) and a control group who engaged in 'irrelevant' checking (i.e. checking a virtual kitchen cooker pre-test and a virtual light bulb post-test) were used in each study. Findings showed that repeated 'relevant' checking led to less detail and vividness of memory for checked events, and those in the experimental group reported that their response was more based on familiarity (i.e. knowing) rather than remembering when compared to controls. Memory accuracy was shown to be intact. Radomsky et al. (2006) and Coles et al. (2006) extended the work of van den Hout and Kindt (2003a, 2003b, 2004) using a fully equipped kitchen and reported similar findings. In summary, evidence is supportive of familiarity biases when threat-relevant checking is induced in healthy student samples.

Recall has been compared between individuals with predominant washing symptoms, individuals with depression and anxiety without OCD symptoms and healthy controls (Klumpp, Amir, & Garfinkel, 2009). Washers recall for OCD threat-relevant material was reported to be predominantly based on familiarity rather than remembering when compared to recall in the control groups. No differences were reported when familiarity responses were assessed using positive and neutral scenarios. It was concluded that reliance on familiarity for OCD threat-relevant material may encourage washers to doubt and this may lead to compulsive symptoms.

Further research has compared attention in terms of recall and recognition performance between sub-clinical checkers and non-checkers (Irak & Flament, 2009). On several different tasks of attention, participants were presented with OCD threat-relevant and neutral stimuli. For all attention tasks, checkers recall and recognition were better for OCD threat-relevant than neutral material. As far as the present author is aware, no study to date has investigated recollection and familiarity across contexts in checking (OCD threat-relevant and non OCD relevant contexts). Although familiarity was not measured directly in this study, this finding suggests that with better recollection for OCD threat-relevant information, familiarity biases (thus poorer recollection) may be evident in non OCD relevant contexts. Despite the fact that familiarity responses were not measured directly by Irak and Flament, recognition was reported to be better for OCD threat-relevant material. This appears contrary to the findings reported by Klumpp et al. (2009). It is difficult to compare these studies due to different methodologies; however it is possible the recognition biases for OCD threat-relevant and non OCD relevant contexts may change depending on the symptom sub-type (washers/checkers).

Limited research into recognition biases in checkers means that it is unclear whether familiarity biases apply across all contexts. Establishing whether recognition biases in checkers extend to non OCD relevant contexts is thus of considerable interest and chapter 5 will address this.

1.5.1.4 The role of prospective memory in OCD and checking.

Prospective memory is 'the ability to formulate intentions, plans and promises, to retain them, to recollect and carry them out at the appropriate time or in the appropriate context' (Cuttler & Graf, 2007, p. 339). The future orientated aspect of prospective memory, involving formulating and remembering intentions, seems closely linked to many of the compulsions experienced by checkers (e.g., remembering to lock the front door upon leaving the home). If individuals experience recurring prospective memory deficits, this may encourage them to doubt their memory and maintain checking behaviours.

A distinction has been made between event-based and time-based prospective memory. Event-based prospective memory tasks involve remembering to perform actions under specific conditions when an external cue (not specific to OCD checking) is provided (Cuttler & Graf, 2007). In contrast, time-based prospective memory involves remembering to perform an action at a particular time or after a specific time period. Further research relating to event and time-based prospective memory will be discussed below.

Evidence based on subjective measures of possible prospective memory impairments has been reported by Cuttler and Graf (2007). Individuals in non-clinical samples with high checking symptoms reported more prospective memory errors than

those with medium checking symptoms. These results applied to episodic prospective memory, habitual prospective memory and internally cued prospective memory. Episodic prospective memory tasks relate to those where, to be remembered information, is not held in conscious awareness and intended actions are performed infrequently, or on a one-off basis (e.g. collecting your sibling from the station in 2 weeks' time). Habitual prospective memory tasks involve repeated, regular performance of the same plan (e.g., picking up the house keys before leaving). Internally cued prospective memory relates to performing tasks where no external cue/reminder is provided to perform already planned tasks (e.g., remember to pay a bill on time). Reports of prospective memory aiding strategies (e.g. writing reminder lists) were also greater for high checkers compared to low checkers (see chapter 3 for further discussion). Similar reports of subjective prospective memory deficits were reported by Cuttler and Graf (2008).

Studies using objective tasks in non-clinical samples have reported that event-based but not time-based prospective memory impairments are evident in individuals with high and medium checking symptoms (Cuttler & Graf, 2007, 2008). Event-based prospective memory deficits have also been reported in clinical samples (Harris, Vaccaro, Jones, & Boots, 2010; Racsmany, Demeter, Csigo, Harsanyi, & Nemeth, 2011). Research in non-clinical and clinical samples supports the claim that event-based prospective memory deficits may be linked to checking behaviours. An understanding of why event-based but not time-based prospective memory deficits exist in checkers may help researchers to further understand what contributes to checking symptoms. In event-based prospective memory tasks, the presence of a cue to trigger memory is

unpredictable, thus uncertainty may arise and contribute to checking behaviours. In time-based tasks, cues are predictable and individuals can be more certain about having completed an action. This difference may help to explain why individuals feel the need to check compulsively. Focus in chapter 4 will be on event-based prospective memory.

It is important for researchers to understand the limitations of tasks employed to measure prospective memory. Studies employing subjective prospective memory instruments provide evidence that this domain of memory may be implicated in checkers (Cuttler & Graf, 2007, 2008). Subjective measures are open to biases and some individuals may not be fully aware of their symptoms or cognitive processes. Objective, laboratory based prospective memory tasks on the other hand may be more reliable than subjective tasks, yet presentation of the cue and prompts to check are determined by the experimenter. This is not the case in real-life, where a person's intention, actions and reflections during ongoing tasks are likely to impact on the manifestations of symptoms. Similarly, if individuals report subjective prospective memory impairments, researchers may interpret this in one of two ways; as either a cognitive deficit or reduced memory confidence. This is why it is important to measure prospective memory both subjectively and objectively. As far as we are aware, all studies to date that have employed objective prospective memory tasks in checkers have used laboratory tasks (Harris et al., 2010; Racsmany et al., 2011). Chapter 4 will further investigate prospective memory performance in an environment where individuals are responsible for utilising cues in the absence of extrinsic reminders or direct instruction to check, similar to requirements in everyday life.

1.5.2 Memory deficit summary.

Some researchers hypothesise that the onset and maintenance of OCD relates to cognitive dysfunction, such as memory impairments; the basic thesis is that a person's difficulty in remembering whether he or she has completed a task may encourage compulsive symptoms, such as checking. Evidence for general memory impairments has been mixed. Cuttler and Graf (2009) proposed that problems in retrospective memory are not specific to checkers and that there are stronger grounds for supposing that checking is related to difficulties in prospective memory. There is evidence to suggest that there may be biases in episodic retrospective recollection. Individuals with high checking symptoms have also been shown to report more prospective memory errors and perform less well on objective prospective memory tasks than low checkers.

1.6 Executive dysfunction in OCD and checking

Executive function is an umbrella term denoting higher order strategic processes such as inhibition, planning, set-shifting and working memory, known to be critical in the control of behaviour. Researchers have reported executive dysfunction in OCD and checking samples. From a theoretical perspective, a common mechanism is thought to underlie all executive function processes, but different aspects of executive functions are clearly separable (Diamond, 2013; Miyake et al., 2000). Theoretical explanations weight the importance of various executive functions differently. Most implicate inhibition, working memory and attention set-shifting as core executive function processes (Diamond & Miyake et al). Higher order executive processes such as planning have also been implicated (Diamond). Miyake et al. (2000, p. 49) indicated that 'it is important to recognize the unity and diversity of executive functions'. Miyake et al. recruited college

students and examined different executive functions. Using factor analytical techniques, it was reported that executive functions had several distinct factors and were clearly separable. It is possible that some executive functions impact more substantially on checking behaviours than others but, at present, we lack evidence. Identifying the relative importance of each of these variables will contribute to our understanding of the causes of checking behaviour and the nature of the disorder. The following section will review and discuss the literature relating to inhibition, planning, set-shifting and working memory.

1.6.1 The role of inhibition in OCD and checking.

The most consistent evidence for executive dysfunction in OCD indicates a deficit in inhibition, the ability to suppress irrelevant or interfering stimuli. Individuals with OCD often report an inability to control or stop repetitive thoughts and behaviours. Evidence to support inhibitory deficits in those with OCD has been reported using several different tasks, for example, the Go/No-go task and Stroop task (Abramovitch, Dar, Schweiger, & Hermesh, 2011; Aycicegi, Dinn, Harris, & Erkmen, 2003; Bannon, Gonsalvez, Croft, & Boyce, 2002; Page et al., 2009; Penades et al., 2007) and the direct forgetting paradigm (Bohne, Keuthen, Tuschen-Caffier, & Wilhelm, 2005; Konishi, Shishikura, Shutaro, Shin-ichi, & Masaru, 2011).

Research investigating inhibition in OCD tends to have used general OCD samples. Few researchers have examined the contribution of inhibitory dysfunction to checking symptoms. If individuals find it difficult to inhibit a prepotent plan (“I must close the bathroom window”) then, despite having undertaken the relevant action, this distracting cognition could recur and prompt checking. Similarly, if individuals have

difficulty inhibiting irrelevant thoughts whilst also experiencing memory deficits, repetitive, compulsive behaviours are likely. It seems plausible that inhibitory deficits may contribute to the clinical symptoms experienced by checkers.

Omori et al. (2007) investigated inhibitory control in checkers vs. washers. Results from the Go/No-go task in which individuals are required to make a motor response (Go) and to withhold a response (No-go), revealed that checkers had significant performance deficits compared to washers. Van der Linden, Ceschi, Zermatten, Dunker, and Perroud (2005) also investigated differences in inhibitory control using the hayling task, whereby individuals are required to complete sentences under two conditions; one where a missing word is required in the context of the sentence and the other where individuals are asked to produce a word that is unrelated to the context of the sentence. Checkers and washers were reported to display inhibitory deficits when compared to a control group with social phobia and healthy controls. Differences in results for checkers and washers could be a result of sample and task differences. In the study conducted by Omori et al. individuals with coexisting checking and contamination/cleaning symptoms were excluded, whereas Van der Linden et al. did not exclude individuals with mixed profiles. It is difficult to compare findings from these studies as performance in the work conducted by Omori et al. was not compared to healthy controls. Nonetheless, findings do suggest that inhibitory deficits may contribute to checking symptoms. In a recent study, Linkovski, Kalanthroff, Henik, and Anholt (2013) investigated whether good inhibitory control can protect from the influences of repeated checking in a healthy sample. A repeated checking task designed by van den Hout and Kindt (2003b) (see section 1.5.1.3 for further discussion of this task) was used, and inhibitory control was

measured using a Stop Signal Task (SST). Findings demonstrated that participants with poorer inhibitory control reported more distrust in memory and uncertainty after checking was induced, when compared to those with good inhibitory control. These results support initial suggestions that inhibitory control impairments may be related to checking symptom severity and memory problems.

Research examining inhibition in individuals with OCD in general and individuals with predominant checking symptoms has used a variety of different tasks. An approach for measuring executive functioning deficits is the use of computerised assessment batteries. One of the most widely used batteries is the Cambridge Neuropsychological Test Automated Battery (CANTAB, Fray, Robbins, & Sahakian, 1996). The CANTAB has been validated in a variety of clinical populations (Fried., Hirshfeld-Becker., Petty., Batchelder., & Biederman., 2012; Levaux et al., 2007; Luciana, 2003; Rhodes, Riby, Park, Fraser, & Campbell, 2010), allowing for quick and efficient measurement of cognitive functioning and objective testing. Nevertheless, few researchers have utilised the CANTAB SST to investigate inhibitory functioning in checkers. Research that has used the SST in OCD samples has reported significant impairments in inhibitory control when compared to clinical controls (Chamberlain, Fineberg, Blackwell, Robbins, & Sahakian, 2006) and healthy controls (Chamberlain, Fineberg, Menzies, et al., 2007; Sottocorno, Martoni, Galimberti, Fadda, & Bellodi, 2011). Accumulating evidence supports inhibitory deficits using the SST, a well validated task, and we would expect there to be a relationship between inhibitory functioning and specific sub-types such as checking. Inhibition appears closely linked to many of the clinical features expressed by checkers. The relative contribution of

inhibitory function whilst examining other executive functions suggested to be linked to OCD symptoms (e.g. planning, set-shifting & working memory) is uncertain.

1.6.2 The role of planning in OCD and checking.

Planning refers to the ability to determine and organise steps needed to carry out an intention. Evidence for impairments in planning in OCD is not consistent. Several different tasks have been used to investigate planning in OCD, including the Tower of Hanoi (TOH), Tower of London (TOL) and the Stockings of Cambridge (SOC) task taken from the CANTAB. The literature relating to these tasks will be discussed below. In terms of how planning deficits might affect those with OCD, it is possible that individuals may have difficulty organising in memory how to execute a plan effectively and experience compulsive behaviours. This appears more related to the checking sub-type and will be discussed in terms of this specific domain below.

Results of studies utilising the TOH and TOL tasks have provided evidence for planning impairments in those with OCD when compared to healthy controls (Cavedini, Cisima, Riboldi, D'Annucci, & Bellodi, 2001; Cavedini, Zorzi, Piccinni, Cavallini, & Bellodi, 2010; van den Heuvel et al., 2005). Cavedini et al. (2010) showed that planning impairments were evident in unaffected OCD relatives compared to healthy controls and their relatives. This suggests a genetic aspect to the disorder and that individuals could experience planning deficits, yet not suffer OCD.

Research using the SOC task is less consistent in supporting planning impairments in OCD. Some researchers have provided evidence for planning impairments when compared to healthy controls (Chamberlain, Fineberg, Blackwell, et al., 2007; Nielen & Den Boer, 2003), but others have not (Purcell, Maruff, Kyrios, &

Pantelis, 1998a, 1998b; Veale, Sahakian, Owen, & Marks, 1996). It is important to try and understand why these studies differ with respect to planning impairments. One suggestion for why planning impairments were evident in the OCD group compared to healthy controls in the study conducted by Chamberlain, Fineberg, Blackwell, et al. (2007) relates to task difficulty. Chamberlain et al. used a more difficult version of the SOC task, where individuals had to work out problems in their mind rather than on the screen and there were six rather than four or five problems. Planning deficits were reported only when task difficulty was greater. Additionally, individuals in the OCD group in the Chamberlain et al. study were reported to be patients with primary checking and washing symptoms and hoarders were excluded. Planning impairments may differ as a consequence of OCD sub-type. There are inconsistent findings across tasks in research that has predominantly treated OCD as a homogenous disorder. Focus will now turn to a study that has treated OCD as a heterogeneous disorder and examined checking symptoms separately.

Planning impairments may contribute to greater checking, as individuals may not be able to organise in memory how to execute actions successfully. As far as we are aware, only one study has been conducted to investigate planning abilities in individuals with predominant checking, washing and mixed symptom profiles using the SOC task. Nedeljkovic et al. (2009) reported that checkers and those in the mixed symptom groups had poorer performance on initial movement times and checkers had poorer subsequent movement times compared to washers, with movement times providing an estimate for cognitive speed and planning time. Performance for the basic measure of planning accuracy 'number of problems solved in the minimum number of moves' was not

reported. This measure has been reported as the main planning accuracy measure in previous work using the SOC task and would have been useful to include in the study conducted by Nedeljkovic et al. Overall, the literature for planning impairments in checkers is inconclusive. The relative importance of planning in the development of checking behaviours whilst examining inhibition, set-shifting and working memory is uncertain.

1.6.3 The role of attention set-shifting in OCD and checking.

Set-shifting refers to the ability to shift attentional focus, requiring individuals to shift attention from one aspect of a stimulus to another during an ongoing task. Due to the long lasting and repetitive nature of OCD, it is possible that set-shifting abilities are impaired in those with OCD. The Wisconsin Card Sorting Task (WCST) and CANTAB Intra-dimensional/Extra-dimensional (ID/ED) tasks have been used to assess set-shifting abilities. Evidence for deficits when using the WCST is mixed. Some researchers have shown set-shifting deficits in those with OCD when compared with healthy controls (Okasha et al., 2000), whilst others have found no such deficits when compared to clinical controls (Moritz et al., 2002). It is difficult to compare these studies, as the study conducted by Moritz et al. did not include a healthy control group.

Research using the ID/ED task, which distinguishes between intra-dimensional shifting (shifting attention from one solid shape to another) and extra-dimensional shifting (shifting attention from one stimulus to another- alteration of the stimulus dimension) has been contradictory. Nielen and Den Boer (2003) did not observe deficits in set-shifting in those with OCD compared to healthy controls. Other researchers have noted that individuals with OCD show deficits in acquiring and maintaining cognitive

sets (Veale et al., 1996). Chamberlain, Blackwell, Fineberg, Robbins, and Sahakian (2005) reviewed the set-shifting literature and suggested that the ability to shift-attention may be affected by the clinical severity or progression of OCD. This suggestion was based on the knowledge that participants in the Veale et al. study were recruited from an inpatient setting and were likely to display more severe symptomology. Evidence concerning set-shifting impairments in OCD samples appears somewhat mixed.

Set-shifting has been investigated in checking samples in two studies (Goodwin & Sher, 1992; Omori et al., 2007). Given the perseverative nature of checking symptoms, it is plausible that checkers may encounter difficulties in moving flexibly from one task or action to another. Goodwin and Sher examined set-shifting using the WCST in a non-clinical checking sample. It was reported that non-clinical checkers had poorer set-shifting abilities than non-checkers (Goodwin & Sher). Omori et al. also reported set-shifting deficits in clinical checkers compared to washers. Impairments were shown on two tasks taken from the Wechsler Adult Intelligent Scales-Revised (WAIS-R), namely the category and letter fluency tasks and digit symbol test. The WCST was used by Omori et al, but no differences were shown between checkers and washers. Omori et al. did not consider the WCST to be a set-shifting task; it was labeled as multi-tasking. Sample differences may have contributed to differences in findings for the WCST. Goodwin et al used a student sample of checkers and non-checkers, whereas Omori et al. recruited clinical checkers and washers with no healthy control group. These differences make it difficult to compare between studies. Nonetheless, both studies provide evidence for set-shifting deficits in those with checking symptoms. The interrelationship between set-shifting and checking symptoms, whilst examining

inhibition, planning and working memory, is uncertain and will be examined in chapter 3.

1.6.4 The role of working memory in OCD and checking.

Working memory involves manipulation and regulation of the short-term storage of information. Working memory is a further aspect of executive function which has been investigated in OCD and findings are inconclusive. Individuals with OCD may not be able to hold in working memory whether a task has been completed and this may result in repetitive, compulsive behaviours. The Spatial Working Memory (SWM) task taken from the CANTAB has been used by several researchers in the OCD literature. Several researchers have suggested that performance on the SWM task in OCD participants is impaired when compared to healthy and/or clinical controls (Chamberlain et al., 2005; Purcell et al., 1998a, 1998b). Contrary to these results, Nielen and Den Boer (2003) and Dittrich, Johansen, Fineberg, and Landro (2011) showed no SWM accuracy deficits when comparing participants with OCD to healthy controls. Dittrich et al. suggested that the differences in results between studies when using the same task may be related to the heterogeneity of symptoms. Any deficits shown in SWM may be closely linked to checking behaviours, with checkers perhaps unable to store in memory whether a task has been completed, leading to compulsive checking behaviours to avoid harm. The literature examining SWM performance in checkers will be discussed below.

Working memory impairments may mean that individuals are unsure whether or not a task was completed, leading to compulsive checking behaviours. Several researchers have investigated this theory. Nedeljkovic et al. (2009) used the SWM task and reported more ‘between search errors’ for checkers and those with mixed symptom

profiles compared to healthy controls. Jaafari et al. (2013) also examined working memory performance in clinical checkers. Checking behaviours were measured using eye-tracking and OCD individuals were reported to check more than controls. Impairments were also shown in verbal and visuospatial working memory when compared to controls. Importantly, working memory performance was shown to predict participants' checking behaviours. Work reported by these researchers supports the proposal that checkers may display working memory impairments. Another interesting possibility is that an orientation to high levels of checking can itself impact on the efficiency of working memory. Harkin and Kessler (2009, 2011) demonstrated this experimentally. The relationship between working memory and checking symptoms will be investigated whilst also examining inhibition, planning and set-shifting. The relative contribution of these executive functions in predicting checking symptom severity is uncertain and will be examined in chapter 3.

1.6.5 Executive dysfunction summary.

Some researchers have hypothesised that executive deficits are related to the onset and maintenance of OCD symptoms. Findings are inconclusive, but it has been suggested that there may be inhibitory, planning, set-shifting and working memory impairments in those with OCD. What is less certain is whether or not these deficits contribute to and maintain checking symptoms. The relative contribution of each of these deficits to checking symptoms is unknown.

1.7 The relationship between memory-deficits and executive dysfunction

So far in this chapter, we have considered the possible contributions of memory deficits and of executive dysfunction to the onset and maintenance of OCD, particularly

to checking symptoms. The question arises of how these two cognitive domains interrelate. We turn to this question now.

It has been proposed that memory deficits may be part of a more general pattern of executive function impairments (Abramovitch et al., 2013; Greisberg & McKay, 2003; Olley et al., 2007; Omori et al., 2007; Penades, Catalan, Andres, Salamero, & Gasto, 2005; Savage et al., 1999). In a review of the memory and attention literature, Muller & Roberts (2005) suggested that it may be a combination of cognitive deficits that contribute to OCD symptoms. In particular, based on the literature reviewed, it was stated that there may be a central deficit of inhibition in OCD.

Executive functions are pivotal to organisation and control of cognition and behaviour and it is arguable that these undermine memory and other cognitive processes, which in turn prompts obsessive and/or compulsive behaviours. Given that there is evidence for memory deficits and executive dysfunction in checking, it is important to determine if these aspects are related. For example, if an individual is unable to inhibit irrelevant information this may result in repetitive checking and this could be mediated by an inability to recall or use cues to complete a prospective memory intention. If this is the case, interventions should target underlying executive deficits in order to improve memory processes. The proposed relationship between memory and executive functions will be discussed in sections 1.7.1 and 1.7.2 and chapter 3 and 5 will investigate these relationships.

1.7.1 Prospective memory and executive functions.

It has been suggested that successful prospective memory relies to some extent on frontal systems and executive functions (McDaniel, Glisky, Rubin, Guynn, &

Routhieaux, 1999). There is evidence to support both prospective memory deficits (see section 1.5.1.4 above) and executive function deficits (see section 1.6 above) in OCD. It is surprising that no work appears to have explicitly investigated the relationship between these variables. Most theoretical accounts propose that prospective memory at some stage requires resource demanding processes (McDaniel & Einstein, 2000; Smith, 2003; Smith & Bayen, 2004). One account in particular, the multi-process model of prospective memory, identifies two possible retrieval routes. One suggests retrieval to be an automatic process and the other requires voluntary, controlled retrieval of intentions and is suggested to involve planned processes (McDaniel & Einstein, 2000). Support for both of these routes was reported by McDaniel, LaMontagne, Beck, Scullin, and Braver (2013). It could, consequently be hypothesised that executive function deficits contribute to prospective memory performance differences. We would then expect to see a relationship between these two processes.

It is possible that certain executive functions could play a more important mediating role in prospective memory than others when investigating checking symptoms. Evidence for impairments in inhibition, planning, set-shifting, working memory in checkers is contradictory. Limited research has been conducted investigating the relationship between prospective memory and inhibition. Shimamura, Janowsky, and Squire (1991) proposed that prospective memory and inhibition share commonalities. In order to successfully plan, develop and retrieve effective strategies for completing prospective memory intentions, individuals must access and monitor their environment for the appropriate cues. The ability to do this may require individuals to inhibit irrelevant information. Checkers may experience prospective memory failures as a result

of poor inhibitory control. Henry, Rendell, Kliegel, and Altgassen (2007), examined the extent to which prospective memory impairments are secondary to other cognitive functions in a sample of individuals diagnosed with schizophrenia. Results from this study showed that both prospective memory and inhibition deficits were evident in individuals with schizophrenia. Additionally, after controlling for cognitive and executive functions (inhibition) and retrospective memory, significant impairments were still evident in prospective memory in the group with schizophrenia. This finding suggests that prospective memory may represent a distinct deficit in individuals with schizophrenia beyond inhibitory dysfunction. This may also apply to checkers and will be investigated in chapter 3.

Successful prospective memory performance may also be related to planning abilities. To complete a prospective memory intention, individuals are required to plan an effective strategy and then execute this plan when particular environmental cues are present. Impairments in planning may result in poorer prospective memory performance. The relationship between planning and prospective memory has been examined in individuals with brain injury and participants with Attention Deficit Hyperactivity Disorder (Fuermaier et al., 2013; Kliegel, Eschen, & Thöne-Otto, 2004). Both of these studies support theoretical accounts of prospective memory in which retrieval is believed to be secondary to executive dysfunction. Further research has provided evidence that prospective memory may also relate to set-shifting abilities and working memory. To successfully detect cues in an environment, individuals need to be able to shift attention from an ongoing task to evaluate responses. If individuals experience set-shifting deficits, then prospective memory intentions may not be completed. A relationship

between set-shifting and prospective memory has been supported by West, Scolaro and Bailey (2011). Successful prospective memory performance has been linked to working memory capacity, as individuals are required to hold an intended action in mind whilst monitoring their environment for potential cues. If individuals exhibit working memory impairments, then research suggests that this may lead to prospective memory failures. Smith and Bayen (2005) provided evidence to support a relationship between working memory capacity and prospective memory performance. There is research suggesting that there may be a relationship between executive functions and prospective memory and evidence suggests that there are deficits in executive functioning and prospective memory in checkers. Further research is warranted in order to investigate the relationship between these variables.

1.7.2 Episodic memory and executive functions.

Episodic memory impairments (Cha et al., 2008; Coles et al., 2006; Radomsky et al., 2006; Sher et al., 1989; Tallis et al., 1999; van den Hout & Kindt, 2003a, 2003b, 2004; Zitterl et al., 2001) and inhibitory deficits have been reported in checkers (Linkovski et al., 2013; Omori et al., 2007). The relationship between these variables should be examined in more depth (for further discussion of these deficits see sections 1.5.1.2, 1.5.1.3 and 1.6.1). These variables may contribute independently to checking symptoms. It is also possible that episodic memory deficits in checkers are secondary to inhibitory impairments. Compulsive checkers may focus too heavily on irrelevant task details due to inhibitory dysfunction, which impacts on successful encoding and results in poor recollection of an event.

Clinical OCD patients were reported to be impaired in the use of organisational strategies which are said to primarily require executive functions (Penades et al., 2005; Savage et al., 1999). Savage et al. revealed that memory impairments were mediated by organisational strategies and concluded that memory performance differences may be secondary to executive functioning impairments. Additionally, Omori et al. (2007) examined the relationship between inhibition and general memory in checkers and washers using correlations. A significant correlation was identified for checkers, with poor inhibition relating to general memory impairments. It can be inferred from this result that the ability to recall previous information proficiently may be reliant to some extent on the ability to inhibit irrelevant information and concentrate on the current task. Individuals who check locks and doors may be less able to inhibit irrelevant information and focus on the action of locking the door. This may result in poor recall of whether a task was completed successfully and contribute to repetitive checking. Evidence suggests that episodic memory biases and inhibitory dysfunction predict checking symptom severity. The relationship between these variables warrants further investigation and will be examined in chapter 5.

1.7.3 Summary of the relationship between memory and executive function. Both memory impairments and executive dysfunction impairments have been hypothesised to contribute to the onset and maintenance of obsessive and/or compulsive symptoms. Researchers have suggested that impairments in memory may be part of a more general pattern of executive function impairments. It is possible that cognitive processes such as memory are undermined by high order processes such as executive functions. Executive functions are key in the organisation and control of cognition and

behaviour. If there are executive deficits and memory impairments, obsessive and/or compulsive symptoms may occur. Despite theoretical reasons to propose a relationship between memory processes and executive impairments, no checking study to date has examined these variables together in the same work. Identifying the relative importance of prospective memory, episodic memory and executive functioning and the relationship between memory and executive processes will help to develop our understanding of checking symptoms.

1.8 Belief and appraisal models in checking – memory confidence

Researchers who have examined belief and appraisal models suggest that low confidence in memory may contribute to the compulsion to check (Cuttler & Graf, 2009; Wells, 2008; Woods et al., 2002). Low confidence in memory could help to explain the pathological doubt evident in checkers (Tolin et al., 2001).

1.8.1 Evidence for low memory confidence in checking.

Research suggests that checking behaviours may be a result of low memory confidence (See Müller & Roberts, 2005 for a review of the literature). The importance of confidence in memory seems likely. Individuals who have checked that doors and windows are locked should have clear memory representations of locking them. If there is mistrust in memory for the event/s, this can result in repeated checking to ensure safety (Rachman, 2002). Several studies have supported the role of diminished memory confidence in checkers (for reviews see Cuttler & Graf, 2009; Moritz, Jacobsen, Willenborg, Jelinek, & Fricke, 2006).

Research examining memory confidence has used virtual and real life environments whilst manipulating checking. Repeated ‘relevant’ but not ‘irrelevant’

checking of a virtual kitchen cooker was shown to lead to lower memory confidence (van den Hout & Kindt, 2003a, 2003b, 2004) in a healthy student sample. These findings were replicated using a real-life environment, where healthy student participants were required to check a cooker (Radomsky et al., 2006). Coles et al. (2006) similarly assigned healthy undergraduates to a high check condition. Findings showed diminished memory confidence in comparison to those in a low check condition. These findings support the suggestion that cognitive confidence is associated with higher checking symptoms.

Evidence for a relationship between memory confidence and checking symptoms extends to confidence in non threatening contexts (Jennings, Nedeljkovic, & Moulding, 2011; Nedeljkovic & Kyrios, 2007). Nedeljkovic and Kyrios reported that general confidence in memory (assessed using the Memory and Cognitive Confidence Subscale - MACCS) was a predictor of overall OCD severity and checking symptoms in a healthy student sample, over and above other OCD relevant beliefs such as responsibility. This study suggests that general memory confidence is low in individuals with higher checking symptoms. Similarly, Jennings et al. assessed general memory using MACCS and objective memory using the visuospatial memory task, whilst manipulating memory confidence using the memory confidence manipulation task. In this task, individuals are presented with images and later asked if images were included in the original set. The experimental group are provided with positive feedback of their results and the control group are not provided with any performance feedback. Participants are asked to rate their memory confidence prior to and following the task. Results showed that cognitive confidence as measured using MACCS predicted OCD symptoms. Nonetheless, even

with successful manipulation of memory confidence, individuals with greater confidence did not exhibit fewer checks on the memory task. Overall, findings suggest that confidence in memory may be affected in checkers. What is uncertain is the relative strength of memory confidence in predicting checking symptoms when other cognitive factors thought to contribute to checking are taken into account. Chapters 4 and 5 will examine the contribution of memory confidence to checking symptoms whilst examining perceived responsibility, memory deficits and executive dysfunction.

1.8.2 Memory confidence summary.

Researchers have proposed that memory confidence may be diminished and contribute to checking symptoms. Low memory confidence may lead to increased doubt in the ability to complete a task successfully and this may encourage checking to ensure successful completion of a task.

1.9 Perceived responsibility in checking

Perceived responsibility has been highlighted as a core element in the appraisal process. It is thought that heightened perceived responsibility may contribute to the compulsion to check (Rachman, 2002) and could help to explain the pathological doubt evident in checkers. Research relating to perceived responsibility in checking will be examined below.

1.9.1 Evidence for heightened perceived responsibility in checking.

A cognitive theory proposed by Rachman (2002) suggests that perceived responsibility contributes to the maintenance of checking behaviours. If individuals feel responsible for ensuring their own or another's safety, repeated checking is likely to avoid any potential danger. Research evaluating responsibility beliefs has used heterogeneous

samples and has provided evidence that heightened responsibility may contribute to obsessive-compulsive symptoms to differing extents, depending on the type of OCD examined. Mancini, D'Olimpio, and D'Ercole (2001) reported that responsibility was a significant predictor of OCD symptoms as measured using the Padua Inventory-Revised (PI-R) in a non-clinical sample. Moreover, results showed that responsibility explained more variance for checking symptoms than for washing symptoms, suggesting that it may play a more important construct for particular symptom domains. Smari, Gylfadottir, and Halldorsdottir (2003) investigated the relationship between obsessive compulsive symptom domains and responsibility attitudes in a non-clinical student sample using very similar measures to Mancini et al. Findings showed that responsibility was most strongly correlated with obsessional thoughts about harm to oneself/others. Responsibility was moderately correlated with checking symptoms, along with contamination obsessions and washing compulsions. This previous work suggests that heightened responsibility attitudes are related to greater checking symptoms in non-clinical samples. We would expect these deficits to be greater in clinical samples.

A clinical study conducted by Lopatka and Rachman (1995) investigated the relationship between responsibility attitudes and checking. A group with checking and/or washing symptoms was recruited. Results indicated that when perceptions of responsibility were lower, the urge to check and associated discomfort was less. Although the data showed that the urge to check was greater when responsibility was heightened, this result did not reach statistical significance. Furthermore, Foa, Sacks, Tolin, Prezworski, and Amir (2002) presented checkers, non-checkers and non-anxious controls with written scenarios that were classed as low (e.g. ‘you see a piece of string

on the ground'), medium (e.g. you see some nails on a road) and high responsibility (e.g. you see a person faint while you are shopping in the supermarket). Results indicated that checkers had an inflated sense of perceived responsibility for harm in low and medium responsibility scenarios. This effect was not shown in high responsibility scenarios. It was suggested that this could be a result of ceiling effects or due to the fact that risk in high responsibility scenarios is less uncertain (Foa et al). Nonetheless, research shows that there is a relationship between checking and responsibility attitudes.

The relationship between checking and perceived responsibility has been examined more recently using computer simulated programs (Boschen & Vuksanovic, 2007; Coles et al., 2006; van den Hout & Kindt, 2004). van den Hout and Kindt recruited students and assigned them to one of two groups; an experimental group who engaged in 'relevant' checking and a control group who engaged in 'irrelevant' checking. Repeated relevant checking resulted in heightened responsibility. These findings were confirmed in a follow-up study using a real kitchen cooker (Coles et al.). Similar findings were reported by Boschen and Vuksanovic where clinical OCD participants were compared to non-clinical controls using the same checking task as designed by van den Hout and Kindt. In this study responsibility was manipulated and participants were assigned to either a responsibility (participants were told that another participant would receive an electric shock if the cooker or light on the simulated checking task was not turned off completely) or no responsibility condition (the procedure was the same as for the responsibility condition, but participants were told that the electric shocks given did not relate to their performance on the checking task). It was reported that participants in the responsibility condition (both OCD participants and

non-clinical checkers) checked the cooker more than those in the no responsibility condition. Perceived responsibility also predicted the urge to check. Non-clinical and clinical research supports a relationship between heightened responsibility and checking and perceived responsibility appears key to the cognitive profile. What is uncertain is the relative contribution of perceived responsibility when other variables thought to be implicated in checking are examined. Chapter 5 will include a measure of perceived responsibility, in order to determine the predictive power of this variable, whilst considering memory deficits, executive dysfunction and memory confidence.

1.9.2 Perceived responsibility summary.

There is considerable empirical support for heightened perceived responsibility perceptions in checkers. If individuals feels responsible for ensuring other's or ones own safety, they may feel the need to repetitively check to ensure a task was completed successfully in order to minimise risk.

1.10 Overall summary of the OCD and checking literature

It is hypothesised that OCD is caused by cognitive dysfunction, such as memory deficits, and/or executive function impairments. Evidence for general memory impairments has been mixed. There is evidence to suggest that there may be biases in episodic retrospective recollection, but further research is necessary in order to explore whether biases extend to non-threat contexts. Prospective memory has been shown to be closely related to checking symptoms, with higher checking symptoms related to more prospective memory errors.

Executive function impairments, namely in inhibition, planning, attention-set-shifting and working memory are reported to contribute to and maintain OCD

symptoms. Relatively little work has examined executive functioning in specific sub-types such as checking, therefore we are uncertain as to the relative contribution of each of these deficits.

Researchers have suggested that impairments in memory may be part of a more general pattern of executive function impairments. It is possible that cognitive processes such as memory are undermined by high order processes such as executive functions. Despite theoretical reasons to propose a relationship between memory processes and executive impairments, no checking study to date has examined these variables together in the same study. Identifying the relative importance of prospective memory, episodic memory and executive functioning and the relationship between memory and executive processes will help to develop our understanding of the onset and maintenance of checking symptoms.

Low confidence in memory and heightened perceived responsibility may contribute to greater checking symptoms. Evidence suggests that memory deficits, executive deficits, low memory confidence and heightened perceived responsibility may maintain checking symptoms. It is surprising that the interrelationship between these variables has not been examined in a single study.

1.11 Organisation of the thesis

Following on from this general introduction, there will be a general method section for the studies presented in this thesis and chapters 3, 4, 5 and 6 present a series of investigations, each addressing research questions pertinent to furthering our understanding of cognitive functioning in OCD and those with prominent checking symptoms.

In chapter 3, prospective memory and executive functions are examined in a checking sample. The first objective of this study was to investigate the contribution of cognitive impairments, namely memory and executive deficits, to checking symptom severity. We then examined the relationship between memory and executive deficits. The prospective memory questionnaire (PMQ) was used to assess self-reports of prospective memory. The Cambridge Neuropsychological Test Battery (CANTAB) was used to measure inhibition, planning, set-shifting and working memory. It was hypothesised that greater self-reports of prospective memory deficits and executive deficits would predict checking symptom severity. Prospective memory and inhibition deficits predicted checking symptom severity when entered into the same regression model. Specifically, internally cued prospective memory and prospective memory aiding strategies were shown to predict checking symptoms. Long-term episodic prospective memory was shown to predict checking symptoms when entered alone, but it no longer predicted checking symptoms when entered with other variables. It was concluded that, long-term episodic prospective memory was not an independent predictor of checking symptoms. Inhibition was the only executive aspect reported to predict checking symptoms. Correlational analyses showed that there was no relationship between prospective memory measures and inhibition. Prospective memory deficits and inhibitory impairments were suggested to be independent predictors of checking symptom severity. The findings from this study highlight prospective memory and inhibition as key contributors to the checking symptom profile. This is supportive of cognitive deficit models of checking. A model in which memory deficits are thought to be secondary to executive impairments is not supported. Nonetheless, examination of a

combination of cognitive deficits, namely memory deficits and executive dysfunction in single studies may help us to better understand the development and variance shown in checking symptoms. Memory and executive functions should be treated as involving several independent processes rather than as unitary processes.

Chapter 4 examined prospective memory deficits in checkers. The main objective of this chapter was to expand on findings reported in chapter 3 by using a task analogous to everyday contexts. The Edinburgh Virtual Errands Task (EVET) was used which requires individuals to detect and respond to cues without any instruction. It was expected that individuals with higher checking symptoms would experience greater prospective memory errors. Confidence in completed EVET tasks was also investigated as a function of memory performance within the EVET environment. It was hypothesised that individuals with greater checking symptoms would report lower confidence in completed tasks. Results showed that participants assigned to high and medium checking groups had more prospective memory errors on the EVET when compared to those in a low checking group. Confidence in completed tasks did not differ between the three groups (low, medium and high checkers). The finding of greater prospective memory errors supports the memory deficits in checking, and expands on previous work by using a task similar to everyday contexts. This finding also suggests that memory deficit models of checking should consider memory as involving several independent memory processes (e.g. prospective memory), as opposed to examining memory as a unitary process.

In chapter 5, we examined the memory deficits in the context of episodic memory. An R/K task was used to examine familiarity biases in checkers. In addition,

we investigated executive dysfunction. The relative contribution of inhibitory control, as measured using the SST was investigated. The relationship between memory and executive deficits was then examined. In addition, the relative contribution of memory confidence and perceived responsibility as part of belief system models was examined. Memory confidence was measured using MACCS and perceived responsibility was measured using the Responsibility Attitudes Scale (RAS). It was expected that higher familiarity responses, greater inhibitory impairments, lower memory confidence and heightened perceived responsibility would predict checking symptom severity. The relationship between familiarity biases and inhibitory control was also assessed. It was hypothesised that the relationship between inhibition and checking may be mediated by familiarity biases. Familiarity, inhibition and perceived responsibility were all shown to be independent predictors of checking. Memory confidence predicted checking symptom severity when examined alone but not when combined with other variables, suggesting that it is not an independent predictor of checking symptoms. The relationship between familiarity responses and checking was not mediated by inhibition. Each of these cognitive variables had an independent role in predicting checking symptoms. This finding does not provide support for a model in which memory deficits are thought to be secondary to executive dysfunction. Overall, these findings highlight the role of familiarity, inhibition and perceived responsibility in predicting checking symptom severity. Cognitive deficit models in terms of memory and executive deficits and belief appraisal models relating to perceived responsibility are supported. Importantly, the findings suggest that examination of a combination of factors from

different cognitive-behavioural models can help to explain the onset and maintenance of checking behaviours.

Chapter 6 examined inhibitory control across two separate experiments. In experiment 1, inhibition was measured using the SST and compared between an OCD group, anxiety group and healthy control group. The aim was to assess whether inhibitory impairments related solely to OCD symptoms or if they arise more generally from the presence of anxiety symptoms. Additionally, experiment 2 examined the relationship between inhibition (SST), anxiety (Depression Anxiety and Stress Scale: DASS) and obsessions (Yale-Brown Obsessive Compulsive Scale: Y-BOCS) and between inhibition, anxiety and compulsions (Y-BOCS). The aim was to determine whether inhibitory impairments were specific to obsessive and/or compulsive symptoms when considering the role of anxiety. Results from experiment 1 showed that inhibition was poorer in the OCD and the anxiety group compared to healthy controls. No performance differences were reported between the OCD and the anxiety group. This finding suggests that inhibitory impairments may not be solely related to the presence of OCD symptoms. Findings from experiment 2 showed that anxiety, but not inhibition, was an independent predictor of obsessive symptoms. Furthermore, inhibition and anxiety were independent predictors of compulsive symptoms. These findings highlight the role of inhibition and anxiety in predicting compulsive symptoms. The results demonstrate that inhibition may independently contribute to compulsive but not obsessive symptoms. The current findings build on previous reports of inhibitory impairment in OCD, highlighting a relationship between inhibition and compulsive behaviours. Findings from experiment 1 and 2 emphasise the role of anxiety and

inhibition in relation to compulsive symptoms in OCD. It can be concluded that inhibitory impairments reported in OCD may arise more generally from the presence of anxiety symptoms. Inhibitory impairments appear to relate more closely to compulsive, rather than obsessive symptoms when taking anxiety into account.

A general discussion of the results from research reported in chapters 3, 4, 5 & 6 is provided in chapter 7. This chapter attempts to integrate findings from previous chapters. Chapter 7 concludes that prospective memory, familiarity biases, inhibitory control, memory confidence and perceived responsibility contribute to the checking symptom profile. Possible methodological limitations as well as directions for future research are highlighted in this chapter.

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Chapter 2

Method

The following section will describe the methodology for each chapter in this thesis. Data collection methods will also be detailed.

2.1 Chapter 3:

A total sample of 122 participants was recruited from a university population. All participants had to be between 18-60 years of age and it was essential that they were fluent in English. Of the 122 participants recruited, 7 reported a previous clinical diagnosis of OCD and were excluded from the analysis. A further 9 participants were excluded due to computer problems resulting in the task file not saving. This left 106 participants for the final analysis (66% female and 34% male). The sample had a mean age of 23.56 (SD = 6.37) years. For significant power to detect significant effects using a regression analysis with 5 key measures (only variables correlated with checking were entered into the regression analysis), 106 participants was within the recommended guidelines (Tabachnick & Fidell, 2007).

The study in Chapter 3 was originally presented as a two-phase study. It was expected that participants would complete the Padua Inventory as a checking measure online and then some participants would be asked to complete the second phase of the study. A range of recruitment methods were used (see below), however due to poor response rates, all participants were invited to take-part in the second phase of the research.

In order to recruit individuals a range of recruitment strategies were used. To ensure the sample included individuals with a range of symptoms on checking

characteristics, some advertisements called explicitly for participants with checking behaviours and in another, checking behaviours were not mentioned. (See Appendix 1 & 2). Both of these advertisements were displayed across the University, the advertisements were sent to all departments and societies across the University and participants were recruited via the Psychology recruitment pool and research platforms (SPIDER) in exchange for Psychology course credits. Ethical approval was granted by the appropriate departmental ethics committee (See Appendix 13) and participants received either course credits or a small financial compensation in return for their participation.

In Chapter 3, the Padua Inventory (See Appendix 7) was used to measure checking symptoms and the Prospective Memory Questionnaire (PMQ – See Appendix 10) was administered to measure self-reported prospective memory. Four tasks were taken from the Cambridge Neuropsychological Test Automated Battery (CANTAB). The Stop-Signal Task (SST) was used to measure inhibition, the Stockings of Cambridge (SOC) task was used to measure planning, the Intra-Dimensional/Extra-Dimensional (ID/ED) task was used to measure attention set-shifting and the Spatial Working Memory (SWM) task was used to measure working memory. The CANTAB tasks were counterbalanced to minimise fatigue effects.

The following measures were also administered in Chapter 3 but they were not used in the main analysis. The Yale-Brown Obsessive Compulsive Scale (Y-BOCS) was administered but was not used for analysis purposes as this tends to be used as a clinical measure and participants in this study were recruited from non-clinical settings (University sample). The Depression Anxiety and Stress Scale, the National Adult

Reading Test (NART) and the Prospective and Retrospective Memory Questionnaire (PRMQ) were also administered, but were not included in the main analysis. Completing all components of the study required approximately one hour.

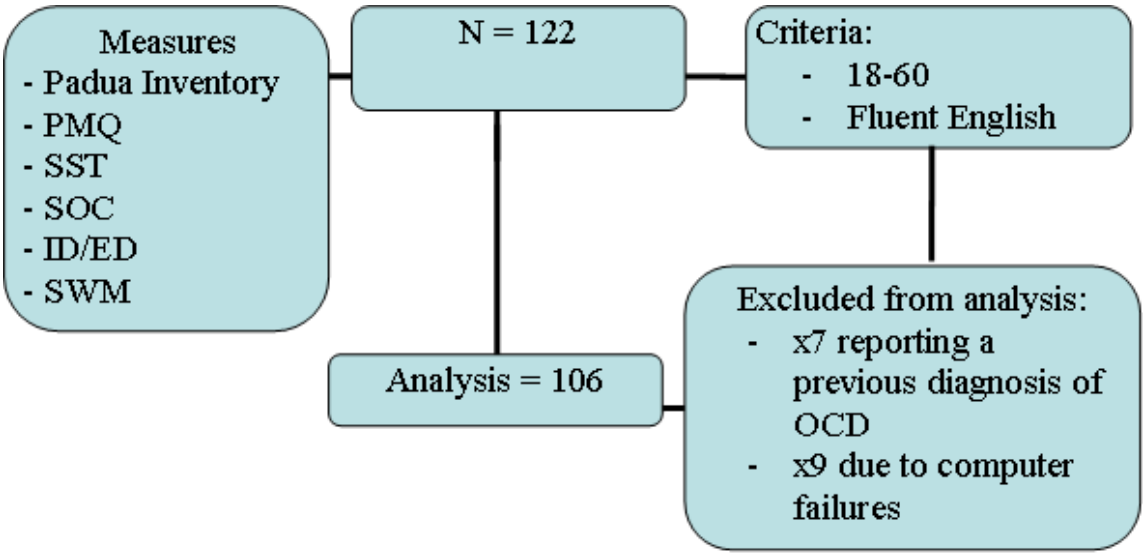

Figure 1. Consort flow diagram for Chapter 3.

2.2 Chapter 4:

A total sample of 84 participants was recruited from a university population. All participants had to be between 18-60 years of age and it was essential that they were fluent in English. Of the 84 participants recruited, 11 participants were excluded due to language barriers and/or the experimental task not running or saving correctly. This left 72 participants for the final analysis (72% female and 38% male). The sample had a mean age of 25.89 (SD = 6.18) years. For significant power to detect significant effects using ANOVA, 72 participants was within the recommended guidelines (Tabachnick & Fidell, 2007).

A range of recruitment strategies were used. To ensure the sample included individuals with a range of symptoms on checking characteristics, some advertisements called explicitly for participants with checking behaviours and in another, checking behaviours were not mentioned. (See Appendix 3 & 4). Both of these advertisements were displayed across the University, the advertisements were sent to all departments across the University and participants were recruited via the Psychology recruitment pool and recruitment platforms (MyPlace and Pegasus). Adverts were also placed in community settings (e.g. public libraries), however, no participants were recruited via this method. Participants who asked to be added to a database to inform them about future studies (see chapter 5 below) were also sent the study advert. Ethical approval was granted by the appropriate departmental ethics committee (See Appendix 14) and participants received either course credits or a small financial compensation in return for their participation.

In Chapter 4, the Padua Inventory was used to measure checking symptoms and for analysis. The Edinburgh Virtual Errands Task (EVET) was used to measure objective prospective memory and a likert scale was used to measure confidence in completed tasks.

The following measures were also administered in Chapter 4 but they were not used in the main analysis. The Y-BOCS was administered but was not used for analysis purposes as this tends to be used as a clinical measure and participants in this study were recruited from non-clinical settings (University sample). The DASS, NART & PMQ were administered, but were not included in the main analysis. The SST was used to measure inhibition but was not included in the final analyses in chapter 3. This data was

collected to form a bigger inhibition data set for chapter 6. The order in which the EVET and SST was presented was counterbalanced to ensure that there were no fatigue effects. Completing all components of the study required approximately one hour.

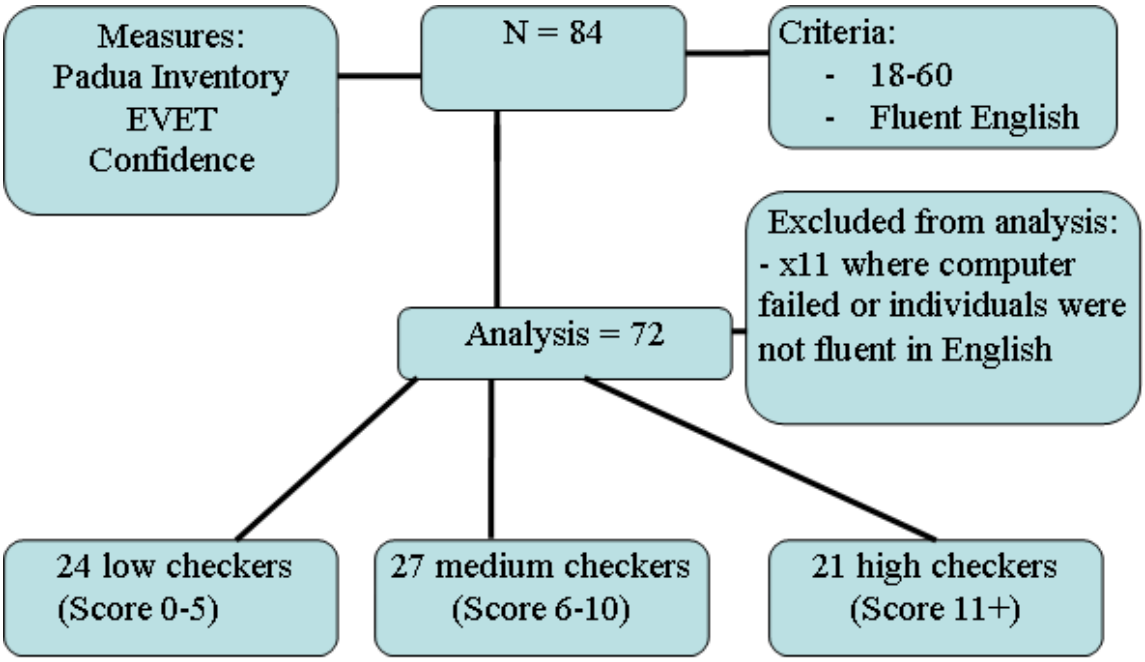

Figure 2. Consort flow diagram for Chapter 4

2.3 Chapter 5:

A total sample of 121 participants was recruited from a university population and via self-help groups. All participants had to be between 18-60 years of age and it was essential that they were fluent in English. Of the 121 participants recruited, 6 participants who reported a previous clinical diagnosis of OCD were excluded from the analysis and 7 participants were excluded due to computer problems resulting in a task file not saving. This left 108 participants for the final analysis (74% female and 26% male). The sample had a mean age of 24.66 (SD = 8.78) years. For significant power to detect significant effects using a regression analysis with 5 key measures (only variables

correlated with checking were entered into the regression analysis), 108 participants was within the recommended guidelines (Tabachnick & Fidell, 2007).

A range of recruitment strategies were used. To ensure the sample included individuals with a range of symptoms, some advertisements called explicitly for participants with a range of OCD behaviours and in another, symptoms were not mentioned (See Appendix 5 & 6). Both of these advertisements were displayed across the University, the advertisements were sent to all departments and societies across the University, posters were displayed across the University, adverts were posted on University recruitment platforms (SPIDER & virtual learning community website) and participants were recruited via the Psychology recruitment pool in exchange for Psychology course credits. The study adverts were also sent to self-help groups in Scotland and England. The current study was approved by the appropriate ethic committees (See Appendix 15 & 16) and participants received either course credits or a small financial compensation in return for their participation.

The following measures were used in chapter 5. The Y-BOCS (See Appendix 8) was used to measure the severity of obsessive and compulsive symptoms as some participants that were recruited attended self-help groups and reported a clinical diagnosis. The Memory and Cognitive Confidence Scale (MACCS – see Appendix 11) was used to measure memory confidence and the Responsibility Attitude Scale (RAS – See Appendix 12) was used to measure perceived responsibility. A Remember/Know (R/K) task was administered to measure episodic memory (familiarity and recollection) and the SST was taken from the CANTAB and used to measure inhibition. The questionnaires were completed first, followed by the experimental tasks. The order in

which the R/K task and SST was presented was counterbalanced to ensure that there were no fatigue effects.

The DASS, NART & Padua Inventory (See Appendices) were also administered in Chapter 5 but they were not used in the main analysis. Completing all components of the study required approximately one hour.

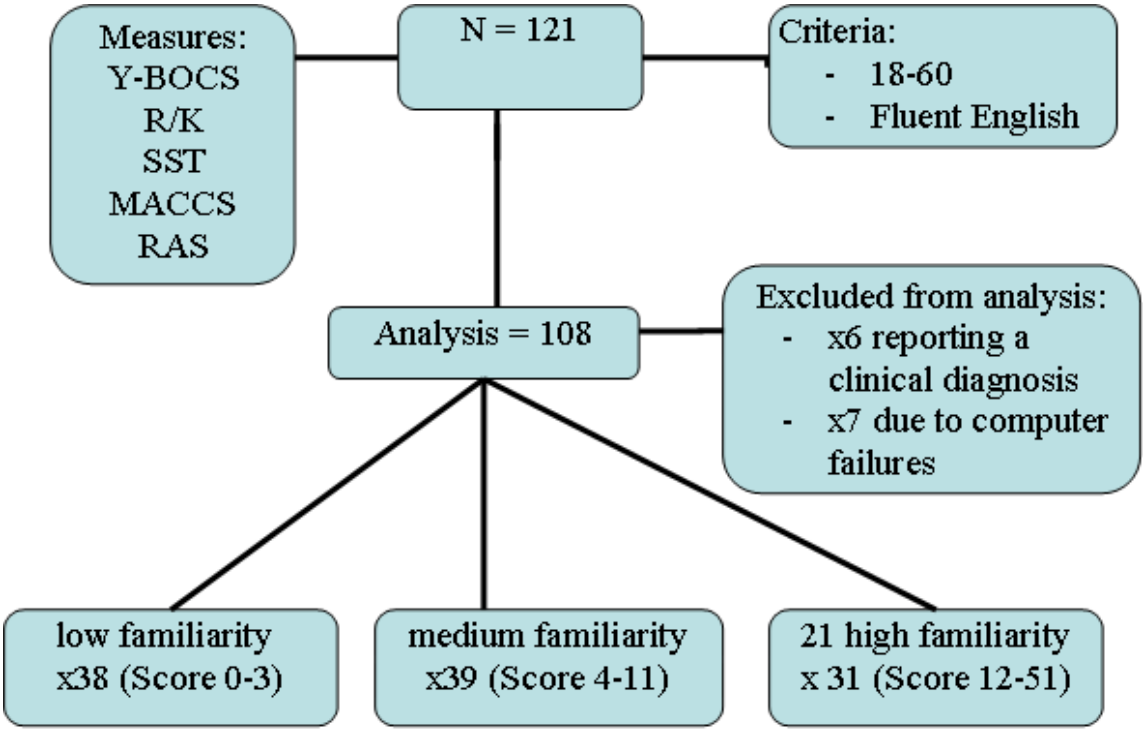

Figure 3. Consort flow diagram for Chapter 5

2.4 Chapter 6:

A total sample of 327 participants was recruited from a university population and via self-help groups across the studies in chapter 3, 4 and 5. Participants for all of these studies had to be between 18-60 years of age and it was essential that they were fluent in English. Of the 327 participants recruited, 27 participants were excluded due to language barriers or the SST task crashing and the output files not saving properly. This left 300

participants. Furthermore, 4 participants were removed as outliers based on standard residual scores. In total there were 296 participants left for the final analysis. Participants were then selected to form three different groups based on a previous diagnosis of OCD (Y-BOCS) and anxiety (anxiety sub-scale from the DASS – See Appendix 9) cut-off scores. Group 1 (N=14), 'OCD group', were selected on the basis of a previous diagnosis of OCD by an adult mental health service. Group 2 was an 'anxiety control' group and group 3 was a 'healthy control' group. Participants assigned to the anxiety group (N = 11) scored low on the Y-BOCS (<7 classed as sub-clinical on Y-BOCS) and scored as moderate to extremely severe on the anxiety sub-scale of the DASS. All participants in the health control group (N = 15) scores 0 on the Y-BOCS, and between 0-1 on the anxiety sub-scale from the DASS.

Participants in Group 1 (OCD group) were recruited by advertisements from within local OCD support groups and within University settings. Participants in group 2 (anxiety controls) and group 3 (healthy controls) were recruited from a university population. A range of recruitment strategies were used in the university setting. To ensure the samples included individuals with a range of symptoms, each study used two advertisements. One advertisement called explicitly for participants with OCD behaviours and OCD behaviours were not mentioned in the other advertisement. These advertisements were displayed across the University, the advertisements were sent to all departments and societies across the University and participants were recruited via the Psychology recruitment pool. Participants recruited received either course credits or a small financial compensation in return for their participation.

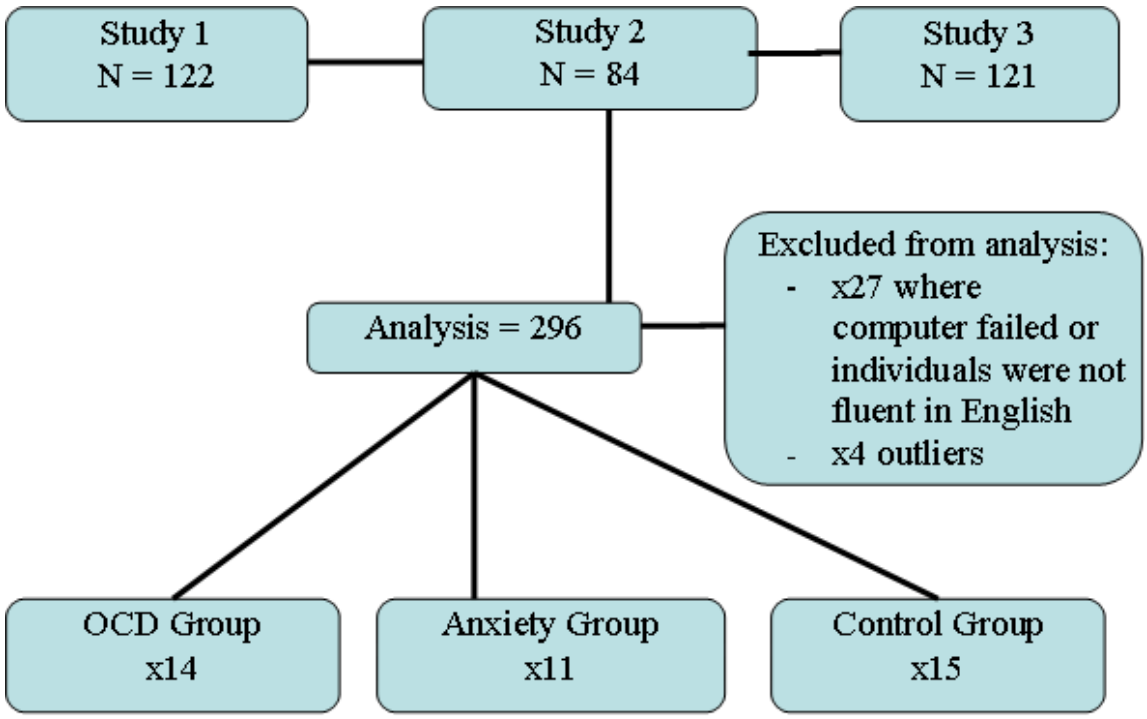

Figure 4. Consort flow diagram for Chapter 6

Chapter 3

Checking Behaviours, Prospective Memory and Executive Functions

This chapter is presented in the format of a manuscript and has been accepted for publication in Behaviour Change

Abstract

Explanations implicating memory in the causes and severity of checking symptoms have focused primarily on retrospective memory and relatively little attention has been paid to prospective memory. Limited research has examined the relationship between prospective memory and executive functions. We assessed whether impairments in prospective memory and executive function predict checking symptoms in a sample of 106 adults. Checking symptoms were assessed using the Padua Inventory Washington State University Revision (PI-WSUR). All participants completed the prospective memory questionnaire (PMQ) and four computerised executive function tasks from the CANTAB, measuring inhibition, planning, attention set-shifting and working memory. Prospective memory and inhibition predicted checking symptom severity. Importantly, there were no correlations between internally cued prospective memory and inhibition or between prospective memory aiding strategies and inhibition. These variables appear to have an independent role in checking. The current findings highlight prospective memory and inhibition as key contributors to the checking symptom profile and provide the first evidence that these cognitive processes may independently contribute to checking symptoms. These findings have implications for a model in which memory performance is thought to be secondary to impairments in executive processes.

Keywords: Checking compulsions; prospective memory; executive function; memory deficits; CANTAB

Obsessive Compulsive Disorder (OCD) is a chronic and debilitating disorder characterized by intrusive thoughts or images (obsessions) and by repetitive behaviours or recurrent mental acts (compulsions) (Stein, 2002). Although there are different types of compulsive behaviours, one of the most common is checking (Henderson & Pollard, 1988). Individuals with checking compulsions have recurrent uncertainties about whether particular acts have been performed or completed (such as locking their car or closing a window) and return repeatedly to ensure completion.

Uncovering the causes of checking compulsions is challenging. Considerable research has documented impaired neuropsychological function in individuals with OCD (Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005; Kuelz, Hohagen, & Voderholzer, 2004). On present evidence, it seems unlikely that there is a single underlying factor. Furthermore, the heterogeneity of symptoms among individuals with OCD indicates that it would be advantageous to identify the etiology of each subtype. Focusing here on the checking subtype, we review literature indicating that memory impairment is an important variable and that there are strong reasons to suspect that executive functions play a role. To date, the respective contributions of these factors to predicting checking behaviour have not been examined in the same sample. In this study, we conduct such an investigation.

Memory and checking

Because checking reflects uncertainty as to whether a specific action has been undertaken, an early hypothesis was that deficits in memory underlie the phenomenon. However, the evidence has been somewhat mixed. Some areas of memory (such as

verbal memory) appear to be unimpaired in individuals with OCD (Olley, Malhi, & Sachdev, 2007). Reviewers of the literature (Müller & Roberts, 2005; Olley et al., 2007) have concluded that OCD does appear to be associated with impairments in memory related to behavioural actions but that the evidence is unclear with respect to whether the problems are primarily in memory itself or reflect the impact of symptoms on functioning and confidence in memory and/or broader organisational difficulties.

Previous research has tended to examine retrospective memory (Cuttler & Graf, 2007, 2009). Cuttler and Graf (2007, 2008, 2009) argued that prospective memory may be particularly compromised in checkers. Prospective memory relates to actions that are to be performed in the future, such as remembering that one has to pay a bill at the end of each month or keeping in mind that one must turn the cooker off after preparing dinner. Cuttler and Graf reasoned that individuals with checking compulsions may have difficulties deactivating mental plans after completing them, may fail to remember specific actions that have been completed, or may be aware of chronic problems with prospective memory and thus worry about the risk of future failure; any or all of these could promote checking to obtain reassurance that all is as it should be. Checking, therefore, may be a compensatory mechanism for prospective memory failures.

Prospective memory

Prospective memory impairments, based on subjective measures, have been indicated in a study by Cuttler and Graf (2007). Individuals with high checking symptoms reported significantly more failures in long-term episodic prospective memory, short-term habitual prospective memory and internally cued prospective memory than did those with medium checking symptoms. Episodic prospective memory

tasks relate to those where to-be remembered information is not held in conscious awareness and intended actions are performed infrequently, or on a one-off basis (e.g. collecting your sibling from the station in 2 weeks time). Habitual prospective memory tasks involve repeated, regular performance of the same plan (e.g., picking up the house keys before leaving). Internally cued prospective memory relates to performing tasks where no external cue/reminder is provided to perform already planned tasks (e.g., remember to pay a bill on time). Individuals with high checking symptoms also reported using more prospective memory aiding strategies than low checkers (e.g., writing reminder lists). Checkers' self-reports may indicate greater difficulties with several aspects of prospective memory.

Objective evidence of prospective memory impairments was also shown in medium and high checkers, using an event-based prospective memory task (Cuttler & Graf, 2007). This involved remembering to perform an action under specific conditions when an external cue occurred, for example, requesting the return of a personal belonging when a specific spoken cue was given. Similar results were reported by Cuttler and Graf (2008). In contrast, low, medium and high checkers were not impaired on a time-based prospective memory task which involved remembering to perform an action at a particular time or after a specific time period, for example reminding the experimenter to make a phone call in 30 minutes (Cuttler & Graf, 2007). Checking occurs when uncertainty cannot be removed or reduced using specific strategies. The occurrence of a relevant cue is unpredictable in event-based remembering. Hence, uncertainty is likely to be high and contribute to repetitive checking behaviours. Time-based tasks, however, provide individuals with a clear cue for when a task should be

completed and thus uncertainty is lower. As event but not time-based prospective memory impairments have been reported in checkers, the current study will focus on event-based prospective remembering (Cuttler & Graf, 2007).

Cuttler and Graf's (2007, 2008) studies were conducted with participants with sub-clinical levels of checking compulsions, on the grounds that evidence in support of a prospective memory account in this population would suggest an even stronger effect in a clinical sample. This reasoning was largely borne out in a subsequent study by Harris, Vaccaro, Jones, and Boots (2010), who investigated prospective memory in a clinical sample using the same subjective and objective tasks employed by Cuttler and Graf (2007, 2008). Harris et al. indicated that OCD-checkers were less accurate than controls on the event-based prospective memory task. A difference was not observed, however, in subjective memory reports made by the OCD and comparison control group. The discrepancy between the studies may have arisen because the clinical manifestation of checking symptoms is related to a less accurate perception of one's own prospective memory performance. Harris et al. found that the OCD-checkers, although performing less well on the event-based task, had greater confidence in their prospective memory than did the controls. Taken together, these studies indicate subjective and objective evidence of prospective memory impairments in samples of checkers.

Executive function and checking

Executive function is an umbrella term denoting higher order strategic processes, such as inhibition, planning, attention set shifting and working memory, known to be critical in the control of behaviour. If individuals engage in repetitive, redundant activity, failing to adjust their behaviour after completing a task, and are unable to recall

relevant past actions with confidence, then an encompassing explanation for difficulties may relate to prefrontal systems and executive functions that these systems support (Burgess, Veitch, de Lacy Costello, & Shallice, 2000; Martin, Kliegel, & McDaniel, 2003; McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999). Executive function impairments have been reported in several studies investigating OCD (Bannon, Gonsalvez, Croft, & Boyce, 2006; Chamberlain et al., 2005; Taner, Bakar, & Oner, 2011).

From a theoretical perspective, a common mechanism is thought to underlie all executive function processes but different aspects of executive function are clearly separable (Diamond, 2013; Miyake et al., 2000). Although theoretical explanations have placed different weighting on executive functions, most implicate inhibition, working memory and attention set-shifting as core executive function processes (Miyake et al.) and higher order functions such as planning and problem solving (Diamond, 2013).

The most consistent evidence for executive dysfunction with respect to OCD indicates a deficit in inhibition, the ability to suppress irrelevant or interfering stimuli (Abramovitch, Dar, Schweiger, & Hermesh, 2011; Aycicegi, Dinn, Harris, & Erkmen, 2003; Bannon et al., 2002; Bohne, Keuthen, Tuschen-Caffier, & Wilhelm, 2005; Chamberlain, Fineberg, Blackwell, Robbins, & Sahakian, 2006; Chamberlain, Fineberg, Menzies, et al., 2007; Morein-Zamir et al., 2010; Page et al., 2009; Penades et al., 2007; Sottocorno, Martoni, Galimberti, Fadda, & Bellodi, 2011). If individuals find it difficult to inhibit a pre-potent plan ("Must close the bathroom window"), then, despite having undertaken the relevant action, this distracting cognition could re-occur and prompt checking. The small numbers of studies addressing this possibility in individuals with

checking compulsions have found evidence of inhibitory control deficits in checkers (Omori et al., 2007; Van der Linden, Ceschi, Zermatten, Dunker, & Perroud, 2005).

Planning impairments may contribute to greater checking arising from a difficulty in organising the execution of actions effectively within memory. Planning impairments have been implicated in OCD, using tasks such as the Stockings of Cambridge and Tower of Hanoi (Cavedini, Cisima, Riboldi, D'Annucci, & Bellodi, 2001; Cavedini, Zorzi, Piccinni, Cavallini, & Bellodi, 2010; Chamberlain, Fineberg, Blackwell, et al., 2007; Nielen & Den Boer, 2003; van den Heuvel et al., 2005). Also see Purcell, Maruff, Kyrios, and Pantelis (1998a, 1998b) and Veale, Sahakian, Owen, and Marks (1996) for null results in this respect. Findings, therefore, are mixed, and the issue of whether planning impairments contribute to and maintain checking symptoms is unresolved. As far as we are aware, two studies have been conducted to investigate planning abilities in individuals with predominant checking symptoms (Chamberlain, Fineberg, Blackwell, et al., 2007; Nedeljkovic et al., 2009). Chamberlain et al. reported planning deficits in a group of individuals with predominant checking and washing symptoms when the task was more difficult. Furthermore, Nedeljkovic et al. reported that checkers and those in a mixed symptom group had poorer performance on initial movement times relating to cognitive speed on the Stockings of Cambridge planning task compared to washers. As far as the present authors are aware, however, a specific planning accuracy measure (problems solved in minimum number of moves) was not included in this analysis.

Given the perseverative nature of checking symptoms, it is plausible that checkers may encounter difficulties in moving flexibly from one task or action to

another (i.e., attention set-shifting). The evidence to date is inconsistent. Some studies have found evidence of an attentional set-shifting deficit in participants with OCD (Okasha et al., 2000; Veale et al., 1996), but others have not (Moritz et al., 2002; Nielen & Den Boer, 2003). Surprisingly little research has investigated set-shifting in checkers. Exceptions are the work of Goodwin and Sher (1992) and Omori et al. (2007). Goodwin and Sher reported that frequent checkers performed significantly worse than non-checkers and Omori et al. reported set-shifting deficits in clinical checkers compared to washers.

Working memory impairments may result in individuals being unsure whether or not a task was completed, resulting in compulsive checking behaviours. Research in those with OCD symptoms has produced inconsistent findings, with some studies finding evidence of working memory impairments (Chamberlain, Fineberg, Blackwell, et al., 2007; Purcell et al., 1998a, 1998b) and others not (Dittrich, Johansen, Fineberg, & Landro, 2011; Morein-Zamir et al., 2010; Nielen & Den Boer, 2003). There is support, however, from two studies for Spatial Working Memory (SWM) impairments in checkers (Jaafari et al., 2013; Nedeljkovic et al., 2009). An interesting possibility is that an orientation to high levels of checking can itself impact on the efficiency of working memory, as demonstrated experimentally by Harkin and Kessler (2009, 2011).

There is some evidence, then, to implicate inhibition, planning, attention set-shifting and working memory in OCD. The relative strength, however, of these executive function impairments in predicting checking symptoms has not been assessed in a single study.

Prospective memory and executive function

If, as the evidence so far suggests, both prospective memory and executive function are implicated in the behaviours of checkers, the question arises as to the nature of the relationship between these variables. In studies not related to OCD, it has been proposed that prospective memory performance may be related to executive functions (Fuermaier et al., 2013; Kliegel, Eschen, & Thöne-Otto, 2004; McNerney & West, 2007; Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013; Smith & Bayen, 2005; West & Craik, 2001; West, Scolaro, & Bailey, 2011). Most theoretical accounts propose that prospective memory at some stage requires resource demanding processes (Marsh & Hicks, 1998; McDaniel & Einstein, 2000; Smith, 2003; Smith & Bayen, 2004).

Supportive of theoretical accounts, studies have indicated that if prospective memory cues occur whilst engaged in another activity, that activity may need to be inhibited to meet a predetermined obligation (Schnitzspahn et al., 2013; West & Craik, 2001). Shimamura, Janowsky, and Squire (1991) proposed that prospective memory and inhibition share commonalities. It is possible therefore that there may be a relationship between inhibition and prospective memory. Limited research, however, has been conducted to investigate this relationship. Henry, Rendell, Kliegel, and Altgassen (2007), examined the extent to which prospective memory impairments are secondary to other cognitive functions in a sample of individuals diagnosed with schizophrenia. Results from this study revealed that both prospective memory and inhibition deficits are evident in schizophrenia. Furthermore, after controlling for cognitive and executive function (inhibition) and retrospective memory, significant impairments were still evident in prospective memory in the group with schizophrenia. This finding suggests

that prospective memory may represent a distinct deficit in individuals with schizophrenia beyond inhibitory dysfunction. This may also apply to checkers and thus will be investigated whilst also examining the relationship between prospective memory, checking symptoms and inhibitory functioning.

Studies investigating prospective memory and planning in other cognitively impaired groups, such as individuals with traumatic brain injury (Kliegel et al., 2004) and participants with Attention Deficit Hyperactivity Disorder (Fuermaier et al., 2013), are supportive of the hypothesis that there may be a relationship between prospective memory performance and executive functions. Kliegel et al. reported that individuals with deficits in executive functioning performed worse than healthy controls on a prospective memory task. Similarly, Fuermaier et al. indicated that impairments in prospective memory in adults with Attention Deficit Hyperactivity Disorder related to planning impairments. To complete a prospective memory intention, individuals are required to plan an effective strategy and then execute this plan when particular environmental cues are present. Impairments in planning may result in poorer prospective memory performance.

Theoretical accounts of prospective memory suggest that shifting attention between the ongoing task and evaluation of responses in the environment is imperative to successful prospective memory performance. Empirical evidence has supported this proposal (McNerney & West, 2007; West et al., 2011). Prospective memory may also require an intended action to be held in mind whilst monitoring the environment for potential cues in order to execute a required response successfully, indicating a relationship between working memory and prospective memory performance (Smith &

Bayen, 2005; West & Craik, 2001). The current study will also examine attention set-shifting and working memory and their relationship with prospective memory in checkers.

The present study

The current study sets out to investigate the role of episodic prospective memory, habitual prospective memory, internally cued prospective memory and prospective memory aiding strategies in checking. We know that prospective memory is related to checking (Cuttler & Graf, 2007, 2008; Harris et al., 2010); therefore, it is expected that deficits in each of these components of prospective memory will predict checking severity. The role of executive functions in checkers will also be examined. OCD studies in general implicate inhibition, planning, attention set-shifting and working memory. Evidence for the role of each of these aspects of executive function in relation to checking is very limited (Chamberlain, Fineberg, Blackwell, et al., 2007; Goodwin & Sher, 1992; Jaafari et al., 2013; Nedeljkovic et al., 2009; Omori et al., 2007; Van der Linden et al., 2005). Despite theoretical reasons to posit a relationship between prospective memory and executive function, it appears that no study has examined both sets of variables together in the same sample of checkers. Identifying the relative importance of each of these variables and the relationship between them will contribute to our understanding of the causes of checking behaviour and the nature of the disorder.

Method

Participants and design

Prospective memory and executive functions will be investigated in relation to checking symptoms using a sample which includes sub-clinical participants. Spinella

(2005) has shown that sub-clinical OCD symptoms are relatively common in non-clinical populations, arguing that they share common neurobiological substrates with clinical OCD. The inclusion of a sample with sub-clinical participants should reduce the impact of medication (Cuttler & Graf, 2007). No participants in the final sample reported using medication. A total sample of 122 participants was recruited from a student population. Individuals reporting a previous clinical diagnosis of OCD (7 participants) were excluded from the analyses. Due to computer problems, the SST did not run correctly for 9 participants, leaving 106 participants for the final analysis (66% female and 34% male). The sample had a mean age of 23.56 (SD = 6.37) years. To ensure our sample included individuals with a range of symptoms on checking characteristics, following Cuttler and Graf (2007), we displayed some advertisements that called explicitly for participants with checking behaviours and others where checking behaviours were not mentioned. Ethical approval was granted by the appropriate departmental ethics committee and participants received either course credits or a small financial compensation in return for their participation.

Measures

Checking symptoms. The Padua Inventory was originally developed (Sanavio, 1988) to provide a self-report measure of the symptoms of OCD. The present study employed a revised version (The Padua Inventory Revised – Washington State University Revision – PI-WSUR) developed by Burns, Keorge, Formea and Sternberger (1996) that distinguishes between worry, obsessions and compulsions. This revised inventory contains 39 items describing common obsessive compulsive behaviours (e.g., I tend to keep on checking things more often than necessary). For each item, participants

use a five point likert type response to indicate their degree of disturbance caused by each behaviour. The response labels are marked: not at all (0), a little (1), quite a lot (2), a lot (3), very much (4). The inventory contains five subscales, each of which measures different obsessive compulsive concerns: contamination obsessions and washing compulsions, dressing/grooming compulsions, checking compulsions, obsessional thoughts of harm to self/others, and obsessional impulses to harm self/others. 'Checking' symptoms were calculated by adding up ratings for the items contained within the checking subscale (Items 14-23). Symptoms on the checking subscale ranged from zero to 40; a higher score indicates greater checking symptoms. The checking sub-scale had good internal reliability with a Cronbach's alpha value of $\alpha = 0.91$ in the current study.

Prospective memory.

The Prospective Memory Questionnaire (PMQ) (Hannon, Adams, Harrington, FriesDias, & Gipson, 1995) is a standardised self-report instrument designed for measuring prospective memory. The scale consists of 52 items examining different prospective memory failures (e.g., I forgot to return a phone call) and memory aiding techniques (e.g., I write myself reminder notes). Participants are asked to rate how often each memory failure is experienced or how often memory aiding technique are used in a specific time period (e.g., a week, month or year). For each item, participants use a nine point likert type response, ranging from not applicable (0), never (1) to 4/6 times a week/month/year (9). The questionnaire contains four sub-scales, 1) long-term episodic tasks, 2) short-term habitual tasks, 3) internally cued tasks and 4) prospective memory aiding strategies. Self-reported 'Prospective Memory Total' scores were calculated by adding responses on sub-scales 1-3 and response scores ranged from 0 – 342. A higher

score indicates more self-reported prospective memory failures. The PMQ had good internal reliability with a Cronbach's alpha value of $\alpha = 0.92$ in the current study.

Executive function tasks.

Participants performed a range of executive function tasks taken from the Cambridge Neuropsychological Test Automated Battery (CANTAB: www.camcog.com, Morris, Evendon, Sahakian, & Robbins, 1987). The executive function tasks used were the Stop Signal Task (inhibition), Stockings of Cambridge task (planning), Intra-Dimensional/Extra-Dimensional task (attention set-shifting) and Spatial Working Memory task (working memory). The tasks have been used extensively in clinical OCD and healthy control samples (Chamberlain, Fineberg, Blackwell, et al., 2007; Chamberlain, Fineberg, Menzies, et al., 2007; Morein-Zamir et al., 2010; Nielen & Den Boer, 2003; Purcell et al., 1998a, 1998b; Watkins et al., 2005). One key outcome measure was chosen for each task with the components described below.

Inhibition.

The Stop-Signal Task (SST) provides an assessment of response inhibition. The test consists of two parts and gives a measure of the ability to inhibit a pre-potent response. In the first part, which involves training, participants are told to press the left hand button when a left-pointing arrow appears and the right hand button when a right-pointing arrow appears. In the second part, participants are told to continue pressing the buttons on the press pad when arrows appear as before but, if there is an auditory signal (a beep), responses should be withheld and the button should not be pressed. The stop-signal paradigm allows a sensitive estimate of inhibitory control. The key outcome measure was stop signal reaction time ('Inhibition') – an estimate of the length of time

between the go stimulus and the stop stimulus at which the participant was able to successfully inhibit their response in the last half of the task (last 50% of trials – the processing time required to inhibit a pre-potent response). A higher response time on this measure indicates less inhibitory control.

Planning.

The Stockings of Cambridge (SOC) task was derived from the Tower of Hanoi task (Shallice, 1982) and measures planning ability. Participants are required to move balls hanging in 'socks' to match a 'goal arrangement' and are told to think of these like snooker balls in pockets. The aim is to use the balls in the lower display to copy the pattern in the upper display. Participants are told that the problems can be solved in a certain 'minimum number of moves', two, three, four or five moves and this number is displayed on the side of the screen. In order to be successful, participants are required to plan out the full set of moves prior to executing a move. For each trial, a control condition is completed to enable estimates of 'movement times' in order to provide an estimate of planning times. The key measure on this task was the number of problems solved in the minimum number of moves ('planning'). A higher score on this measure indicates better planning abilities, with a minimum score of 0 and maximum score of 12.

Attention set-shifting.

The executive Intra-Dimensional/Extra-Dimensional (ID/ED) task assesses attention set-shifting, involving the executive function ability of shifting flexibly from focusing attention on one aspect of stimulus to another. The task measures a participant's ability to focus attention on specific attributes of compound stimuli (intra-dimensional stages) and to shift attention when required to a previously irrelevant stimulus dimension (extra-

dimensional stages). There are nine stages in the task. At each stage, two different stimuli are presented (e.g., solid shapes). Participants are instructed to choose the correct stimulus and feedback is given. Once the participant correctly chooses the same stimuli over 6 trials the task moves to the next stage. The intra-dimensional stages involve shifting from one solid shape to another whereas the executive extra-dimensional stages require shifting from one type of stimulus to another (solid shape to a line). The key measure on this task was the stage-reached score ('Set-shifting'). A higher stage-reached score indicates higher performance for executive set-shifting and reversal.

Working memory.

The Spatial Working Memory (SWM) task is a searching task which assesses working memory for spatial stimuli and requires participants to use mnemonic information to work towards a goal. Participants are asked to search through a spatial array of coloured boxes to collect blue tokens hidden behind the boxes. Participants must keep searching through all the boxes until a blue token is found. Ultimately, participants will find a blue token behind each of the boxes. Experimental trials commence with a four box search and the highest difficulty level involves eight box trials. Participants can use a (self-initiated) strategy to aid performance, for example always starting at the top left of the array of boxes moving across to bottom right. If a participant returns to a box where a token has already been found, this constitutes a between search error ('Spatial Working Memory') and this was the key outcome measure for this task. A higher between search error on this measure indicates poorer spatial working memory.

Procedure

Before taking part in the study, participants provided informed written consent. In the experimental phase, participants completed the Padua Inventory first followed by the PMQ. The executive function tasks were then completed and were presented on a high resolution colour monitor utilising a touch sensitive screen. The order of the executive function tasks was counterbalanced to mitigate any fatigue effects. Completing all components of the study required approximately one hour. Upon completing the final task, participants were given a debriefing form explaining the purpose of the study.

Results

Means and standard deviations of experimental measures and Pearson Correlations between study measures are presented in Table 1. Prior to carrying out statistical analyses, the data were screened to determine whether statistical assumptions were met (Field, 2009; Tabachnick & Fidell, 2007). Assumptions of linearity, normality and homogeneity of variance were met when residuals scatter plots were examined with checking as the dependent variable for all variables. Multi-collinearity was not a problem as no predictor variables were highly correlated above 0.80 (Field).

A multiple linear regression analysis with checking score as the dependent variable was used to determine the independent predictors of checking symptoms. Only variables correlated with checking were entered into the regression model. Each of the remaining independent variables (long-term episodic prospective memory, short-term habitual prospective memory, internally-cued prospective memory, prospective memory aiding strategies and inhibition) were entered into the regression analysis to examine whether they predicted checking symptom severity. In a sample of 106 participants, the

use of 5 key measures to test individual predictors was within the recommended guidelines for sufficient power to detect significant effects within a regression analysis (Tabachnick & Fidell, 2007).

Correlational analyses

Pearson's correlations revealed significant positive relationships between checking and each of the prospective memory sub-categories. Higher self-reported checking symptoms were associated with higher reports of long-term episodic, short-term habitual and internally cued prospective memory failures. A significant positive relationship was shown between checking and prospective memory aiding strategies; higher checking symptoms were associated with greater use of strategies to aid prospective memory. A positive relationship was shown between checking and inhibition. Higher self-reported checking symptoms was associated with slower reaction times (higher scores) on the inhibitory task indicating greater inhibitory impairment. A significant positive correlation was also shown between long-term episodic prospective memory failures and poorer spatial working memory. Similarly, higher scores for long-term episodic memory failures were associated with lower planning scores (reflecting a poorer ability to plan). There were significant correlations between some of the executive function measures (see Table 1).

'Insert Table 1 here'

Linear regression analysis

A multiple linear regression analysis was conducted with checking symptoms as the dependent variable. After entry of long-term episodic prospective memory, short-term habitual prospective memory, internally-cued prospective memory, prospective

memory aiding strategies, and inhibition, a significant model emerged, $F(5, 100) = 8.95$, $p < .001$. This model explained 28% of the variance in checking symptoms (Adjusted $R^2 = .28$). Table 2 reveals that prospective memory aiding strategies ($p < .001$) and inhibition ($p = .04$) were independent predictors of checking symptoms. Internally-cued prospective memory approached significance as a predictor of checking symptoms ($p = .06$). Exploratory analyses revealed that when long-term episodic prospective memory was entered alone it was a significant predictor of checking symptoms, $F(1, 104) = 10.19$, $p = .002$, Adjusted $R^2 = .08$, Beta = .30; however, it no longer accounted for any unique variance when the other variables were entered into the model, suggesting potential suppressor effects. As no significant correlations were observed between prospective memory and inhibition, meditational analyses (see figure 1) were not included.

'Insert Table 2 here'

Discussion

The current study set out to examine the predictive power of prospective memory and executive functions on checking symptom severity. Checking symptom severity was predicted by internally cued prospective memory and prospective memory aiding strategies. Specifically, higher internally cued prospective memory failures and higher prospective memory aiding strategies predicted higher checking symptoms. Long-term episodic prospective memory was a predictor of checking symptoms when entered alone, but was no longer a predictor when entered with other variables, suggesting that it may not be an independent predictor of checking symptoms. Previous reports of prospective memory deficits are, therefore, supported (Cuttler & Graf, 2007, 2008).

Inhibition also contributed to the prediction of checking severity. This finding is consistent with previous work (Omori et al., 2007; Van der Linden et al., 2005).

The relationship between prospective memory and inhibition was examined. No correlations were observed between internally cued prospective memory and inhibition or between prospective memory aiding strategies and inhibition. These results suggest that each of the variables contribute independently to checking symptoms. The association was greatest between prospective memory aiding strategies and checking symptoms (as assessed by the standardised beta and R^2 change), suggesting that this aspect of prospective memory provides a greater contribution to the frequency of checking symptoms. Internally cued prospective memory provided the next greatest contribution, followed by inhibition.

The prospective memory data reported here are in line with previous work (Cuttler & Graf, 2007, 2008). Cuttler and Graf indicated that individuals with high checking symptoms had more long-term episodic, short-term habitual and internally cued prospective memory impairments, and used more prospective memory aiding strategies. In the current study, higher internally cued prospective memory failures and prospective memory aiding strategies predicted higher checking symptoms when entered alone and when entered with other variables, indicating that they are independent predictors of checking. Long-term episodic prospective memory predicted checking symptoms when entered alone but not when entered into the model with other variables, implying that it is not an independent predictor of checking.

Short- term habitual prospective memory impairments, however, were not shown to predict checking symptoms in the current study. These memory impairments involve

performing behaviours on a routine basis and it might be anticipated that problems in managing short-term routine tasks would be strongly linked to a perceived need to check; thus, this finding is surprising. This finding is contrary to work presented by Cuttler and Graf (2007). Differences in results may be due to the subjective assessment of prospective memory. Nonetheless, with both the current study and Cuttler and Graf (2007, 2008) reporting prospective memory deficits using self-report questionnaires, impairment in samples which comprise of participants with sub-clinical checking symptoms is strongly indicated.

Current findings are incongruent with the findings of Harris et al. (2010), who indicated that OCD-checkers did not self-report prospective memory impairments. The current study and Cuttler and Graf (2007, 2008) used samples recruited from non-clinical settings whilst Harris et al. recruited participants from clinical settings. The differences between studies could be due to genuine differences in prospective memory abilities in non-clinical and clinical samples, or groups may differ in self-awareness and insight into their own characteristics. Despite these differences, it is important to recognise the accumulating evidence that sub-clinical checkers do perceive themselves as having problems in this respect (see Hermann, Sheets, Gruneberg & Torres, 2005, for evidence of the validity of self-reported memory failures, especially prospective memory failures).

The current study revealed that executive function impairments were not uniformly associated with checking symptom severity. Out of the executive functions measured, only inhibition was shown to be related to checking symptoms, with poorer inhibitory control predicting higher checking symptoms. Difficulties of individuals with

this compulsion cannot, therefore, be explained in terms of a pervasive and unified deficit in executive function but relate to a specific dimension of cognitive regulation.

The current findings are consistent with those of Omori et al. (2007) and Van der Linden et al. (2005) who reported that checkers displayed significant inhibitory impairments. Similarly, previous reports of impaired inhibition when general OCD symptoms were measured are supported (Abramovitch et al., 2011; Chamberlain, Fineberg, Menzies, et al., 2007; Morein-Zamir et al., 2010). Checkers may have difficulty in suppressing irrelevant information, including removing a completed task from their 'to do' list, and focusing on the task in hand, which could then trigger concerns and doubts about the behaviour being completed and thus subsequent compulsions to check.

Planning ability was not shown to predict checking symptoms. The present findings are similar to those reported in clinical OCD samples (Purcell et al., 1998a, 1998b; Veale et al., 1996). The current findings, however, are contrary to some previous work, also with OCD samples (Cavedini et al., 2001; Cavedini et al., 2010; Chamberlain, Fineberg, Blackwell, et al., 2007; Nielen & Den Boer, 2003; van den Heuvel et al., 2005). Surprisingly, Nielen and Den Boer, used the same planning outcome variable as the current study and Purcell et al. (1998a, 1998b), yet found evidence of planning impairments in a clinical sample. It is important to consider why there may be discrepancies in these findings when the same tasks were used. Both studies used clinical samples; however, compulsive behaviours were greater in the study conducted by Nielen and Den Boer in comparison to those in the Purcell et al. studies. A possible explanation for the contradictory findings may link to symptom severity,

particularly since Nakao et al. (2009) indicated that severity may affect neuropsychological functioning.

Attentional flexibility was not shown to be a significant predictor of checking symptoms in the current study. Previous findings are, therefore, not supported (Goodwin & Sher, 1992; Omori et al., 2007). It is difficult, however, to compare earlier findings with the current study, as attention-shifting was measured differently by Goodwin and Sher and Omori et al. The present findings are consistent with results from a previous study using a clinical sample (Nielen & Den Boer, 2003). The role of attention set-shifting in the expression of OCD and in particular checking symptoms is an unresolved issue.

Working memory performance was not shown to predict checking symptoms in the current study. This is supportive of previous studies also using the CANTAB SWM task but in general OCD samples (Dittrich et al., 2011; Morein-Zamir et al., 2010; Nielen & Den Boer, 2003). Nonetheless, the current findings are inconsistent with work presented by Jaafari et al. (2013) and Nedeljkovic et al. (2009), where working memory performance was shown to predict checking behaviours in clinical samples. The results are also contrary to research indicating poorer working memory performance in individuals clinically diagnosed with OCD (Chamberlain, Fineberg, Blackwell, et al., 2007; Purcell et al., 1998a, 1998b). Conflicting findings in spatial working memory performance may be attributable to differences in severity and subtype (Nakao et al., 2009). It is also possible that some working memory tasks are more sensitive to the impairments of checkers (see Harkin & Kessler, 2011).

Importantly, no relationship was shown between prospective memory sub-scales and inhibitory function. This is consistent with an argument advanced by McDaniel and Einstein (2000), that prospective memory involves automatic retrieval processes. The current results, however, are inconsistent with an argument developed by McDaniel and Einstein that preparatory processes are not automatic and should be influenced by executive functions. The current finding is also contrary to what was expected based on previous literature (Martin et al., 2003; McNerney & West, 2007; Salthouse, Berish, & Siedlecki, 2004; Schnitzspahn et al., 2013; Smith & Bayen, 2005; West & Craik, 2001; West et al., 2011). It is difficult to compare these studies as both prospective memory and executive functions have been measured differently in varying populations. It has been proposed that a more complex prospective memory task theoretically demands the largest involvement of executive function processes (Martin et al. & McNerney & West). This proposal may help to explain why no relationships were observed between prospective memory measures and inhibition in the current study. Further research, therefore, should investigate the relationship between prospective memory and inhibition using a more complex objective prospective memory paradigm.

The lack of significant relationships between prospective memory and inhibition is supportive of research reported by Henry et al. (2007). Henry et al. reported that prospective memory deficits may present as an independent deficit in patients with schizophrenia. After controlling for executive function impairments, significant impairments were still evident in prospective memory in the group with schizophrenia (Henry et al.). The current findings indicate that prospective memory deficits that predict checking cannot be explained as secondary to impairments in executive functions.

Overall, internally cued prospective memory and prospective memory aiding strategies significantly predicted checking symptom severity in this study. Inhibition, planning, attention set-shifting and working memory were all examined in relation to checking symptoms but, of these, only inhibition was shown to predict checking severity. Correlational analyses showed that prospective memory and inhibition were independent predictors of checking severity. A clearer understanding of the range of cognitive impairments in participants with checking-like traits can potentially help us to improve the everyday functioning of individuals clinically diagnosed with the disorder. Identifying the difficulties that lead to the engagement of compulsive behaviours can contribute to therapeutic approaches aimed at reducing the behaviours.

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Table 1
Means and standard deviations and correlations for key measures

	Mean (SD)	2.	3.	4.	5.	6.	7.	8.	9.
1. Checking	12.51 (9.02)	0.30**	0.17*	0.40***	0.47***	0.21*	0.04	0.04	-0.12
2. Long-term Episodic Prospective Memory	37.37 (16.14)		0.56***	0.72***	0.25**	-0.01	-0.02	0.17*	-0.17*
3. Short-term Habitual Prospective Memory	19.20 (7.63)			0.47***	0.08	0.00	0.00	0.07	0.00
4. Internally-cued Prospective Memory	29.32 (13.46)				0.37***	-0.02	0.09	0.05	0.00
5. Prospective Memory Aiding Strategies	59.25 (25.54)					0.09	0.03	-0.02	-0.11
6.. Inhibition	173.93(51.37)						0.17*	-0.01	0.14
7. Set-shifting	8.65 (0.73)							-0.24**	0.19*
8. Spatial Working Memory	13.06 (12.29)								-0.56***
9. Planning	9.49 (1.89)								

*Note: *p <.05, **p<.01, ***p<.001*

Table 2

Standardised regression coefficients predicting checking symptoms

Predictors	Predicting Checking					
	Beta	95% CI		*SE* B	Standardised	R^2
		Lower Bound	Upper Bound		Beta (β)	Change
Constant	-6.04	-13.12	-1.05	3.57		
Long-term Episodic Prospective Memory	0.17	-0.13	0.16	0.07	0.03	0.09
Short-term Habitual Prospective Memory	0.14	-0.22	0.25	0.12	0.01	0.00
Internally-cued Prospective Memory	0.17	-0.00	0.33	0.08	0.25+	0.07
Prospective Memory Aiding Strategies	0.12	0.06	1.87	0.03	0.35***	0.12
Inhibition	0.03	0.00	0.06	0.02	0.18*	0.03

Note: * *p* <.05, ***p* <.001, + = .06

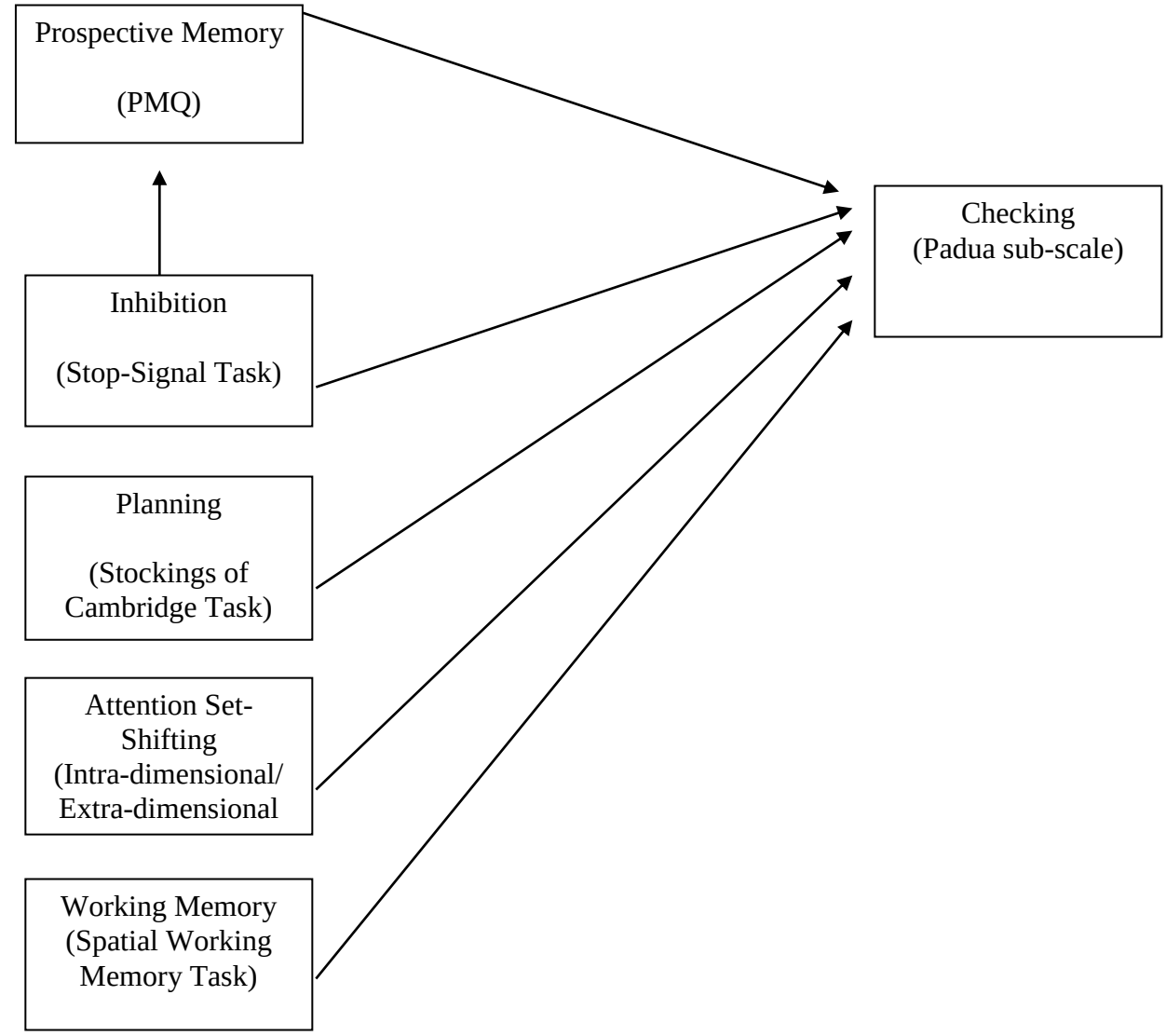

Figure 1. Proposed model of pathways

Chapter 4

Checking behaviours, prospective memory and memory confidence

This chapter is presented in the format of a manuscript

Abstract

Research evidence has pointed to a relationship between prospective memory deficits and checking symptoms in Obsessive Compulsive Disorder (OCD). This study sought to examine prospective memory, memory confidence and checking symptoms in a virtual environment. Detecting and responding to cues was under the participant's autonomy, analogous to many everyday contexts. A sample of 72 adults took part. The Padua Inventory was used to assess checking symptoms. All participants completed the Edinburgh Virtual Errands Task (EVET) to measure objective prospective memory. Confidence in completed tasks was also measured. Higher checking symptoms were related to greater prospective memory errors. Medium and high checkers had greater prospective memory errors when compared with low checkers. There were no differences in confidence in completed tasks between the three checking groups. The current findings enhance previous studies by reporting objective prospective memory errors in individuals with higher checking symptoms using a virtual environment task.
Keywords: Checking symptoms; prospective memory; memory confidence; virtual environment

Checking behaviours, prospective memory and memory confidence

Obsessive and compulsive symptoms are intrusive, recurrent impulses, reflecting and exacerbating high levels of anxiety. Although there are different types of compulsive behaviours, checking appears to be the most common (Henderson & Pollard, 1988). Individuals with checking compulsions often have recurring uncertainties about whether acts have been performed or completed (such as turning the oven off or locking the door) and continue to check to ensure completion. Given the repetitive nature of checking, a possible explanation is that individuals with these symptoms suffer an underlying memory deficit (Müller & Roberts, 2005; Olley, Malhi, & Sachdev, 2007). They fail to recall or to take into account that they have already completed the task. Much research has focused on the memory limitations of persons with checking and related symptoms (Sher, Frost, & Otto, 1983; Woods, Vevea, Chambless, & Bayen, 2002).

Early research focused on memory for past actions (retrospective memory). Cuttler and Graf (2007) proposed that 'prospective memory', memory for actions to be performed in the future, may be an important and hitherto overlooked component of the cognitive difficulties of individuals with checking symptoms. Cuttler and Graf suggested that as well as failing to remember that particular actions have already been completed, individuals with checking compulsions may have difficulties deactivating mental plans after completing them. Frequent experiences of prospective memory failures may cause individuals to question their ability to carry out actions successfully and this may maintain checking.

Several studies have investigated prospective memory in sub-clinical and clinical populations. Sub-clinical OCD is defined as the presence of obsessions and/or compulsions without functional impairment (Black & Gaffney, 2008). Prospective memory failures have been identified in those with checking symptoms using both subjective and objective measures. Cuttler and Graf (2007, 2008) investigated prospective memory in a non-clinical population using two subjective questionnaires, as well as objective event-based and objective time-cued prospective memory tasks. Individuals classified as 'high checkers' reported more prospective memory errors than those classified as either 'medium' or 'low checkers'. High and medium checkers performance was poorer on the event-cued prospective memory task when compared to low checkers, but there were no differences in time-cued prospective memory. Palmer, Durkin and Rhodes (in press) further investigated subjective prospective memory reports using a sample that included sub-clinical checkers. Greater prospective memory errors were reported to predict higher checking symptoms. Cuttler and Graf (2009) reported that checkers performed worse on prospective memory tasks than did individuals with washing compulsions (another common manifestation of OCD) and controls.

The findings from studies conducted with non-clinical samples lead to the expectation that prospective memory deficits should be marked in individuals experiencing clinical levels of checking symptoms. This has been broadly confirmed by Harris, Vaccaro, Jones, and Boots (2010) and Racsmany, Demeter, Csigo, Harsanyi, and Nemeth (2011), both testing clinical samples. Harris et al used the same task as Cuttler and Graf (2007, 2008). Findings were very similar to those of Cuttler and Graf, in that the OCD-check group performed worse than the control group on the event-based task.

In a reaction time task, Racsmany et al. also found that participants with OCD (sub-types not identified) were differentially affected, compared to healthy controls, by prospective memory task instructions. Taken together, the available findings demonstrate that prospective memory deficits are implicated in OCD, and particularly so in checkers.

Recent research investigating the memory deficits has implicated memory confidence in checking behaviours (Boschen & Vuksanovic, 2007; Coles, Radomsky, & Horng, 2006; Cougle, Salkovskis, & Wahl, 2007; Radomsky & Alcolado, 2010; Radomsky, Gilchrist, & Dussault, 2006; van den Hout & Kindt, 2003a, 2003b, 2004). It has been argued that repeated checking results in diminished confidence in the dependability of one's memory about the specific actions undertaken (van den Hout & Kindt, 2003a, 2003b, 2004). That is, repeated checking itself may have the ironic outcome of heightening a checker's uncertainty about whether a target behaviour has been performed. van den Hout and Kindt (2003a, 2003b, 2004) provided interesting demonstrations of this phenomenon among participants with no clinical symptoms. Participants were instructed to perform actions analogous to those of individuals with checking compulsions. For example, in a computer-animated representation of a kitchen, participants were required unexpectedly to repeat actions with a cooker that had already been undertaken; confidence in having completed the actions was tested subsequently. In different conditions, testing was either 'relevant' (i.e., checking a virtual kitchen cooker at pre-test and at post-test) or 'irrelevant' (i.e., checking a virtual kitchen cooker at pre-test and checking a simulated light bulb at post-test). Only 'relevant' checking led to diminished confidence in memory, suggesting that uncertainty was not due to the

cognitive load of checking per se (equivalent in both conditions) but to the repetitive checking of familiar events. These findings have been replicated using fully equipped, real kitchen environments (Coles et al., 2006; Radomsky & Alcolado, 2010; Radomsky et al., 2006). Findings suggest that in non-clinical samples, when checking symptoms are greater in OCD-relevant conditions, confidence in memory accuracy is lower.

Memory confidence has also been investigated using clinical samples and results are similar to those presented in healthy samples. Cougle et al. (2007) examined confidence in recollections across a range of different situations, obsessive and non-obsessive, whilst comparing clinical checkers, non-checkers, anxious controls and non-clinical controls. In comparison to the other groups, checkers were shown to report lower confidence in recollections in obsessive and non-obsessive situations. These findings support work in non-clinical samples. Boschen and Vuksanovic (2007) compared clinical and non-clinical groups and also supported this idea. Both groups showed lower confidence in memory accuracy when checking a virtual cooker. Based on the literature to date, it appears that repeated checking is counter-productive and reduces confidence in one's memory for task completion.

Studies assessing prospective memory using both subjective instruments and laboratory tasks have, then, provided important indications that this dimension of memory is implicated in checking. Subjective reports, however, have the limitation that respondents may not be fully aware of all of their symptoms or cognitive processes. Laboratory tasks provide means of controlling factors theorised to be influential. Often the experimenter determines when potential cues are encountered and when the participant is prompted to check. In spontaneous behaviour, actions and reflections in

the course of ongoing events are likely to bear substantially on the manifestations of symptoms. For example, as individuals move around their home, significant objects have the potential to cue prospective memories ("I must close that window", "I have to take that package when I leave"). To date, little research has examined the relationship between actual prospective memory performance in an environment where participants are responsible for exploiting available cues in the absence of extrinsic reminders or direct instructions to check. Performance in such a context is analogous to much everyday activity and, as such, has the potential to provide valuable complementary evidence to that collected under prompted checking instructions.

To assess prospective memory performance, a virtual environment task was employed. Such tasks have been used by researchers to investigate prospective memory in healthy adult samples. Trawley, Law, and Logie (2011) investigated how event-based prospective memory failures in the Edinburgh Virtual Errands Task (EVET) were related to planning, cognitive functioning and participant driven actions. Participants were required to remember a series of errands and then asked to complete these in a large virtual building. Prospective memory failures were recorded as the number of times individuals encountered a cue, failed to complete the required task on encountering this cue, yet successfully recalled the intention post study. Results revealed that planning ability, an independent measure of prospective memory (the breakfast task: Craik & Bialystok, 2006) and verbal working memory predicted prospective memory errors on the EVET. The authors suggested that by enabling free movements in an environment they were allowing for a better measurement of the factors that contribute to prospective memory performance. The current study aims to expand on previous

literature by using a virtual environment task to measure prospective memory ability and memory confidence in checkers.

Individuals who become increasingly aware of prospective memory failures may then check to ensure that an intention/action has been completed successfully, irrespective of their actual memory ability. It could be suggested that a combination of greater prospective memory failures and diminished memory confidence maintains checking behaviours. The current study assessed prospective memory using a virtual environment, examining confidence as a function of memory performance within that environment. The sample included participants with sub-clinical checking symptoms. Spinella (2005) suggested that sub-clinical OCD symptoms are relatively common in non-clinical populations, arguing that they share common neurobiological substrates with clinical OCD. It appears that no study to date has examined prospective memory using a virtual environment whilst also measuring confidence in memory in a sample of checkers. There is evidence that both prospective memory (Cuttler & Graf, 2007, 2008, 2009; Harris et al, 2010; Palmer et al, in press; Racsmany et al, 2011) and memory confidence (Boschen & Vuksanovic, 2007; Coles et al, 2005; Cougle et al, 2007; Radomsky et al, 2006; Radomsky & Alcolado, 2010; Van den Hout & Kindt, 2003a, 2003b, 2004) are related to checking symptoms. A key objective of this work was to assess both of these factors.

Based on previous literature, it was hypothesised that individuals with higher checking symptoms (high and medium checkers) would commit more prospective memory errors than would those with low checking symptoms. Furthermore, we

expected that individuals reporting higher levels of checking symptoms would have lower confidence.

Method

Participants and design

A total sample of 84 participants (20 males and 52 females) was recruited from a university population. One individual reported a previous clinical diagnosis of OCD and was excluded from analysis. The EVET task did not run or save correctly and/or there were language barriers for 11 participants, leaving 72 participants for the final analysis (72% female and 38% male). The sample had a mean age of 25.89 (SD = 6.18) years. The Padua Inventory, described in the measures section, was used in the present study to assess checking symptoms (see Table 1 for range of checking symptoms on Padua Inventory). Symptoms on the checking subscale of the Padua Inventory were used to assign them to one of three groups: low checkers, medium checkers and high checkers (cf. Cuttler & Graf, 2007). Participants with scores between 0 and 5 were assigned to the low checkers group, participants with scores between 6 and 10 were assigned to the medium checkers group, and participants with scores 11 or above were assigned to the high checkers group. These cut-offs were chosen to ensure approximately even numbers for each group (see Table 1 for means and standard deviation for each group). A one-way ANOVA showed that the three groups did not differ in age, $F(2, 69) = 0.11$, $p = .90$. The three groups also did not differ in gender balance, $\chi^2(2) = 1.90$, $p = .39$.

The current study was approved by the appropriate departmental ethics committee. Participants received either course credits or a small financial compensation in return for their participation.

Measures

Checking symptoms.

The Padua Inventory– Washington State University Revision (PI-WSUR) was used in the current study to measure checking symptoms (Burns, Keortge, Formea & Sternberger, 1996). This revised version of the Padua Inventory makes a distinction was made between worry, obsessions and compulsions and contains 39 statements describing common obsessive compulsive symptoms (e.g. I tend to keep on checking things more often than necessary). For each item, participants use a five point Likert-type scale to indicate their degree of disturbance caused by each behaviour. The scales points are marked: not at all (0), a little (1), quite a lot (2), a lot (3), very much (4). The inventory contains five subscales, each of which measures different obsessive compulsive concerns: contamination obsessions and washing compulsions, dressing/grooming compulsions, checking compulsions, obsessional thoughts of harm to self/others, and obsessional impulses to harm self/others. A checking severity score was calculated by adding up ratings for the items contained within the checking subscale of the inventory. Symptoms on the checking subscale ranged from 0 to 40, with higher scores indicating higher levels of checking symptoms. The checking sub-scale had good internal reliability, with a Cronbach's alpha value of $\alpha = 0.80$ in the current study.

Prospective memory.

The Edinburgh Virtual Errands Task (EVET) was created using the Hammer environment editor, supplied as a software development kit with the computer game Half Life 2. A 3-D model of a four storey building (see figure 1) was constructed as detailed by Trawley et al. (2011) and Logie, Trawley, and Law (2011). Participants were

to complete eight event-based errands in eight minutes (see Table 2). Three errands required two stages (object collection and object drop-off) and five required one stage. The tasks could be performed at any time, in any order, for as long as participants wished within the eight minute time-period. Half of the participants were instructed to start on the ground floor (Set A) outside room G1 and the other half were instructed to start on the third/top floor (Set B) in the equivalent position. Participants' start position was assigned randomly.

Participants were asked to read the EVET instructions, which detailed the building layout and rules. Following this, participants were given a practice with the controls (the keys, 'w', 's', 'a' and 'd' were used for forward, backward, left and right movements, respectively; the mouse was used to look around and up and down and the 'e' key was used to collect and drop objects and open doors). In this practice session, there were five errands to complete. None of the tasks used in this practice session were used in the main testing session. The practice session took approximately five minutes.

Participants were then given the main testing errands list and asked to study this for two minutes. This was followed by a free recall session. Participants had a further five minutes to study the errands, and this was followed by a cued recall task. The errands list was then removed and participants were asked to freely recall the errands list along with the building rules; no constraints were placed on order of recall. Any mistakes were corrected and this continued until participants could fully recall the errands list. This procedure was intended to minimise the chances of participants failing to complete the errands during the task because the specific requirements could not be recalled. The EVET task was then performed for eight minutes with no restriction on the

order in which the tasks were completed. Participants were placed into the virtual environment and asked to complete as many tasks as possible from the original list in this limited time. The errands list was not present during the task. After eight minutes, participants were asked again to freely recall the complete errands list. If participants failed to recall any of the errands from the original list, errands that had been forgotten in the free recall were cued.

The main outcome measure derived from this task was a prospective memory error score. This was calculated as the number of times participants walked past a room that should have been entered to complete an errand. If at the end of the session, when asked to freely recall or when cued to remember the errands, participants could still successfully recall an errand, but had not completed it during the task, then this was marked as a prospective memory error. The greater the prospective memory error score, the more times a participant walked past a prospective memory cue/room in the environment and did not respond to this cue/enter the room to complete a task.

"(Figure 1 about here)"

Confidence.

A measure of subjective performance confidence was collected. Participants were asked to rate how confident they were that they had completed each task on a scale from 1 (not confident at all) to 10 (extremely confident). They were asked to leave blank any tasks that they did not complete. A confidence total score was calculated by adding together confidence ratings for all completed/partly completed tasks and dividing this value by the number of tasks completed and multiplying by 100 to compute a percentage. A higher 'confidence total' indicated that participants were much more confident in having

completed tasks. The confidence measurement had good internal reliability, with a Cronbach's alpha value of $\alpha = 0.71$ in the current study.

Procedure

Before taking part in the study, participants provided informed written consent. Participants firstly completed the Padua Inventory in paper format. The EVET task was then administered and following this participants were asked for their task completion confidence ratings. Completing all components of the study required approximately one hour. Upon completing the final task, participants were given a debrief form explaining the purpose of the study.

Results

Data preparation

Prospective memory and performance confidence data were examined for univariate outliers, scores falling more than three standard deviations away from the means. One outlier was discovered in the data from the high checkers group on performance confidence. This outlier was replaced with the nearest non-outlying value (i.e. a score -3 standard deviations away from the group mean); this method was also used by Cuttler et al. (2007). See Table 1 for means and standard deviations for key variables across the three checking groups.

"(Table 1 about here)"

Prospective memory task performance

A one-way ANOVA of prospective memory errors, with group (low, medium, and high checkers) as the between-subjects factor was significant, $F(2, 69) = 3.15$, $p = .05$, $\omega = .30$. There was a significant linear trend, $F(1, 69) = 6.3$, $p = .014$, $\omega = .30$,

indicating that higher checking symptoms were related to greater prospective memory errors. Planned contrasts revealed that individuals with medium or high checking symptoms had significantly greater prospective memory errors compared to those with low checking symptoms, $t(61) = 2.72$, $p = .0045$ (one-tailed), $r = .12$. Prospective memory errors did not differ significantly between those with high checking symptoms and those with medium checking symptoms, $t(39) = -1.1$, $p = .14$ (one-tailed).

Confidence ratings

A one-way ANOVA of performance confidence with group (low, medium & high checkers) as the between-subjects factor was not significant, $F(2, 69) = 1.02$, $p = .37$.

Discussion

As far as the researchers are aware, this is the first study to examine prospective memory in a sample that consisted of participants with sub-clinical checking symptoms using a virtual environment task. Results showed that higher checking symptoms resulted in more prospective memory errors. More specifically, participants with medium or high checking symptoms committed more prospective memory errors than did individuals with low checking symptoms. Previous reports of greater prospective memory problems in those reporting higher checking symptoms are supported (Cuttler & Graf, 2007, 2008, 2009; Harris, Vaccaro, Jones, & Boots, 2010; Racsmany et al., 2011). Confidence ratings did not differ between the three checking groups. The findings add to the OCD checking literature by assessing prospective memory using a task analogous to everyday contexts.

The prospective memory data from the current study support findings of Cuttler and Graf (2007, 2008) and Palmer et al (in press). Cuttler and Graf (2007, 2008) showed that non-clinical individuals assigned to high and medium check groups showed more objective prospective memory impairments when compared to those assigned to a low checking group. There was no difference in prospective memory performance between high and medium checkers. Palmer et al (in press) supported subjective prospective memory deficits and showed that greater self-reports of prospective memory errors predicted higher checking symptoms. The current findings of greater prospective memory errors for sub-clinical checkers using an objective measurement, also supports the literature using clinical samples. Harris et al (2010) and Racsmany et al (2011) similarly reported greater prospective memory errors in clinical samples when measured using experimental tasks. Both the current study and Cuttler and Graf indicated that sub-clinical checkers exhibit more prospective memory errors on objective tasks. With similar reports of objective prospective memory failures in clinical samples (Harris et al. & Racsmany et al.), it is expected that if the EVET task was used to measure prospective memory performance in a clinical sample, deficits would be greater.

The current finding that overall confidence in memory did not differ between checking groups is not consistent with previous work. Previous findings in non-clinical samples have reported low confidence in memory when asked to repeat 'relevant' checking but not when asked to repeat 'irrelevant checking' on a virtual cooker (van den Hout & Kindt, 2003a, 2003b, 2004) and on a real cooker (Coles et al., 2006; Radomsky et al., 2006). Similarly, individuals assigned to 'high check' conditions reported diminished memory confidence in relation to those assigned to 'low check' conditions.

In the studies conducted by Coles et al, Radomsky et al and van den Hout & Kindt (2003a, 2003b, 2004), checking was induced rather than taking a subjective measure of checking symptoms and memory confidence was measured pre and post test. It may be that memory confidence is only lower in non-clinical samples when checking is induced and compared before and after an experimental manipulation. If individuals are encouraged to check OCD-relevant items, this may result in greater perceived responsibility and contribute to diminished confidence. In addition, the current findings do not support low memory confidence shown in clinical checking samples (Boschen & Vuksanovic, 2007; Cougle et al., 2007). These clinical studies highlighted the role of perceived responsibility in checking. It was reported that perceived responsibility perceptions may be important when measuring memory confidence. Future work should examine the relationship between perceived responsibility, memory confidence and checking to further understand the checking symptom profile.

The way in which confidence is measured may play a key role in apparent differences between the current findings and previous literature. It is important to note that van den Hout and Kindt (2003a, 2003b, 2004) and Radomsky et al. (2006) took two measurements of confidence. Firstly 'confidence in memory accuracy' was assessed with participants shown a schematic drawing of six cooker rings and asked to indicate which three they checked in their last checking event, and how confident they were in their answer. The second measure relied on 'outcome confidence' with participants being asked to specify how confident they were that the cooker rings had been turned off. Both studies showed that relevant checking resulted in a reduction in the former confidence in memory accuracy. There were no differences in outcome confidence,

between the relevant and irrelevant checking groups. This indicates that all participants tended to be highly confident in having turned off the cooker. In the current study, participants were asked to rate how confident they were in their performance. This measurement of confidence appears similar to outcome confidence measures used in previous literature and may explain why confidence in the current study was not shown to be related to checking symptoms. This explanation also helps to explain why the current findings differ from those presented by Coles et al. (2006) and Boschen and Vuksanovic (2007). Future studies should alter the confidence measure and assess confidence in memory accuracy using the virtual environment. Similarly, regression findings presented by Cuttler, Alcolado, and Taylor (2013) assessing the relationship between doubt and memory confidence, suggest that it may be important for future research to incorporate a measure of doubt. It was shown in this study that memory confidence (measured using the Memory and Cognitive Confidence Scale -MACCS) failed to account for any variance in checking symptoms, however doubt predicted checking symptoms in a non-clinical sample (Cuttler et al., 2013).

Recent research conducted by Cuttler et al. (2013) proposed that more failures in memory, and awareness that future failures could occur, may then result in greater doubt and thus repetitive checking, particularly if individuals want to avoid potentially serious consequences (for example, checking that the cooker is turned off in order to avoid starting a fire). Perceived threat resulting from poor performance may lead to greater prospective memory errors. This would support a cognitive theory proposed by Rachman (2002), which suggests that heightened responsibility and perceived probability and severity of self-harm combined may result in checking behaviours.

Cuttler et al. aimed to investigate an integrative model proposed by Cuttler and Taylor (2012). This model suggests that prospective memory, retrospective memory and dysfunctional beliefs such as heightened perceived responsibility contributed to checking compulsions. Results from this study revealed that doubt interacted with dysfunctional beliefs and low confidence also interacted with dysfunctional beliefs contributing to checking symptoms (Cuttler et al., 2013). Future work should attempt to replicate and extend the current study incorporating responsibility aspects. Examination of the relationship between different variables thought to contribute to checking symptoms would be useful.

The EVET task was originally developed and administered by Trawley et al. (2011) to investigate cognitive factors which influence event-based prospective remembering in a healthy adult sample. Observed deficits in prospective memory using the EVET in a non-clinical checking sample support the use of a virtual world to measure prospective memory. The current results validate the use of this virtual environment to measure prospective memory. The use of a virtual environment task to measure prospective memory errors has allowed the researchers to expand on past literature and support the proposal that prospective memory failures are evident in individuals reporting higher checking symptoms. The findings also show that confidence in completing tasks does not predict checking symptom severity. A clearer understanding of the cognitive deficits which may contribute to checking symptoms can help to improve therapeutic approaches aimed at reducing compulsive symptoms.

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Table 1.

Means and standard deviations for key variables across the three checking groups

Variable (Mean/SD)	Low Checkers (N = 24)	Medium Checkers (N = 27)	High Checkers (N = 21)
Checking Severity	3.5 (1.72)	7.93 (1.44)	14.9 (3.24)
Prospective Memory Errors	0.58 (1.02)	1.26 (1.97)	1.95 (2.29)
Confidence Total	95.64 (1.02)	95.44 (8.48)	92.14 (11.56)

Table 2.

Edinburgh Virtual Errands Task (EVET) lists

Errand List	A	B
1	Pick up brown package in T4 and take to G6	Pick up computer in G4 and take to T7
2	Get key card in F9 and unlock G6 (via G5)	Get key card in S9 and unlock T7 (via T6)
3	Get stair code from notice board in G8 and unlock stairwell	Get stair code from notice board in T10 and unlock stairwell
4	Meet person in S10	Meet person in F10
5	Pick up gun in G3 and take to trashcan in S4	Pick up broken glass in T3 and take to trashcan in F4
6	Turn light out in G1	Turn light out in T5
7	Ensure door is locked in S2	Ensure door is locked in F2
8	Turn stove off in S7	Turn stove off in F7

Note: EVET = Edinburgh Virtual Errands Task

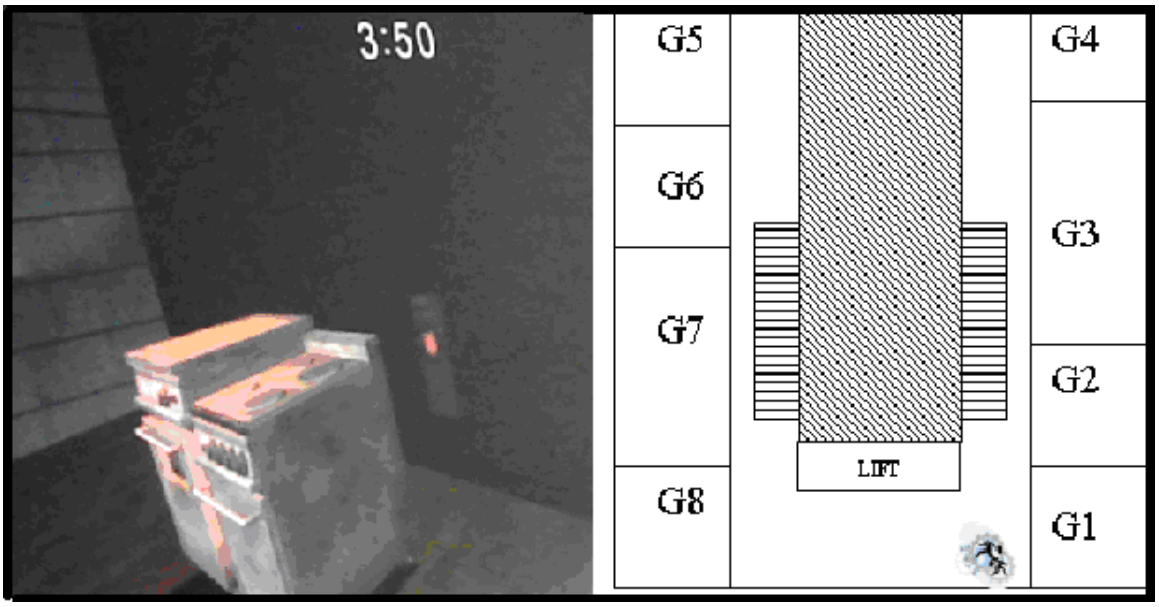

Figure 1. Screen shot of Edinburgh Virtual Errands Task (EVET) errand (left) and birds-eye view of the building (right) showing details of ground floor and start location for Set A.

Chapter 5

Predicting checking symptoms: The independent contribution of familiarity, inhibition and perceived responsibility

This chapter is presented in the format of a manuscript

Abstract

Accumulating evidence suggests that episodic memory plays a role in the cause and severity of checking symptoms. The literature has predominantly concentrated on examining recollection and relatively little attention has been paid to the role of familiarity in checking. This study assessed whether impairments in familiarity, inhibition, confidence and responsibility predict checking symptoms. 108 adults participated. Checking symptoms were assessed using the checking sub-scale from the Yale Brown Obsessive Compulsive scale. All participants completed a Remember/Know task as a measure of episodic memory recollection (familiarity), the Stop Signal Task (SST) taken from the CANTAB as a measure of inhibition, the Memory and Cognitive Confidence Scale (MACCS) and the Responsibility Attitudes Scale (RAS). Familiarity, inhibition and perceived responsibility were independent predictors of checking symptom severity. The relationship between inhibition and checking symptoms was not mediated by familiarity responses, suggesting that each of these variables had an independent role in predicting checking symptoms. The findings highlight the role of familiarity, inhibition and perceived responsibility and demonstrate that these cognitive processes may independently contribute to checking symptoms. These findings have implications for a model in which memory performance is thought to be secondary to impairments in executive processes.

Keywords: Checking symptoms; episodic memory; inhibition; memory confidence; perceived responsibility

Predicting checking symptoms: The independent contribution of familiarity, inhibition and perceived responsibility

Obsessive and compulsive symptoms are intrusive, recurrent impulses, reflecting and exacerbating high levels of anxiety. Although there are different types of compulsive behaviours, checking appears to be the most common (Henderson & Pollard, 1988). Ball, Baer, and Otto (1996) suggested that 75% of those with OCD reported primarily checking and/or cleaning rituals. Individuals with checking compulsions have recurrent uncertainties about whether particular acts have been performed or completed (such as locking a car, or closing a window) and return repeatedly to ensure completion.

Establishing the causes of checking compulsions is challenging and considerable research has provided evidence for cognitive deficits in individuals with checking compulsions (Moritz, Jacobsen, Willenborg, Jelinek, & Fricke, 2006; Omori et al., 2007; Sher, Frost, & Otto, 1983). Based on the literature to date, it seems unlikely that there is a single underlying factor (Cuttler & Taylor, 2012). Given the repetitive nature of checking, first we review the literature indicating that memory impairments are important. There is also reason to believe that inhibitory functioning may play a role in maintaining checking symptoms and memory performance may be secondary to impairments in inhibition (Deckersbach, Otto, Savage, Baer, & Jenike, 2000; Kashyap, Kumar, Kandavel, & Reddy, 2013; Penades, Catalan, Andres, Salamero, & Gasto, 2005; Savage, Deckersbach, Heckers, et al., 2000). Memory confidence and perceived responsibility may also contribute to checking symptoms. The combined contribution of each of these factors in predicting checking symptoms has not yet been examined in the

same sample. The current study will investigate the respective contribution of each of these factors.

Checking reflects uncertainty as to whether an action has been completed or not. It has been suggested that memory deficits may contribute to repetitive checking symptoms (Sher, Frost, Kushner, Crews, & Alexander, 1989). Individuals who check repeatedly may do so to try and obtain certainty than an action has been completed. Memory for previous events or "episodic memory" is one aspect of memory that has received attention in the OCD literature (Exner et al., 2009; Omori et al., 2007; Savage, Deckersbach, Wilhelm, et al., 2000). Evidence is unclear as to whether problems are primarily in memory or if they reflect the impact of checking symptoms on functioning and confidence in memory and/or broader organisational difficulties.

Episodic memory: Familiarity

Proponents of dual process models argue that episodic retrieval involves two distinct processes, familiarity and recollection (Yonelinas, 2002). Most studies focused on OCD have reported retrieval measures that reflect recollection only (Cha et al., 2008; Segalas et al., 2010; Sher et al., 1989; Tallis, Pratt, & Jamani, 1999; Zitterl et al., 2001). "Familiarity", involves a feeling of knowing that you have encountered something before in the absence of a specific recollection. "Recollection" involves remembering detailed qualitative information about studied events (Yonelinas, 2002). It has been argued that checking may, at least in part, reflect an over-reliance on familiarity (Coles, Radomsky, & Horng, 2006; Radomsky, Gilchrist, & Dussault, 2006; van den Hout & Kindt, 2003a, 2003b, 2004). By this account, individuals who feel the need to check whether a cooker is turned off may feel a sense of familiarity with turning it off rather

than specifically recollecting that it has been turned it off. Familiarity based remembering does not rely on contextual processing, merely involving a feeling that an action (or more generally an event) has been encountered before. Less detailed and vivid source memories may encourage individuals to continue checking in order to gain a more concrete memory of having completed the action.

There is evidence for impaired recollection in samples that have recruited individuals with OCD and checking symptoms. For example, Sher et al. (1989) compared non-verbal episodic memory between clinical OCD participants with checking as their prominent symptom and a healthy control group. Non-verbal recall and recognition memory deficits were reported for checkers when compared to controls. Tallis et al. (1999) also compared non-verbal memory between clinical OCD participants with checking symptoms and healthy controls. Performance differed in recall and recognition of non-verbal memory, with impairments reported in the OCD group. These findings have been supported in other studies with OCD samples (Segalas et al., 2010) and more specifically in checking samples (Cha et al., 2008; Zitterl et al., 2001).

A small number of studies have implicated altered familiarity processing in OCD, particularly in relation to checking symptoms (Coles et al., 2006; Radomsky et al., 2006; van den Hout & Kindt, 2003a, 2003b, 2004). Most of these investigations have employed Remember/Know tasks (R/K), which provide measures of recollection (remember responses) and familiarity (know responses). van den Hout and Kindt used threat-relevant simulation tasks which included performing checking rituals on a virtual kitchen cooker, to examine familiarity and recollection in a healthy student sample. Each

study included an experimental group who engaged in "relevant" checking (i.e. checking a virtual kitchen cooker pre-test and post-test) and a control group who engaged in "irrelevant" checking (i.e. checking a virtual kitchen cooker pre-test and a virtual light bulb post-test). The findings suggested that whilst memory accuracy was left intact, repeated relevant checking led to less detail and vividness of memory for checked events. Participants in the experimental group reported that their response was based more on familiarity rather than remembering in comparison to controls. Coles et al. and Radomsky et al. reported similar findings using real kitchen environments. Collectively these studies suggest that OCD checkers may show distrust in their episodic memory leading to checking symptoms.

Familiarity and recollection were investigated in a non-clinical sample of individuals with washing symptoms (Klumpp, Amir, & Garfinkel, 2009). In this study, students with obsessive compulsive washing symptoms were matched with individuals suffering from depression and anxiety without OCD symptoms and non-anxious individuals. All participants read OCD threat relevant, positive and neutral scenarios and then performed an R/K recognition task. Individuals in the OCD group gave more familiarity responses for false memories relating to threat words but not positive and neutral words, suggesting that threat-relevant material may lead to a greater reliance on familiarity for remembering events. Consequently, the idea that individuals who experience washing symptoms suffer from a general memory deficit seems unlikely, with this impairment appearing to be specific to threat-relevant information.

Further research has compared attention in terms of recall and recognition performance between non-clinical checkers and non-checkers (Irak & Flament, 2009).

On several different tasks of attention, participants were presented with OCD threat-relevant and neutral words. For all attention tasks, checkers' recall and recognition was better for OCD threat-relevant than neutral material. This appears contrary to the findings presented by Klumpp et al. (2009). Although it is difficult to compare these studies due to different methodologies, it is possible the recognition biases for threat and non-threat materials change depending on the symptom sub-type (washers/checkers). Familiarity was not measured directly by Irak and Flament, however the findings from this study suggest that with better recollection for OCD threat-relevant information, familiarity biases (thus poorer recollection) may be evident in non-threat relevant contexts. To our knowledge, no studies have investigated whether familiarity biases extend to non-threat contexts in a checking sample; the current study will address this.

Previous work tends to suggest that there is a relationship between checking and familiarity recognition. It is suggested however, that checking occurs as a coping strategy when memory deficits occur. The relationship between familiarity and checking will be examined in the current study. It is expected that less recollection, thus greater familiarity responses, will predict higher checking symptoms.

Inhibition

The role of executive functions in relation to the repetitive nature of OCD and checking symptoms has been a focus of OCD research. Executive function is an umbrella term used in the literature to refer to higher order strategic processes known to be critical in the control of behaviour. Key executive functions include inhibition, working memory, and attention set-shifting (Diamond, 2013; Miyake et al., 2000). Consistent performance deficits have been reported on executive function tasks in OCD

samples, in particular for inhibitory control (Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005; Linkovski, Kalanthroff, Henik, & Anholt, 2013; Palmer, Durkin & Rhodes, in press), the ability to suppress irrelevant or interfering stimuli. Individuals with OCD may have difficulty in selectively controlling unwanted or irrelevant intrusive thoughts, thus it seems plausible that this may trigger subsequent neutralising compulsions (e.g. repeatedly checking that a door is locked) and/or memory impairments. Chamberlain et al. emphasised the importance of inhibitory processes in understanding the etiology of OCD. Abramovitch, Dar, Schweiger, and Hermesh (2011) and Penades et al. (2007) provided support for inhibitory dysfunction in a clinical sample. OCD participant's performance was poorer on a Go/NoGo inhibition task in comparison to healthy controls. Several other researchers have provided support for inhibitory impairments in OCD participants when compared to clinical controls (Bannon, Gonsalvez, Croft, & Boyce, 2006; Chamberlain, Fineberg, Blackwell, Robbins, & Sahakian, 2006) and healthy controls (Chamberlain et al., 2007; Menzies et al., 2007; Sottocorno, Martoni, Galimberti, Fadda, & Bellodi, 2011).

Inhibitory functioning appears to have received less attention in the checking literature, with research focusing on OCD in general. If individuals find it difficult to inhibit a pre-potent plan (e.g. "I must lock the front door") and/or irrelevant information, then, despite having undertaken the relevant action, distracting cognitions could prompt checking. Omori et al. (2007) has provided support for inhibition deficits in checkers. Checkers were shown to display inhibitory impairments compared to washers when using the Go/NoGo task. Recently, Linkovski et al. (2013) investigated whether preserved inhibitory control can protect from influences of repeated checking in a non-

clinical student sample using the Stop-Signal inhibition task. Participants who were less able to inhibit responses reported greater memory uncertainty and distrust after checking. With limited evidence for inhibitory impairments in checkers, further research is necessary to confirm the role of inhibition in checking.

Familiarity and inhibition

Accumulating evidence supports episodic memory impairments in participants with OCD (Exner et al., 2009; Omori et al., 2007; Savage, Deckersbach, Wilhelm, et al., 2000; Segalas et al., 2010) and checkers (Cha et al., 2008; Coles et al., 2006; Radomsky et al., 2006; Sher et al., 1989; Tallis et al., 1999; van den Hout & Kindt, 2003a, 2003b, 2004; Zitterl et al., 2001). Similarly, inhibitory impairments have been consistently reported in participants with OCD (Abramovitch et al., 2011; Bannon et al., 2006; Chamberlain et al., 2006; Chamberlain et al., 2007; Menzies et al., 2007; Penades et al., 2007; Sottocorno et al., 2011) and checkers (Linkovski et al., 2013; Omori et al., 2007; Palmer et al, in press). Research indicates that both episodic memory and inhibitory impairments may play a role in the expression of checking symptoms. Investigating the relationship between these variables is desirable. Savage et al. (1999) reported that memory impairments were mediated by organisational strategies in a clinical OCD sample and concluded that differences in memory performance are secondary to impairments in executive processes. Similarly, Omori et al. (2007) reported that there was a relationship between general memory and inhibitory functioning in checkers. To our knowledge the specific relationship between episodic memory recollection and inhibition has not been investigated in OCD. This relationship merits further research attention given reports of impairments in both of these aspects of functioning in OCD

and evidence of a relationship between them in non-OCD samples (El Haj & Allain, 2012; Lövdén, 2003).

The authors propose that familiarity responding may mediate the relationship between inhibitory function and checking. Checkers may be unable to inhibit irrelevant information due to interference effects. If individuals show impairment in inhibitory control, they may be less able to monitor, focus on the task in hand and evaluate their memory strength and consequently might report that they are familiar with having completed the task but they cannot recollect. As a result, repetitive checking may occur in order to achieve certainty that a task has been completed. Identifying the relative importance of each of these variables will contribute to our understanding of the causes of checking symptoms and the nature of the disorder. Evidence suggests that both greater familiarity responses (Cha et al., 2008; Coles et al., 2006; Radomsky et al., 2006; Sher et al., 1989; Tallis et al., 1999; van den Hout & Kindt, 2003a, 2003b, 2004; Zitterl et al., 2001) and poor inhibitory control (Linkovski et al., 2013; Omori et al., 2007) predict checking symptom severity. It is, therefore, hypothesised that familiarity and inhibition will predict checking symptoms and that familiarity may mediate the relationship between inhibition and checking.

Memory confidence and perceived responsibility

Both memory confidence and perceived responsibility are thought to account for variance in checking symptoms. Accumulating evidence suggests that confidence in memory performance, may contribute to the explanation for repetitive checking symptoms in OCD (Boschen & Vuksanovic, 2007; Coles et al., 2006; Cougle, Salkovskis, & Wahl, 2007; Jennings, Nedeljkovic, & Moulding, 2011; Nedeljkovic &

Kyrios, 2007; Radomsky & Alcolado, 2010; Radomsky et al., 2006; van den Hout & Kindt, 2003a, 2003b, 2004). For example, individuals who worry about their memory being poor may then check to ensure that a cooker has been turned off, irrespective of their actual memory ability. Nedeljkovic and Kyrios (2007) assessed whether reduced memory confidence extended to non-threat situations and reported that general confidence in memory (assessed using the Memory and Cognitive Confidence Scale - MACCS) was a predictor of overall OCD severity and checking symptoms in a healthy student sample, over and above other OCD relevant beliefs such as responsibility. Similar findings were presented by Jennings et al. (2011). Based on these findings, it could be suggested that low memory confidence is related to checking.

Perceived responsibility has been examined in individuals with checking symptoms. Evidence suggests that heightened perceived responsibility may be related to higher checking symptoms (Arntz, Voncken, & Goosen, 2007; Boschen & Vuksanovic, 2007; Coles et al., 2006; Foa, Sacks, Tolin, Prezworski, & Amir, 2002; Lopatka & Rachman, 1995; Mancini, D'Olimpio, & D'Ercole, 2001; Smari, Gylfadottir, & Halldorsdottir, 2003; van den Hout & Kindt, 2004). Rachman (2002) proposed a cognitive model which suggested that in circumstances where perceived responsibility for preventing harm is high, individuals consistently check. One study reported that repeated relevant checking of a virtual cooker led to heightened perceived responsibility (van den Hout & Kindt, 2004). Coles et al. (2006) also indicated that when individuals were asked to check a real kitchen cooker, heightened perceived responsibility was evident. Arntz et al. (2007) reported that high responsibility encouraged new OCD like responses in OCD patients but not for an anxiety control group. Evidence for heightened

perceived responsibility in individuals with higher checking symptoms is convincing. Additionally, researchers have reported that perceived responsibility perceptions may be important when measuring memory confidence (Boschen & Vuksanovic, 2007; Cougle et al., 2007). The current study will examine the predictive power of memory confidence and perceived responsibility in relation to checking symptoms in a model that includes both familiarity and inhibition.

The present study

The current study will assess episodic memory retrieval and inhibitory control in a sample which includes participants with a range of checking symptoms as defined by the Yale-Brown Obsessive Compulsive Scale (Y-BOCS). No study has examined these variables together in the same sample of checkers. There is evidence that familiarity and inhibition are related to checking symptoms. Despite reports by Omori et al. (2007) that there may be a relationship between general memory and inhibition in a checking sample, there is still uncertainty as to the importance of familiarity and inhibition in checking and the relationship between them. Furthermore, memory confidence and perceived responsibility has been reported to contribute to the checking symptom profile. The aim of the current study is to investigate the role of inhibition in checking whilst also examining the relationship with episodic memory (familiarity), which is predicted to mediate the relationship between inhibition and checking. As memory confidence and perceived responsibility has also been implicated in checking, the interrelations among these variables and memory and inhibition will be measured in a single cognitive model.

Method

2.1 Participants and design

A total sample of 121 participants was recruited from a university population and via self-helps groups. Individuals reporting a previous clinical diagnosis of OCD (6 participants) were excluded from the analyses. The R/K and/or Stop Signal Task (SST), also, did not run correctly for 7 participants leaving 108 participants for the final analysis (74% female and 26% male). No participants in the final sample reported using medication. The sample had a mean age of 24.66 (SD = 8.78) years. To ensure the sample included individuals with a wide range of symptoms, and in line with previous studies (Cuttler & Graf, 2007, 2008), we displayed one set of advertisements that called explicitly for participants with OCD symptoms and another set where OCD symptoms were not referred to (see Table 1). A self-report version of the Yale-Brown Obsessive Compulsive scale (Y-BOCS) was used in the present study to measure OCD checking symptoms and has been reported to be appropriate for use as a self-report measure (Steketee, Frost, & Bogart, 1996) and in samples of individuals with non-clinical symptoms (Frost, Steketee, Krause, & Trepanier, 1995; Spinella, 2005). The Depression, Anxiety and Stress Scale (DASS) (Lovibond & Lovibond, 1995) was administered to examine whether depression and anxiety symptoms were contributing to self-reported checking symptoms. Participants' familiarity scores were used to assign them to one of three groups: low familiarity, medium familiarity and high familiarity. Familiarity scores ranged from 0-3 in the low familiarity group (38 participants), from 4-11 in the medium familiarity group (39 participants) and 12-51 in the high familiarity group (31

participants). These cut-offs were chosen to ensure approximately even numbers for each group (Cuttler & Graf, 2007).

The current study was approved by the appropriate ethic committees and participants received either course credits or money in return for their participation.

"Insert Table 1 about here"

2.2 Measures

2.2.1 OCD.

The Yale-Brown Obsessive Compulsive scale (Y-BOCS) (Goodman, Price, Rasmussen, Mazure, Delgado, et al., 1989; Goodman, Price, Rasmussen, Mazure, Fleischmann, et al., 1989) is an extensively used semi-structured measure which assesses the severity of obsessions and compulsions over a one week period. The first part of the scale contains a checklist of 55 symptoms evaluating the presence (yes/no) of current and past symptoms and determines the types of obsessions and/or compulsions experienced. There are 14 different sub-types measured in this section, including checking. A "checking total" score was calculated from the checking sub-section. This was used as the main outcome variable and included current and past symptoms. Checking total ranges from 0-5, with higher scores indicating more self-reported checking symptoms. Following this, 10 items are used to assess the severity of these obsessions and compulsions equating to a total OCD severity score (Total Y-BOCS). In the present administration, good internal reliability was shown for Total Y-BOCS. The Cronbach's alpha value for this measure was 0.92 (see Table 1 for the range of OCD severity and checking symptoms as measured using Y-BOCS).

2.2.2 Depression and anxiety.

The Depression, Anxiety and Stress Scale (DASS) (Lovibond & Lovibond, 1995) includes three self-report scales which are designed to measure the negative emotional states of depression, anxiety and stress. Each scale contains 14 items. The depression and anxiety scales were used in the current study. The depression scale includes items such as "I just couldn't seem to get going" and "I felt like I had nothing to look forward to". The anxiety scale includes items such as "I was aware of dryness in my mouth" and "I had a feeling of faintness". Participants were asked to use a four point scale to rate the extent to which they have experienced each state over the last week, ranging from "does not apply to me at all" (0) to "applied to me very much, or most of the time" (3). Each subscale score can range from 0 to 42 with higher scores showing greater levels of depression and anxiety. In the present administration, good internal reliability was shown for the depression and anxiety sub-scales. The Cronbach's alpha value for the depression scale was 0.93 and for the anxiety scale was 0.86.

2.2.3 Episodic memory task (familiarity).

All participants performed a Remember/Know (R/K) task to assess the engagement of episodic retrieval processes (Rhodes, Murphy, & Hancock, 2011). The task was created using the experimental program Eprime. In study phases of the experiment, participants were shown pictures on either the left or right hand side of the screen. The pictures included concrete objects based on common objects normed for adults and children (Snodgrass & Vanderwart, 1980). Each image in the study phase was followed by a fixation cross and this appeared on the screen for 2 seconds. The study images were presented for 3 seconds and participants were asked to try and remember each image and location on the screen as it was presented. In the test phase, participants were presented

with either old (studied) or new (unstudied) pictures which were centrally fixated for 3 seconds. The task had a three-step response procedure. Participants were asked to indicate whether the pictures were old or new. If they indicated that the item was new they exited the trial and proceeded to the next trial. If they indicated that the item was old they were given a choice of whether they have specifically remembered seeing the item, if they simply felt they knew that they had encountered the item before without remembering any specific information, or if their response was a guess. Instructions for R/K judgments were adopted from (Gardiner & Richardson-Klavehn, 2000). A guess response was provided as Eldridge, Sarfatti, and Knowlton (2002) reported that allowing participants to use a guess response may help them to confine their R/K judgements. When participants are not provided with a guess response, it is possible that they could use the R/K distinction to indicate the trace strength of memory (Eldridge et al). Finally, if participants chose the remember response they were asked if the item was on the left or right hand side of the screen at study, providing an index of source memory (see Figure 1). Participants completed a practice block of 4 pictures at study and 8 pictures at test (four old, four new). There were 4 blocks in the main part of the experiment. There were 16 study pictures and 32 test pictures (16 old, 16 new) presented in each block. All images were centred and appeared on the screen for 3000ms. The duration between the study and memory phase was determined by the participant via a button press. The main outcome measure was "familiarity" and was measured using Know responses. Familiarity responses were calculated by adding up the number of times individuals responded Know after having previously stated that the item was old.

2.2.4 Inhibition task.

Participants performed the Stop Signal Task (SST) measuring inhibition taken from the Cambridge Neuropsychological Test Automated Battery (CANTAB: www.camcog.com, Morris, Evendon, Sahakian, & Robbins, 1987). This task has been used extensively in patient/impaired populations (Matthews, Coghill, & Rhodes, 2008; Rhodes, Coghill, & Matthews, 2005; Rhodes, Riby, Park, Fraser, & Campbell, 2010). The SST provides an assessment of response inhibition. The test consists of two parts and gives a measure of the ability to inhibit a pre-potent response. In the first part, which involves training, participants were told to press the left hand button when they saw a left-pointing arrow and the right hand button when they saw a right-pointing arrow. In the second part, participants were told to continue pressing the buttons on the press pad when they saw the arrows as before, but if they heard an auditory signal (a beep) they should withhold their response and not press the button. The stop-signal paradigm allows a sensitive estimate of inhibitory control – the stop signal reaction time (SSRT) – reflecting the time it takes to suppress a response. Higher SSRT scores represent poorer inhibitory control.

2.2.5 Memory and cognitive confidence scale.

The Memory and Cognitive Confidence Scale *(*MACCS- Nedeljkovic & Kyrios, 2007*)* is a 28 item scale with four sub-scales referring to the beliefs individuals hold about their own memory (general memory), planning, concentration and decision making abilities and their confidence in these abilities. The general memory confidence sub-scale includes 15 items and this was used as the memory confidence measure in this study. Participants were instructed to read each statement and circle the response that most accurately described how strongly they agreed or disagreed with each statement. They were asked to respond to all items even though some were repetitive and told that there

are no right or wrong answers. Each item was scored on a 5 point scale ranging from 1 = strongly disagree to 5 = strongly agree. Scores on the general memory confidence subscale ranged from 15-75 with higher scores indicating poorer memory confidence. An example of one item is "I have little confidence in my memory generally". The MACCS scale was shown to be highly reliable, with a Cronbach's alpha value of 0.93 in the current study.

2.2.6 Responsibility attitude scale.

The Responsibility Attitude Scale *(*RAS- Salkovskis et al, 2000) is a 26 item scale referring to attitudes concerning responsibility. Each item is scored on a 7 point scale ranging from 1 = totally disagree to 7 = totally agree. An example of an item is "If I think bad things, this is as bad as doing bad things". The RAS has good internal reliability, with a Cronbach's alpha value of 0.93 in the current study.

2.3 Procedure

Before taking part in the study participants provided informed written consent. Participants completed the questionnaires followed by the episodic memory and inhibition tasks. The inhibition task was presented on a high resolution colour monitor utilising a touch sensitive screen. The order of the episodic memory and inhibition task was counterbalanced to ensure that there were no fatigue effects. Completing all components of the study required approximately one hour. Upon completion of the final task participants were given a debriefing form explaining the purpose of the study.

2.4 Statistical analyses

Means and standard deviations of experimental measures and Pearson Correlations between study measures were calculated. Prior to carrying out statistical

analyses, the data were screened to determine whether statistical assumptions were met (Field, 2009; Tabachnick & Fidell, 2007). Assumptions of linearity, normality and homogeneity of variance were met when residuals scatter plots were examined with Total Checking as the dependent variable for all variables except familiarity responses (Episodic Memory). Familiarity response was not normally distributed and was treated as a categorical variable, with three categories: low familiarity, medium familiarity and high familiarity. Dummy variables were created for "familiarity" responses with one dummy variable representing high familiarity responses and the other representing low familiarity responses. The medium familiarity group was assigned as the reference group. The medium familiarity group was chosen as the reference group because it was believed that this represented the best choice for comparison. No predictor variables were highly correlated above 0.80, suggesting that multi-collinearity was not a problem (Field, 2009).

A one-way ANOVA was conducted to examine whether depression and anxiety scores differed between the low familiarity, medium familiarity and high familiarity groups. This was conducted to determine whether higher self-reported depression and anxiety symptoms lead to higher self-reported checking symptoms.

A multiple linear regression analysis with Total Checking symptoms as the dependent variable was used to determine the independent predictors of checking symptoms. The high and low familiarity dummy variables were entered into the regression analysis along with the remaining independent variables (Inhibition: SSRT; confidence: MACCS; perceived responsibility: RAS) to examine whether they were predictive of checking symptoms. In a sample of 108 participants, the use of 5 key

measures to test individual predictors was within the recommended guidelines for sufficient power to detect significant effects within a regression analysis (Tabachnick & Fidell, 2007).

The Preacher and Hayes (2008) bootstrapping procedure was then employed to test whether familiarity mediated the relationship between inhibition and checking (see Figure 2). Bootstrapping in the current analysis involved re-sampling one thousand sub-sets of data. This procedure is preferable to the use of Sobel tests. A non-parametric estimation of the sampling distribution of the products of the paths is calculated. This is between the independent variables (inhibition) and the proposed mediator (familiarity) and between the proposed mediator and the dependent variable (checking symptoms) (Elliott & Ainsworth, 2012).

Results

The range of OCD and checking symptoms for all participants are presented in Table 1. Means and standard deviations for all key variables are presented in Table 2.

"Insert Table 2 about here"

3.1 One-way ANOVA

A one-way ANOVA revealed no significant differences in depression symptoms between the three groups (low, medium and high familiarity), *Welch F* (2, 67.82) = 1.23, p = 2.83. There was a significant difference in anxiety symptoms between the three groups, *Welch F* (2, 67.82) = 4.94, p = .01. Games-Howell post-hoc tests revealed a significant difference in anxiety symptoms between the medium (M = 6.79, SD = 5.19) and high (M = 3.61, SD = 3.63) familiarity groups, p = .02. With higher anxiety

symptoms in the medium checking group, increased anxiety does not appear to have impacted on self-reports of checking symptoms.

3.2. Correlational Analyses

Pearson's correlations revealed a significant positive relationship between checking symptoms and inhibition. Higher checking symptoms were related to poorer inhibitory performance (greater SSRT scores). A positive correlation was shown between checking and perceived responsibility. Higher checking symptoms were related to greater perceived responsibility. Similarly, there was a positive correlation between checking symptoms and memory confidence. That is, a greater incidence of checking was related to poorer confidence in memory (higher scores). There was also a significant relationship between confidence and perceived responsibility (see Table 3).

"Insert Table 3 about here"

3.3 Linear regression analysis

A multiple linear regression analysis conducted with checking symptoms as the dependent variable and episodic memory (high and low familiarity dummy variables), inhibition, confidence and perceived responsibility as predictors revealed a significant model, $F(5, 102) = 8.94$, $p < .001$. This model explained 27% of the variance in checking symptoms (Adjusted $R^2 = .27$). Table 4 reveals that a higher number of familiarity responses, ($p = .01$) inhibition ($p = .04$) and perceived responsibility ($p < .001$) were all independent predictors of checking symptoms. Those with low numbers of familiarity responses did not differ from those with a medium number of familiarity responses in regard to checking symptoms. Exploratory analyses revealed that when confidence was entered alone it was a significant predictor of checking symptoms, F(1,

106) = 8.38, p = .005, Adjusted R^2 = .07, Beta = .27, however, it no longer accounted for any unique variance when the other variables were entered into the model suggesting potential suppressor effects.

"Insert Table 4 about here"

3.4 Mediation analysis

The Preacher and Hayes (2008) bootstrapping procedure showed that high familiarity responses did not mediate the relationship between inhibition and checking symptoms as evidenced by non-significant indirect effects (see Table 5).

"Insert Table 5 about here"

Discussion

In the current study, checking symptom severity was predicted by greater familiarity based responding. Previous reports of familiarity biases in checkers are supported (Coles et al., 2006; Radomsky et al., 2006; van den Hout & Kindt, 2003a, 2003b, 2004). Specifically, greater familiarity responses on the episodic memory task predicted higher checking symptoms than medium or low numbers of familiarity responses. Checking symptom severity was also predicted by inhibitory functioning. Slower reaction times, reflecting poorer inhibitory control on the inhibition task, predicted higher checking symptoms. Importantly, familiarity responses did not mediate the relationship between inhibition and checking symptoms. This suggests that each of these variables contribute independently to checking symptoms.

High perceived responsibility attitudes predicted checking severity. Confidence was a predictor of checking symptoms when examined alone, but was no longer a predictor when combined with other variables. General confidence in memory may,

therefore, not be an independent predictor of checking symptoms. No correlations were shown between familiarity responses, inhibition or perceived responsibility. The greatest predictor of checking symptoms (as assessed by the standardised beta and R^2 change) was perceived responsibility, suggesting that responsibility provides a greater contribution to checking symptoms than familiarity (as evidenced by greater Know responses) or inhibitory functioning. Familiarity provided the next greatest contribution to checking symptoms followed by inhibitory functioning. To our knowledge, this is the first study that has examined the relationship between episodic familiarity and inhibition whilst also investigating the contribution of memory confidence and perceived responsibility.

The familiarity biases reported here are in line with previous investigations (Coles et al., 2006; Irak & Flament, 2009; Radomsky et al., 2006; van den Hout & Kindt, 2003a, 2003b, 2004) in which higher checking has been associated with more familiarity responses. The current findings expand on previous literature suggesting that familiarity biases are also evident in checkers in non-threat relevant situations. Both the current findings and previous research suggests that checkers exhibit greater familiarity responses. It appears that checking symptoms may arise, at least in part, from an over-reliance on familiarity for remembering. Klumpp et al. (2009) revealed no differences when familiarity responses were assessed using non-threatening (positive and neutral) scenarios and the current findings are not supportive of this study. The current study found greater familiarity responses when a non-threat relevant task was used. The studies varied in that the current study and those conducted by Coles et al. (2006), Radomsky et al. (2006) and van den Hout and Kindt (2003a, 2003b, 2004) investigated

recollection and familiarity using undergraduate samples, whilst Klumpp et al. (2009) used a washing sample. Familiarity biases may only extend to non-threat relevant situations in samples that include individuals with checking compulsions. Determining the role of episodic memory in different OCD sub-types is important. With previous work (Coles et al., 2006; Radomsky et al., 2006; van den Hout & Kindt, 2003a, 2003b, 2004) suggesting that checking leads to increased familiarity and the current finding suggesting that increased familiarity predicts checking symptom severity, the authors are uncertain as to the cause and effect relationship. Future studies should examine the relationship between checking and recollection using a longitudinal design.

The current study reported that SSRT, a direct objective measure of inhibitory control, predicted checking symptoms on the Y-BOCS, with poorer inhibitory control predicting higher checking symptoms. Inhibitory impairments appear to extend beyond general OCD to checking symptoms. Previous reports of impaired inhibition in circumstances where checking and/or OCD symptoms are greater are supported (Abramovitch et al., 2011; Chamberlain et al., 2006; Chamberlain et al., 2007; Linkovski et al., 2013; Menzies et al., 2007; Palmer et al, in press; Penades et al., 2007; Sottocorno et al., 2011). The current study reported similar inhibitory deficits in those with higher checking symptoms using a non-clinical sample. Inhibitory impairments may be present at a clinical (Omori et al., 2007) and non-clinical level in those with higher checking symptoms. Individuals with checking symptoms may have difficulty in inhibiting a prepotent plan and/or irrelevant information and this may trigger concerns and doubts about the behaviour not being completed and thus subsequent neutralising compulsions (e.g. checking).

The current findings suggest that episodic memory biases in familiarity are not related to inhibitory deficits. The relationship between inhibition and checking symptoms was not mediated by familiarity responses. Similarly, high familiarity responses were shown to predict higher checking symptoms even when other cognitive processes were taken into consideration. When predicting checking symptoms, inhibitory functioning was not reliant on familiarity responses. As far as we are aware, this is the first study to address the relationship between episodic memory, specifically familiarity and inhibition in OCD. The current finding is contrary to previous work providing support for a relationship between episodic memory and inhibition in non-OCD samples (El Haj & Allain, 2012; Lövdén, 2003). It is difficult to compare results between these different samples (OCD and non-OCD). The current finding is also contrary to what was expected based on reports and evidence that memory performance may be secondary to executive function impairments (Omori et al., 2007; Savage et al., 1999). Important to note is that the relationship shown by Omori et al. (2007) was between general memory and inhibitory functioning, thus the current findings suggest that this relationship does not extend to other aspects of memory.

On further examination of the literature pertaining to episodic memory and inhibition many researchers discuss the mediating effect of organisational strategies when examining the relationship between memory and OCD. Organisational strategies are thought to primarily require executive functions. In light of the current findings and previous research, a wider assessment battery may be useful. The SST used in the current study allowed the authors to look at behavioural inhibition, but a battery that also assessed organisational strategies would be beneficial.

It is noteworthy that when general memory confidence was examined alone, reduced confidence in memory predicted higher checking symptoms. Confidence was no longer a predictor when combined with other variables, suggesting that it is not an independent predictor of checking symptoms. The former is in line with previous work which has shown a relationship between checking severity and confidence in memory (Boschen & Vuksanovic, 2007; Coles et al., 2006; Cougle et al., 2007; Jennings et al., 2011; Nedeljkovic & Kyrios, 2007; Radomsky & Alcolado, 2010; Radomsky et al., 2006; van den Hout & Kindt, 2003a, 2003b, 2004). The latter finding, however, suggests potential suppressor effects. The current study examined memory confidence using MACCS, a self-report measure of general memory confidence. In order to further understand the current findings, future work may wish to examine an integrated model of checking using an objective measure of memory confidence, whilst also considering other variables thought to contribute to checking symptoms (e.g. memory deficits, inhibition and perceived responsibility).

Perceived responsibility was a predictor of checking symptoms in the present study. This finding is supportive of the cognitive model proposed by Rachman (2002) and supports previous research that has reported a relationship between perceived responsibility and checking (Arntz et al., 2007; Boschen & Vuksanovic, 2007; Coles et al., 2006; Foa et al., 2002; Lopatka & Rachman, 1995; Mancini et al., 2001; Smari et al., 2003; van den Hout & Kindt, 2004). In addition, perceived responsibility was shown to be an independent predictor of checking symptoms indicating that perceived responsibility is not related to memory biases or inhibitory control, but does add to the variance shown in checking symptoms. Importantly these findings may help researchers

to further understand the relative contribution of both memory confidence and perceived responsibility whilst examining memory and inhibitory function in checkers. Developing our understanding of the most important variables that contribute to and maintain checking symptoms and the relationship between them is important. This may lead to a suggestion of an integrated cognitive model, whereby several different variables are reported to account for checking symptom severity (Cuttler & Taylor, 2012).

Overall the data reveal that episodic memory biases in familiarity predict checking symptoms beyond threat relevant situations. Inhibition also predicted checking symptoms. Notably, the findings suggest that there is no relationship between familiarity responses and inhibition. Furthermore, perceived responsibility accounted for some of the remaining variance shown in checking symptoms. A clearer understanding of the range of impairments and relationship between them in participants with checking symptoms can help us to improve the everyday functioning of individuals clinically diagnosed with the disorder. Identifying the difficulties that lead to the engagement of compulsive behaviours can contribute to therapeutic approaches aimed at reducing the behaviours.

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Table 1

Range of OCD severity and checking symptoms based on Y-BOCS

	Group/Score	Percent of sample % (N = 108)
Y-BOCS:		
Range of OCD severity	Subclinical (0-7)	49%
	Mild (8-15)	38%
	Moderate (16-23)	10.2%
	Severe (24-32)	2.8%
	Extreme (32-40)	0%
Y-BOCS:		
Range of checking symptoms	0	27.8%
	1	31.5%
	2	19.4%
	3	11.1%
	4	7.4%
	5	2.8%

Table 2

Means and standard deviations for key variables

		Mean (SD)
1. Checking Total		1.49 (1.41)
2. Familiarity:	Low	1.16 (1.17)
	Medium	7.41 (2.55)
	High	21.84 (9.73)
4. Inhibition: SST		169.83 (45.31)
5. Confidence: MACCS		38.59 (11.64)
6. Responsibility: RAS		103.48 (23.92)
7. Depression		5.68 (7.43)
8. Anxiety		5.85 (6.23)

Note: SST: Stop-Signal Task; MACCS: Memory and Cognitive Confidence Scale; RAS: Responsibility Attitudes Scale.

Table 3

Correlations among variables

	2.	3.	4.	5.
1. Checking Total	0.06	0.20*	0.27**	0.46***
2. Familiarity		-0.15+	0.03	-0.09
3. Inhibition: SST			0.10	0.05
4. Confidence: MACCS				0.40***
5. Responsibility: RAS				

*Note: *p <.05, **p<.01, ***p<.001, + p=.06; SST: Stop-Signal Task; MACCS: Memory and Cognitive Confidence Scale; RAS: Responsibility Attitudes Scale*

Table 4

Standardised regression coefficients predicting OCD symptoms

Predictors	Checking as criterion					
	Beta	95% CI		*SE* B	Standardised	R^2
		Lower Bound	Upper Bound		Beta (β)	Change
Constant	-2.75	-4.14	-1.38	0.70		
Confidence	0.01	-0.01	0.03	0.01	0.09	0.07
Responsibility	0.03	0.01	0.04	0.01	0.42***	0.15
Inhibition	0.01	0.00	0.01	0.00	0.17*	0.03
High Familiarity	0.82	0.24	1.39	0.29	0.26**	0.05
Low Familiarity	0.35	-0.21	0.90	0.28	0.12	0.01

Note: *$p < .05$, **$p < .01$, ***$p < .001$; Reference group for know dummy variables was medium group

Table 5

Mediation analysis with checking as the DV, inhibition as the IV and familiarity (high) as the mediator

Path estimated	Effect	Beta	SE	95% Confidence intervals
Checking	Total effect	0.0062	0.0030	0.0003 to 0.0121 *
	Indirect effect	-0.0005	0.0006	-0.0017 to 0.0007
	Direct effect	0.0067	0.0029	0.001 to 0.0124 *

Note: * $p < .05$

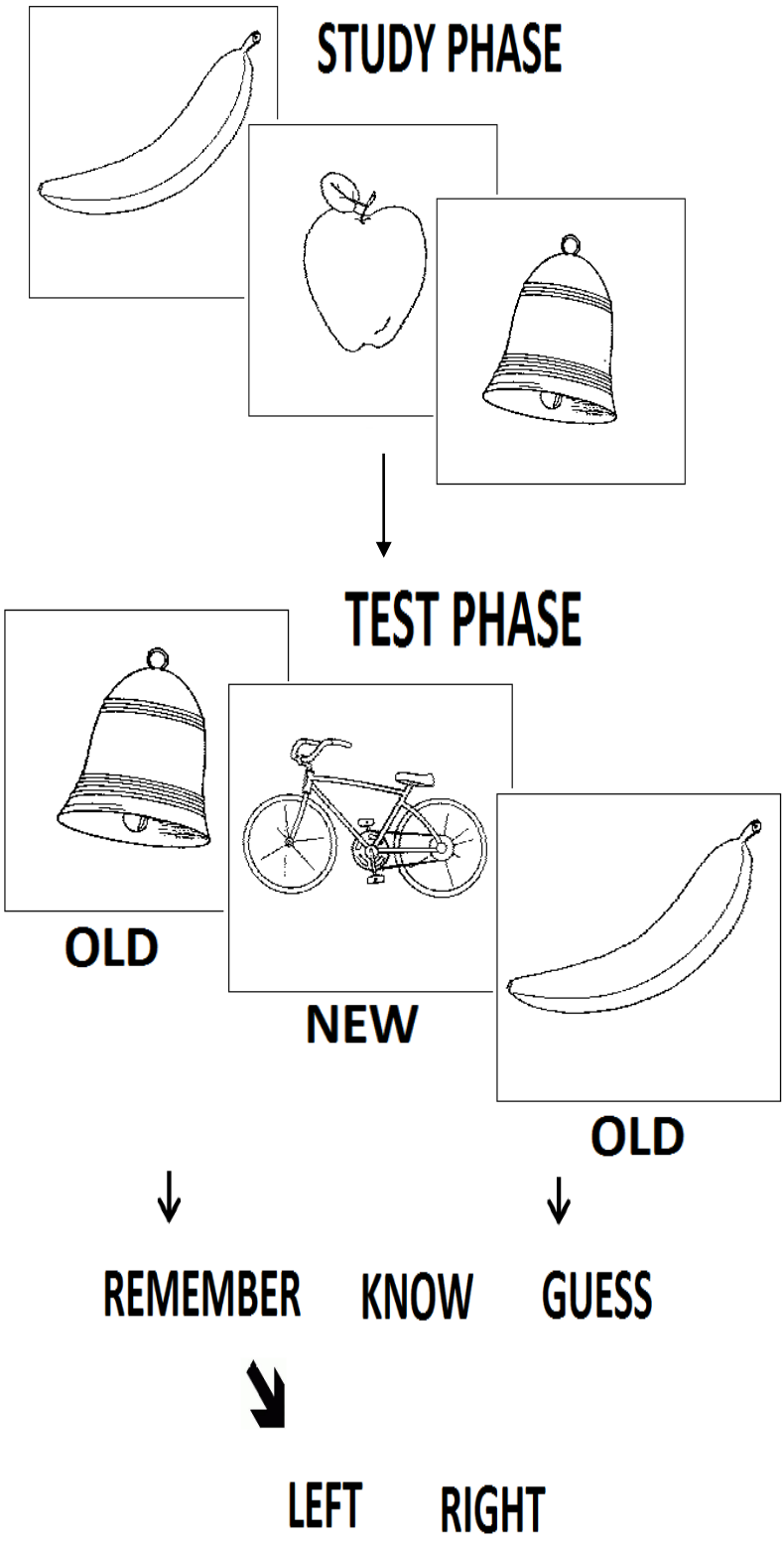

Figure 1. Remember/Know task procedure

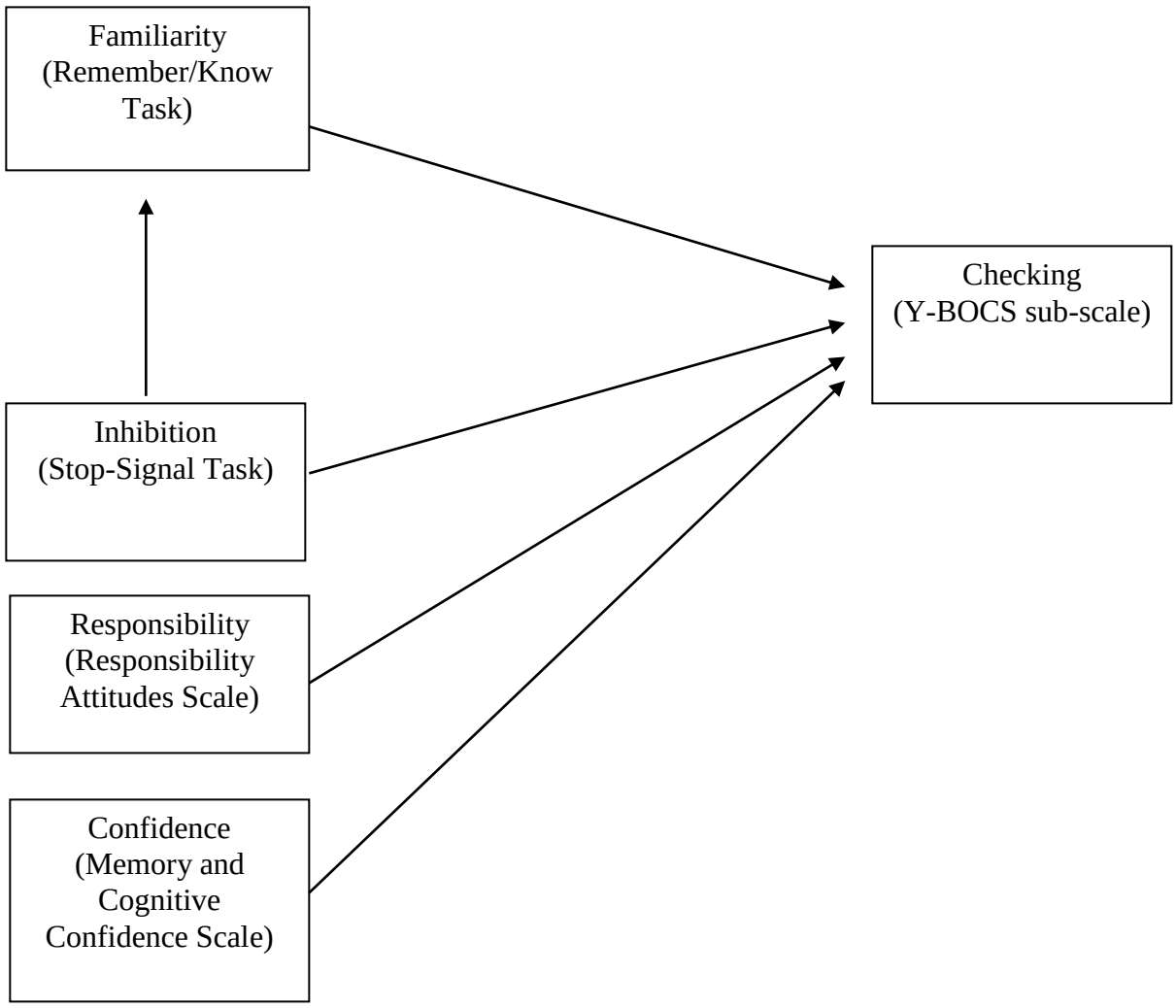

Figure 2. A model of tested pathways

Chapter 6

Obsessive Compulsive Disorder and inhibitory impairment: The role of anxiety and compulsions

This chapter is presented in the format of a manuscript

Abstract

It is unclear whether inhibitory deficits are solely related to OCD symptoms or arise more generally from the presence of anxiety. In experiment I, 14 OCD participants, 11 anxiety controls and 15 healthy controls completed the Stop Signal Task. Inhibition was poorer in OCD and anxiety groups compared to healthy controls. Performance did not differ between the OCD and anxiety group. Inhibitory impairments therefore, may not be solely related to the presence of OCD symptoms. It is also unclear whether inhibitory control impairments are specific to obsessions and/or compulsions. Experiment II examined this in 294 adults. Anxiety, but not inhibition, was an independent predictor of obsessive symptoms. Inhibition and anxiety were independent predictors of compulsive symptoms. The results demonstrate that inhibition may independently contribute to compulsions but not obsessions. Findings from both of these experiments emphasise the role of anxiety and inhibition in relation to compulsive symptoms in OCD.

Keywords: Obsessive Compulsive Disorder; inhibition; anxiety; obsessions; compulsions

Obsessive Compulsive Disorder and inhibitory impairment: The role of anxiety and compulsions

Obsessive and compulsive symptoms are intrusive recurrent impulses, reflecting and exacerbating high levels of anxiety. Obsessive Compulsive Disorder (OCD) was classified as an anxiety disorder in the Diagnostic and Statistical Manual of Mental Disorders up to this point, (4th ed., text rev.; DSM-IV; American Psychiatric Association, 2000) but has now been classified under obsessive compulsive and related disorders in the recently published Diagnostic and Statistical Manual of Mental Disorders (5th ed., DSM-5; American Psychiatric Association, 2013). Despite this change on a diagnostic level, OCD is known to be highly comorbid with anxiety disorders (Ruscio, Stein, Chiu, & Kessler, 2010). Comorbidity results in challenges when uncovering the etiology of OCD. Several researchers have now documented impaired functioning in individuals with OCD across a range of cognitive processes including memory and executive functions (for reviews see; Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005; Cuttler & Graf, 2009; Greisberg & McKay, 2003; Kuelz, Hohagen, & Voderholzer, 2004; Müller & Roberts, 2005; Olley, Malhi, & Sachdev, 2007; Tallis, 1997; Woods, Vevea, Chambless, & Bayen, 2002). The role of comorbid symptoms such as anxiety, which may also be associated with cognitive impairment, makes characterisation of such impairments difficult.

The role of executive functions in relation to the repetitive nature of OCD symptoms has been a particular focus of recent research. Executive function is an umbrella term used in the literature to refer to higher order strategic processes known to be critical in the control of behaviour. Consistent performance deficits in OCD samples

have been reported in executive function tasks, in particular for inhibitory control (Abramovitch, Dar, Schweiger, & Hermesh, 2011; Menzies et al., 2007; Morein-Zamir, Fineberg, Robbins, & Sahakian, 2010), the ability to suppress interfering or irrelevant information. As individuals with OCD have difficulty in selectively controlling unwanted or irrelevant intrusive thoughts, it seems plausible that these thoughts might trigger subsequent neutralising compulsions (e.g. repeatedly checking that a door is locked). Similarly, if individuals have difficulty in inhibiting a pre-potent plan (e.g. I must ensure cooker is turned off) and/or inhibiting irrelevant information, then despite having completed the action, these distracting cognitions could prompt checking behaviours. Poor inhibitory control may, consequently, contribute to obsessions and/or compulsions experienced by those with OCD.

Individuals with OCD often have high rates of comorbid anxiety (Ruscio et al., 2010). Researchers report that there are inhibitory impairments in those with OCD and these deficits may maintain symptoms (Abramovitch et al., 2011; Aycicegi, Dinn, Harris, & Erkmen, 2003; Bannon, Gonsalvez, Croft, & Boyce, 2002; Bohne, Keuthen, Tuschen-Caffier, & Wilhelm, 2005; Chamberlain, Fineberg, Blackwell, Robbins, & Sahakian, 2006; Chamberlain et al., 2007; Konishi, Shishikura, Shutaro, Shin-ichi, & Masaru, 2011; Page et al., 2009; Penades et al., 2007; Sottocorno, Martoni, Galimberti, Fadda, & Bellodi, 2011). Determining whether executive function impairments are solely related to OCD symptoms or if they are more generally associated with high levels of anxiety is important (Bannon, Gonsalvez, & Croft, 2008). A small number of OCD studies have assessed inhibitory control with the inclusion of specific anxiety control groups (e.g. individuals with social phobia, panic disorder). Bannon et al. (2002)

assessed the inhibitory performance of a clinical OCD group, panic disorder group and healthy controls using Go/No-go and Stroop tasks. OCD participants showed inhibition impairments on both tasks when compared to individuals with panic disorder. A very similar study using a novel inhibition task reported that the OCD group displayed less inhibitory control in comparison to the panic disorder group and control group (Bannon et al., 2008). Examination of the mean scores on the inhibition task suggests that the anxiety group were less successful in inhibiting responses compared to the control group for threat words. Nonetheless, this difference was not compared statistically. Inhibitory control has been compared between individuals with OCD (checkers and washers), individuals with social phobia and non-anxious controls using the Hayling task (Van der Linden, Ceschi, Zermatten, Dunker, & Perroud, 2005). The authors reported that washers and checkers performance was poorer than individuals with social phobia and controls. Inhibitory performance for individuals with social phobia did not differ from non-anxious controls (Van der Linden et al). These findings collectively suggest that inhibitory differences may solely be related to OCD and do not arise more generally from the presence of anxiety symptoms. Studies in this area are highly limited in number, making definitive conclusions problematic.

A small number of studies have been conducted comparing OCD groups with specific anxiety groups (e.g., social phobia). Focus will now move to studies that have compared inhibitory performance between OCD groups and clinical groups that include a specific anxiety component to the disorder (for example; trichotillomania). Examination of their findings may facilitate evaluation of the specificity of inhibition to OCD symptoms. Performance on the Stop Signal Task (SST) (Chamberlain et al., 2006)

and a direct forgetting paradigm (Bohne et al., 2005) was compared between participants with OCD, those with trichotillomania and healthy controls. Trichotillomania involves repetitive hair pulling. Chamberlain et al. reported inhibitory impairments in response inhibition for both OCD and trichotillomania groups compared to healthy controls. Individuals with trichotillomania had slower reaction times on the SST, reflecting poorer inhibitory control than those with OCD. Bohne et al concluded that OCD participants were impaired in the intentional inhibition of negative words and inhibition deficits were specific to the OCD group. With a small sample in each of the groups, replication with larger numbers would be useful. Nevertheless, results reported by Chamberlain et al. raise the possibility that inhibitory deficits may relate more generally to the presence of anxiety symptoms.

The discrepancy in findings in the anxiety groups between these two studies may reflect task differences. The direct forgetting task used by Bohne et al. (2005) measured cognitive inhibition as opposed to response inhibition measured by Chamberlain et al. (2006). The findings may also relate to the specific clinical symptoms of the disorders examined. Trichotillomania is likely associated with uncontrollable impulses (repetitive hair pulling), possibly reflecting motor inhibition deficits. On the other hand, OCD involves repetitive obsessive thoughts and compulsive behaviours which may reflect both cognitive and motor inhibition impairments. The contradictory findings may be a result of group differences. Some of the OCD and trichotillomania participants recruited by Bohne et al were reported to have comorbidities (for example; social phobia, body dysmorphic disorder, generalised anxiety disorder) and were taking medication. In comparison, Chamberlain et al. excluded participants with comorbidities, some

participants in the OCD group were medicated, but the trichotillomania group had been un-medicated for at least six months prior to testing. Inhibitory performance has been compared between participants with OCD, participants with anorexia nervosa and healthy control participants (Sottocorno et al., 2011). Low inhibitory control on the SST was reported for both an OCD group and anorexia nervosa group when compared to a healthy control group.

While limited, there is some suggestion that inhibitory deficits may not be specific to OCD symptoms. The comparison of inhibitory performance between OCD groups and clinical groups with a specific anxiety component but not categorised as an anxiety disorder makes it difficult to determine whether inhibitory impairments are solely related to OCD or if they arise more generally from the presence of anxiety symptoms. A key aim of the first experiment in this paper is to investigate whether inhibitory impairments in individuals with OCD are solely related to OCD symptoms, or if they are more generally a feature of high anxiety symptoms known to be comorbid with OCD.

Support for inhibitory dysfunction in individuals with OCD has been shown when using a variety of different tasks. An approach which has clear advantages in the objective assessment of executive function deficits concerns the use of computerised assessment batteries. One of the most widely used batteries is the Cambridge Neuropsychological Test Automated Battery (CANTAB, Fray, Robbins, & Sahakian, 1996). The CANTAB has been validated in a variety of clinical populations (Fried., Hirshfeld-Becker., Petty., Batchelder., & Biederman., 2012; Levaux et al., 2007; Luciana, 2003; Rhodes, Riby, Park, Fraser, & Campbell, 2010), allowing for quick and

efficient measurement of cognitive functioning and objective testing. Despite this, relatively few studies have employed the CANTAB SST to investigate response inhibition in OCD (Chamberlain et al., 2006; Chamberlain et al., 2007; Chamberlain & Menzies, 2012; Menzies et al., 2007; Sottocorno et al., 2011).

Studies that have used the CANTAB in OCD samples have compared inhibitory function between those with OCD and a number of different types of clinical control groups (Chamberlain et al., 2006; Sottocorno et al., 2011) and healthy controls group (Chamberlain et al., 2007; Menzies et al., 2007; Sottocorno et al., 2011). Chamberlain et al. (2006) reported inhibitory impairments in a group of individuals with clinical OCD and a group of individuals with trichotillomania when compared to healthy comparisons using the SST. Both Chamberlain et al. (2007) and Menzies et al. used the SST to compare inhibitory performance between participants with OCD (washers and checkers), unaffected first-degree relatives of OCD participants and a group of healthy controls. The OCD groups and unaffected relatives had poorer inhibitory control in comparison to the healthy controls. In a more recent study using the SST it was reported that participants with OCD and anorexia nervosa were impaired in inhibitory performance when compared to healthy controls (Sottocorno et al.). Evidence for inhibitory deficits on the SST have been reported in a healthy adult sample where the relationship between inhibitory control and checking was investigated (Linkovski, Kalanthroff, Henik, & Anholt, 2013). Findings indicated that participants with less inhibitory control, reported greater levels of memory distrust and uncertainty as a result of repeating checking. Several researchers have provided support for inhibitory impairments in OCD using the SST, and in control groups. With support for inhibitory

impairments using the SST, experiment I will employ this measure. Evidence is still mixed with regards to whether inhibitory impairments are related to OCD symptoms or if they are more generally associated with anxiety symptoms. This will be examined in experiment I.

Evidence for behavioural inhibition deficits in OCD when using the SST in both clinical and non-clinical samples is convincing. The current study will employ the SST to investigate behavioural inhibition. Deriving a specific hypothesis as to whether inhibitory deficits in those with OCD are related solely to OCD symptoms, or if they arise more generally from the presence of anxiety symptoms, is difficult due to the limited and contradictory literature. The current study will examine and compare inhibitory performance between an OCD group, an anxiety group and a healthy control group in order to assess whether there are performance differences.

Experiment I

Method

Participants and Design

A total sample of 299 participants were recruited. The participants were selected to form three different groups based on a previous diagnosis of OCD (Y-BOCS) and anxiety (anxiety sub-scale from the Depression, Anxiety and Stress Scale - DASS) cut-off scores (see Table 1 for these cut-off scores). Group 1 (N = 14), "OCD group", were recruited by advertisements from within local OCD support groups and within University settings and were selected on the basis of a previous diagnosis of OCD by an adult mental health service. As an independent check on symptom severity, participants completed a self-report form of the Y-BOCS (Steketee, Frost, & Bogart, 1996). This showed that one

participant from this group was classed as having extreme severity on the Y-BOCS, 8 were classed as severe severity, 4 were classed as moderate severity and one was classed as having mild severity according to the Y-BOCS sub-scale. Group 2 was an "anxiety control" group and group 3 was a "healthy control" group. Participants assigned to the anxiety group and healthy control group were recruited from a University setting and were chosen based on cut-off scores as measured using the Y-BOCS and anxiety sub-scale from the DASS. Participants in the anxiety group (N = 11) scored low on the Y-BOCS (all scored <7 – classed as sub-clinical on Y-BOCS) and scored as moderate to extremely severe on the anxiety sub-scale of the DASS. All participants in the healthy control group (N = 15) scored 0 on the Y-BOCS, and between 0-1 on the anxiety sub-scale from the DASS.

The assumption of homogeneity of variance was violated when comparing anxiety symptoms between groups, as a result Welch F is reported. There was a significant effect of group on anxiety symptoms, $F(2, 15.29), = 80.71$, $p < .000$. Post-hoc tests revealed that there was a significant difference in anxiety symptoms between the OCD group and healthy control group, $p < .001$ and between anxiety controls and healthy controls, $p < .001$. There was no significant difference in anxiety symptoms between the OCD group and anxiety control group. There was also a significant effect of group on OCD symptoms, $F(2,37) = 131.82$, $p < .001$. Post-hoc tests revealed that there was a significant difference in OCD symptoms between the OCD group and healthy control group, $p < .001$ and between the OCD group and anxiety control group, $p < .001$. There was no significant difference in OCD symptoms between the healthy control group and anxiety control group.

The current data were collected with the approval of the appropriate departmental and University ethics committee and participants received either course credits or money in return for their participation (see Table 1 for descriptive statistics).

("Table 1 about here")

Procedure

Before taking part, participants provided informed written consent. All participants completed the Y-BOCS and DASS questionnaires. The SST taken from the CANTAB (www.camcog.com, Morris et al., 1987) was then presented on a high resolution colour monitor, with a button box to record participants' responses. Completing these components required approximately 30 minutes. Upon completing the SST task participants were given a debrief form explaining the purpose of the study.

Measures

The Yale-Brown Obsessive Compulsive scale

The Yale-Brown Obsessive Compulsive Scale (Y-BOCS) (Goodman, Price, Rasmussen, Mazure, Delgado, et al., 1989; Goodman, Price, Rasmussen, Mazure, Fleischmann, et al., 1989) is an extensively used semi-structured measure which assesses the severity of obsessions and compulsions over one week. The first part of the scale contains a checklist of 55 symptoms evaluating the presence (yes/no) of current and past symptoms (e.g. "checking locks, cooker appliances, water faucets, emergency brake", "repeating of rewriting"). This determines the types of obsessions and/or compulsions experienced. Following this, 10 items are used to assess the severity of these obsessions and compulsions (e.g. "time spent on obsessions": Obsession Total, "control over compulsions": Compulsion Total) equating to a total OCD severity score (Total Y-

BOCS). Total severity score ranged from 0-40 with higher scores representing greater OCD symptom severity. In the present administration (experiment I), good internal reliability was shown for Total Y-BOCS with a Cronbach's alpha score of 0.99. Each sub-scale was also highly reliable (Cronbach's alpha scores: Obsessions = 0.97, Compulsions = 0.98).

Depression anxiety stress scale

The Depression and Anxiety Stress Scale (DASS) is a set of three self-report scales designed to measure the negative emotional states of depression, anxiety and stress (Lovibond & Lovibond, 1995). Each scale contains fourteen items. Participants were asked to use a four point likert scale to rate the extent to which they had experienced each state over the last week. A score for depression, anxiety and stress was then obtained by summing the scores for all of the relevant items. The anxiety scale was used in the current study and related very specifically to physical and mental states associated with anxiety (e.g. "I was aware of dryness in my mouth", "I had a feeling of shakiness", "I perspired noticeably in the absence of high temperatures or physical exertion", "I was worried about situations in which I might panic and make a fool of myself"). The anxiety scale assesses autonomic arousal, skeletal muscle effects, situational anxiety, and the subjective experiences of anxious effect. The characteristics of individuals who score high on the anxiety sub-scale of the DASS are apprehensiveness and panicky, trembly and shaky, aware of dryness of the mouth, have breathing difficulties, pounding of the heart and sweatiness of the hands and are worried about performance and potential loss of control (Lovibond & Lovibond, 1995). Scores on this scale ranged from 0-42, with higher scores showing greater anxiety. The DASS-42 was shown to exhibit

high internal consistency with Cronbach's alpha scores of 0.97 overall and 0.88 for the anxiety sub-scale.

Inhibition

The Stop Signal Task (SST) taken from the CANTAB provides an assessment of response inhibition and has been used to investigating inhibitory performance in participants with OCD (Chamberlain et al., 2006; Chamberlain et al., 2007; Menzies et al., 2007; Sottocorno et al., 2011). The test consists of two parts and gives a measure of an individual's ability to inhibit a pre-potent response. In the first part, which involves training, participants were told to press the left hand button when they saw a left-pointing arrow and the right hand button when they saw a right-pointing arrow. In the second part, participants were told to continue pressing the buttons on the press pad when they saw the arrows as before but, if they heard an auditory signal (a beep), they should withhold their response and not press the button. The stop signal paradigm allows a sensitive estimate of inhibitory control. The key outcome measure was stop signal reaction time ("SSRT") an estimate of the length of time between the go stimulus and the stop stimulus at which the participant was able to successfully inhibit their response in the last half of the task (last 50% of trials – the processing time required to inhibit a pre-potent response). Greater response times on this measure indicated less inhibitory control. Three further measures were "go responses", the mean reaction time taken in milliseconds to press the key pad when no auditory signal was presented, "Direction Errors" which measured the number of errors pressing the wrong button in the stop and go trials and "Successful Stops" measuring the number of times the participants were able to stop their automatic response when the auditory signal was presented.

Statistical Analyses

A one-way ANOVA was conducted to compare group performance on the SST. Planned comparisons were then performed. The first planned comparison compared healthy controls with OCD and anxiety groups. The second planned comparison compared the OCD group to the anxiety control group. Inhibitory data were skewed across the four measures; hence, all scores were log transformed to reduce skewness. Following transformation there were no differences between analyses, thus non-transformed data are reported.

Results

A one-way ANOVA on SSRT scores, with group as the between-subjects factor, was significant, $F(2, 37) = 3.57$, $p = .04$. There was a significant linear trend, $F(1, 37) = 7.09$, $p = .01$, ɯ = .32 when comparing SSRT performance between groups. Planned contrasts revealed that individuals in the OCD group and anxiety group had significantly higher SSRT scores, indicating poorer inhibitory control when compared to controls, $t(33.45) = 2.83$, $p = .008$ (one-tailed), $r = .19$. SSRT scores did not differ significantly between those in the OCD group and those in the anxiety group, $t(19.83) = -0.99$, $p = .33$ (one-tailed). There was no significant main effect of groups for Go responses, Direction Errors or Successful Stops (see Table 2).

("Table 2 about here")

Discussion of Experiment I

In experiment I, inhibitory performance on the SST was compared between an OCD group, a general anxiety group and a control group. Slower reaction times were reported on the SST for both the OCD and the anxiety group when compared to the

healthy control group, indicating poorer inhibitory control in the OCD and anxiety groups. There were no differences in inhibitory control between the OCD group and anxiety control group. This raises the possibility that inhibitory dysfunction may not be solely related to OCD symptoms and may arise more generally from the presence of anxiety symptoms (see below for further discussion). This finding must be interpreted with caution due to small sample size. As with previous work that has investigated the contribution of OCD symptoms and anxiety to inhibitory performance, a specific clinical anxiety group may help to reveal any potential differences in cognitive functioning. As well as recognising what symptoms (OCD and/or anxiety) are related to inhibitory deficits, it is important to understand if inhibition impairments are specific to certain OCD behaviours (obsessions and/or compulsions); experiment II will examine this.

Experiment II

Introduction

OCD is a heterogeneous condition with multiple symptoms and subtypes (McKay et al., 2004). Research investigating OCD in the British national psychiatric morbidity survey in 2000, reported that 55% of the individuals in this study experienced obsessions, 11% compulsions only and 34% had both obsessions and compulsions (Torres et al., 2006). Based on such data, it would seem appropriate to investigate cognitive functioning across different symptoms and subtypes. Most researchers who have used the SST (Chamberlain et al., 2006; Chamberlain et al., 2007; Menzies et al., 2007) Go/No-go and Stroop tasks (Bannon, Gonsalvez, Croft, & Boyce, 2006; Page et al., 2009; Penades et al., 2007; Woolley et al., 2008) have investigated inhibition in relation to overall OCD symptoms. Based on symptom presentation it is possible that

individuals experiencing obsessions, for example contamination obsessions, have an inability to suppress these thoughts. Similarly, if individuals find it difficult to inhibit a pre-potent plan (for example making sure a door is locked) then despite having undertaken the relevant action, this cognition could re-occur and prompt compulsive checking.

Some research suggests that individuals with compulsions may experience greater inhibitory dysfunction than those with obsessions. One study that attempted to assess the relationship between OCD behaviours and inhibitory control was conducted by Van der Linden et al. (2005). Here response inhibition performance on the Hayling task was compared between an OCD group with compulsive washing symptoms, an OCD group with compulsive checking symptoms, a group of individuals with social phobia and a group of non-anxious controls. The Hayling task requires individuals to firstly complete sentences and secondly to complete sentences using non-sense words, inhibiting sensible responses. Response inhibition was poorer in individuals with compulsive symptoms (washers and checkers). Furthermore, correlational analyses revealed that the number of errors made was related to OCD and compulsive symptoms, but not with obsessive symptoms. Correlations from this study suggest that inhibitory deficits are related to compulsive rather than to obsessive behaviours. Individuals may be unable to inhibit a pre-potent response and experience repetitive compulsive behaviours. Chamberlain et al. (2007) conducted a very similar experiment comparing inhibitory performance of washers and checkers with unaffected first degree relatives of OCD patients and healthy controls using the SST. Post-hoc analyses revealed that OCD patients and their relatives showed motor impairment compared to healthy controls.

Contrary to Van der Linden et al. no correlations were shown between clinical symptoms (obsessions/compulsions) and inhibitory performance. It is important to note that the OCD participants in both of these studies were recruited on the basis of having predominant washing/checking behaviours. Findings from these studies suggest that inhibitory dysfunction may be related to compulsive symptoms, yet the sample types may have biased these findings.

A small number of studies have investigated whether inhibitory impairments are related to obsessive and compulsive behaviours. Morein-Zamir et al. (2010) investigated inhibition of thoughts and actions in non-depressed OCD patients, depressed OCD patients and healthy controls. The thought stop signal task (TSST) was used to assess inhibitory control of actions and thoughts, and involved performing speeded word judgments (OCD relevant and neutral stimuli were presented) whilst occasionally being asked to stop. The authors reported that inhibitory performance on the stop signal part of the task was impaired in OCD participants when compared to controls irrespective of stimuli type. OCD participants' ability to inhibit thought processes, as measured using repetition priming was shown to be intact. Morein-Zamir et al. concluded that inhibitory impairments for actions were evident in OCD participants with and without depression but that inhibition of thought was intact.

A further study investigated inhibitory function across sub-types (Coles, Schofield, & Pietrefesa, 2006) in a non-clinical sample. To examine whether behavioural inhibition was more strongly related to particular OCD symptoms, Coles et al. conducted correlations between different OCD sub-types and performance on the retrospective self-report of inhibition (RSRI) in an undergraduate sample. Correlations

were shown between inhibitory scores and OCD symptoms of checking, doubt, obsessing, hoarding and neutralizing. Findings from this study contradict those presented by Morein-Zamir et al. (2010) and suggest that behavioural inhibition may be related to both obsessions and compulsions. To our knowledge, this is the first study to suggest that both obsessions and compulsions may be related to inhibitory deficits. The findings are tentative and with limited research examining the relationship between obsessions and inhibition and compulsions and inhibition, further work is necessary. The use of a self-report questionnaire to measure behavioural inhibition needs verification from a study with an objective measure of inhibition. Experiment II aims to further investigate the role of inhibitory performance in obsessive and compulsive behaviours using the CANTAB SST. Anxiety symptoms will be taken into account based on findings presented in experiment I.

Method

Participants and Design

In total there were 299 participants recruited. The sample had a mean age of 25.01 (SD = 7.93) years. Fourteen individuals in this sample were recruited on the basis of a previous diagnosis of OCD within an adult mental health service (see experiment I). All other participants were recruited within a University setting. The Y-BOCS, described in the measures section, was used in the present study to assess individuals obsessions, compulsions and symptom severity (see Table 3 for the range of OCD severity).

The current study was approved by the appropriate departmental ethics committee and participants received either course credits or money in return for their participation.

("Table 3 about here")

Procedure and Measures

As with experiment I, all participants in experiment II completed the Y-BOCS and SST. See Measures section in experiment I. The Y-BOCS has been deemed appropriate for use in clinical and non-clinical populations (Frost, Steketee, Krause, & Trepanier, 1995).

Statistical Analyses

Prior to carrying out statistical analyses, the data were screened to determine whether statistical assumptions were met (Field, 2009; Tabachnick & Fidell, 2007). Three outliers with a standard residual above the critical value +/- 3.29 were removed, leaving 296 participants in the data set. Means and standard deviations of experimental measures and Pearson correlations between measures are provided (see Table 4). A linear regression analysis was conducted to examine whether inhibitory impairments and anxiety symptoms predicted obsession severity. A second linear regression analysis was conducted to examine whether inhibitory impairments and anxiety symptoms predicted compulsion severity. Assumptions of linearity, normality and homogeneity of variance were met when residual scatter-plots were examined with obsessions and compulsions as the dependent variables.

Results

Correlational Analyses

Pearson's correlations revealed a significant correlation between obsession total and SSRT, higher obsessive symptoms were related to greater SSRT scores. A positive relationship was shown between obsessive symptoms and anxiety symptoms. Higher obsessive symptoms were related to greater anxiety symptoms. Similarly, there was a

significant relationship between anxiety symptoms and SSRT performance scores. That is, higher anxiety symptoms were related to greater SSRT scores (slower reaction times), (See Table 4).

A significant relationship was reported between compulsion total and SSRT; higher compulsive symptoms were related to greater SSRT scores (slower reaction time). A positive relationship was shown between anxiety symptoms and compulsive symptoms. Higher anxiety symptoms were related to greater compulsive symptoms. Furthermore, there was a significant relationship between anxiety symptoms and SSRT performance. Higher anxiety symptoms were related to greater SSRT scores (See Table 4).

"Insert Table 4 about here"

Linear Regression Analyses

A multiple linear regression analysis conducted with obsessions as the dependent variable and SSRT performance and anxiety as predictors, revealed a significant model, $F(2, 291) = 31.62$, $p < .001$. This model explained 17% of the variance in obsessive symptoms (Adjusted $R^2 = .17$). Table 5 reveals that anxiety ($p < .001$) was an independent predictor of obsessive symptoms. Exploratory analyses revealed that when SSRT performance was entered alone it was a significant predictor of obsessive symptoms, $F(1, 292) = 8.357$, $p = .004$, Adjusted $R^2 = .03$, Beta = .17. SSRT no longer accounted for any unique variance when the other variables were entered into the model, suggesting potential suppressor effects.

A second multiple linear regression analysis was performed, with compulsion symptoms as the dependent variable and SSRT performance and anxiety as predictors. A significant model, F (2, 291) = 24.46, p <.001 was reported. This model explained 14% of the variance in compulsive symptoms (Adjusted R^2 = .14). Table 5 reveals that anxiety (*p* <.001) and SSRT performance (p = .03) were independent predictors of compulsions (see Table 5 for details of the final models).

("Table 5 about here")

Discussion of Experiment II

In the current study, obsession symptom severity was predicted by greater anxiety symptoms. OCD is known to be highly comorbid with anxiety symptoms and this finding is supportive of symptom presentation (Ruscio et al., 2010). Inhibition was a predictor of obsessions when examined alone, but no longer predicted obsessions when combined with anxiety. The former finding supports previous work showing a relationship between obsessions and inhibition (Coles et al., 2006). The latter finding suggests that inhibitory control is not an independent contributor to obsessive symptom severity. It may be important for researchers to take into account anxiety when examining the relationship between inhibition and obsessions.

Inhibition and anxiety were both reported to predict compulsive symptoms when examined in the same regression model. That is, greater inhibitory deficits and anxiety symptoms predicted higher compulsion severity. This finding suggests that each of these variables contribute independently to compulsions, supporting previous research showing a relationship between compulsions and inhibition (Morein-Zamir et al., 2010; Van der Linden et al., 2005). The greatest predictor of compulsive symptoms (as

assessed by the standardised beta and R^2 change) was anxiety. This suggests that anxiety provides a greater contribution to compulsive symptoms than inhibition.

Overall, the findings from experiment II suggest that inhibitory dysfunction may play an independent role in predicting compulsions when anxiety is taken into account. This did not apply to obsessions. When investigating inhibitory dysfunction, future research should make a distinction between compulsive and obsessive symptoms whilst examining the contribution of anxiety.

General Discussion

As far as the researchers are aware, experiment I is the first study to use the SST task to assess differences in inhibitory function between an OCD group, a general anxiety control group and a healthy control group. The study findings demonstrated that both the OCD group and the anxiety control group had poorer inhibitory control in comparison to the healthy control group. There were no differences in inhibitory performance between the OCD group and anxiety control group (these two groups showed no differences in anxiety symptoms but differed on OCD symptoms). These findings raise the possibility that inhibitory impairments may not be solely related to the presence of OCD symptoms, but arise more generally from the presence of anxiety symptoms.

The finding that OCD participants showed inhibitory impairments on the SST task when compared to healthy controls is supportive of previous research (Bannon et al., 2002; Chamberlain et al., 2006; Chamberlain et al., 2007; Menzies et al., 2007; Sottocorno et al., 2011). No differences were shown between groups for go responses, direction errors or successful stops on the SST. These variables are however, not direct

measures of inhibitory control and this finding supports previous work (Chamberlain et al., 2006; Menzies et al.). Greater inhibitory impairments were reported in the anxiety group when compared to the healthy control group. Although this supports figures presented by Bannon et al. (2008), this finding contradicts results reported by Van der Linden et al. (2005). Van der Linden et al. reported that there was no difference in inhibitory performance between a group of participants with social phobia and healthy controls. These differences are likely a result of group differences. Van der Linden et al. recruited a clinical anxiety group with social phobia in comparison to a general anxiety group in the current study.

The finding that there were no differences in inhibitory performance between the OCD group and general anxiety group is supportive of previous work (Chamberlain et al., 2006; Sottocorno et al., 2011). Chamberlain et al. used a trichotillomania control group and this condition has recently been included under obsessive compulsive and related disorders in DSM-5. Findings reported by Chamberlain et al. suggest that inhibitory deficits may be evident across OCD sub-types. Comparison between OCD and trichotillomania groups, however, may not allow researchers to examine whether there are differences in inhibition performance between individuals with OCD and those with anxiety symptoms. Sottocorno et al. examined inhibitory control in OCD participants and those with anorexia nervosa. Although individuals with anorexia nervosa are likely to have high rates of comorbid anxiety, it appears that comparing performance between individuals with OCD and anorexia nervosa may not allow researchers to determine if inhibitory deficits are solely related to OCD or arise from other anxiety based symptoms. We must be careful when inferring from these findings

as OCD groups were compared with groups with an anxiety component rather than specific anxiety groups (e.g. social phobia, panic disorder).

The current findings are contrary to previous work employing both OCD and specific anxiety control groups (Bannon et al., 2008; Bannon et al., 2002; Van der Linden et al., 2005). Previously, OCD groups were shown to have poorer inhibitory control when compared to a panic disorder control group (Bannon et al., 2008; Bannon et al., 2002) and a social phobic control group (Van der Linden et al.). Group differences may have contributed to these contradictory findings with previous studies using specific anxiety groups compared to a general anxiety group used in the current study. Furthermore, although participants in the anxiety group in the current study reported high levels of anxiety on the DASS-anxiety sub-scale, all participants confirmed that they did not have a clinical diagnosis. Previous work comparing inhibitory performance between OCD and anxiety groups has recruited individuals clinically diagnosed with anxiety. It is possible that anxiety levels were higher in previous work compared to the current study and explain the discrepancy in findings.

In experiment I in the current study, 299 participants' data were screened and participants were selected based on specific group cut-off points. Sample size for each individual group was small. Nevertheless, even with small numbers there was still a medium effect size for the current finding. Further research should target recruitment with specific advertisements for each group. In recruiting specifically for each group, this may help to obtain a larger, more reliable sample. In sum, the findings from experiment I suggest that inhibitory deficits may not be solely related to the presence of OCD symptoms but may occur more generally from the presence of anxiety symptoms.

Inhibitory impairments have been reported across many studies investigating OCD (Abramovitch et al., 2011; Authors, 2014; Aycicegi et al., 2003; Bannon et al., 2002; Bohne et al., 2005; Chamberlain et al., 2006; Chamberlain et al., 2007; Konishi et al., 2011; Page et al., 2009; Palmer, Durkin & Rhodes, in press; Penades et al., 2007; Sottocorno et al., 2011). As well as having an understanding of what symptoms (OCD and/or anxiety) are related to these deficits, it is important to examine whether they are specific to certain OCD behaviours (obsessions and/or compulsions). Experiment II aimed to test this. To our knowledge, this is the first study to separately examine the predictive power of inhibition in obsessions and compulsions whilst taking into account the role of anxiety.

Anxiety symptoms predicted obsessive symptoms, with higher anxiety symptoms relating to more obsessions. OCD has been reported to be highly comorbid with anxiety and this finding is supportive of symptom presentation (Ruscio et al, 2010). Importantly, inhibition scores were shown to predict obsessive symptoms when examined alone, but not when combined with anxiety symptoms. The former finding is supportive of work presented by Coles et al. (2006), where correlations were reported between inhibitory performance and obsessive symptoms. The latter finding suggests that inhibition may not be an independent predictor of obsession severity and that anxiety symptoms could be suppressing inhibition effects. When examining obsessions in OCD, the current findings suggest that it may be important to consider the contribution of both inhibition and anxiety.

Inhibition and anxiety were reported to be related to compulsions when examined in the same model. This finding suggests that both inhibition and anxiety are

independent predictors of compulsions. The relationship shown between inhibition and compulsions is in line with previous work (Van der Linden et al., 2005). Van der Linden et al. indicated that inhibitory impairments were related to compulsions. In addition, Morein-Zamir et al. (2010) reported inhibitory impairments for actions in individuals with OCD. The current findings add weight to previous work by supporting the independent role of inhibition in compulsive symptoms whilst taking into account the role of anxiety.

In the obsession model, anxiety was reported to account for 17% of the variance in obsessions. In the compulsion model, inhibition and anxiety accounted for 14% of the variance in compulsions. In the latter model, anxiety was reported to be the greatest predictor of compulsions, followed by inhibition. Researchers report that memory deficits may contribute to compulsion severity (Müller & Roberts, 2005). It could be suggested that these deficits may explain some of the unaccounted variance in obsessions and compulsions. Furthermore, previous research suggests that perceived responsibility may account for some of the unexplained variance in symptoms in studies of this nature (Arntz, Voncken, & Goosen, 2007; Authors, 2014; Cougle, Salkovskis, & Wahl, 2007; Smari, Gylfadottir, & Halldorsdottir, 2003; Snorrason, Smari, & Olafsson, 2011). In particular, Snorrason et al. (2011) reported that there was an interaction between responsibility and inhibitory performance on the SST when predicting OCD symptoms. A combination of factors may contribute to inhibition impairments in those with OCD and should be investigated in further research in this area.

Findings from experiment II add weight to previous reports that compulsions are related to inhibitory control (Morein-Zamir et al., 2010; Van der Linden et al., 2005).

Inhibitory control was measured differently in the current study and the study conducted by Morein-Zamir et al. Morein-Zamir et al. used the TTST to assess whether clinical participants were able to successfully inhibit actions and ongoing thoughts. In the current study, inhibition was measured using the SST and subjective measurements of obsessive and compulsive behaviours were taken. Both studies suggest that there is a relationship between inhibitory deficits and compulsive symptoms. The use of different methodologies but similar results strengthens the findings. In addition, the finding that inhibition was an independent predictor of compulsions when taking anxiety into account, adds support for the role of inhibitory impairments in the onset and maintenance of compulsive symptoms. The current findings indicate that further research should make a distinction between compulsive and obsessive behaviours in the investigation of inhibition whilst examining the relative contribution of anxiety symptoms.

Determination of the underlying cognitive deficits involved in clinical disorders in order for interventions to be tailored and improved is essential. If inhibitory dysfunction results from a combination of both OCD and anxiety symptoms, interventions should focus on both of these rather than OCD symptoms alone. If inhibitory dysfunction is related to compulsion but not obsession severity when taking into account anxiety symptoms, future research would benefit from examining the role of anxiety whilst focusing on symptoms separately rather than OCD as a whole.

In summary, the data reveal that inhibitory performance is impaired in those with a previous diagnosis of OCD and those with general anxiety symptoms in comparison to healthy controls. Inhibition did not appear to differ between participants previously

diagnosed with OCD and anxiety controls. Inhibition and anxiety were reported to be independent predictors of compulsion severity. Inhibition was not an independent predictor of obsession severity when the role of anxiety was examined. A clearer understanding of the relationship between symptom severity, sub-type and cognitive performance can potentially help us to improve the everyday functioning of individuals clinically diagnosed with the disorder.

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Table 1

Descriptive statistics for study measures

Group	Y-BOCS Total (Mean/SD)	Anxiety Total (Mean/SD)	DASS Total (Mean/SD)
OCD (n=14)	24.43 (6.79)	10.71 (7.47)	44.86 (24.41)
Anxiety (n=11)	3.36 (2.94)	14.36 (3.91)	43.82 (20.27)
Healthy (n=15)	0	0.27 (0.46)	2.87 (2.97)

Table 2

Mean (SD) group scores for key SST measures

Group	SSRT (Mean/SD)	Go responses (Mean/SD)	Direction Errors (Mean/SD)	Successful Stops (Mean/SD)
OCD	193.23 (57.70)	427.08 (68.42)	3.93 (4.12)	0.51 (0.04)
Anxiety	175.67 (28.46)	408.78 (83.32)	4.45 (4.34)	0.49 (0.03)
Healthy	153.17 (25.73)	415.44 (85.50)	2.67 (1.91)	0.47 (0.08)

Table 3

Range of OCD severity based on participants total Y-BOCS score (%).

Y-BOCS Score %	Subclinical (0-7)	Mild (8-15)	Moderate (16-23)	Severe (24-32)	Extreme (32-40)
Overall (N = 296)	45.61%	35.47%	14.53%	4.05%	0.34%

Note: Excluding 3 outliers (see statistical analyses section). Participants with previous diagnoses fell into the following groups: 1 = Mild, 4 = Moderate,8 = Severe and 1 = Extreme.

Table 4

Means and standard deviations and correlations among variables

Analysis	Mean (SD)	1.	2.	3.
1. Obsession Total	4.81 (3.66)		0.12*	0.42***
2. SSRT	171.63 (44.23)			0.14**
3. Anxiety				
1. Compulsion Total	4.21 (3.75)		0.17**	0.36***
2. SSRT	171.56 (44.09)			0.14**
3. Anxiety	5.22 (5.58)			

*Note: *p<.05; **p <.01; ***p<.001*

Table 5

Standardised regression coefficients predicting obsessive and compulsive symptoms

Predictors	Obsession score as criterion					
	Beta	95% CI		*SE* B	Standardised	R^2
		Lower Bound	Upper Bound		Beta (β)	Change
Constant	2.46	0.92	4.00	0.78		
SSRT	0.01	-0.00	0.01	0.00	0.07	0.02
Anxiety	0.27	0.20	0.34	0.04	0.41***	0.16
Predictors	Compulsion score as criterion					
	Beta	95% CI		*SE* B	Standardised	R^2
		Lower Bound	Upper Bound		Beta (β)	Change
Constant	1.25	-0.37	2.86	0.82		
SSRT	0.01	0.00	0.02	0.01	0.12*	0.03
Anxiety	0.23	0.16	0.30	0.04	0.34***	0.12

*Note: *p<.05; ***p* < .001.

Chapter 7

Discussion and conclusion

Cognitive-behavioural models of Obsessive Compulsive Disorder (OCD) were examined in this thesis, namely cognitive deficit models and belief and appraisal models. Cognitive deficit models of OCD suggest that deficits in memory and/or executive functioning contribute to and maintain checking symptoms. The first objective of this thesis was to examine memory deficits and executive dysfunction in relation to OCD and checking. Having examined memory and executive deficits, the second aim was to explore a model in which memory deficits are thought to be secondary to deficits in executive function. Finally belief and appraisal models of OCD were examined. Specifically, low memory confidence and heightened perceived responsibility were examined in relation to checking symptoms. The relative contribution of these variables to the OCD and checking symptom profile was examined in single studies.

It is important to improve our understanding of the underlying causes of mental health disorders. As far as the author is aware the interrelations among memory deficits, executive dysfunction, low memory confidence and heightened perceived responsibility has not been investigated together in a single study. In addition, many researchers have focused on OCD as a homogeneous disorder. OCD is comprised of many different sub-types and researchers have suggested that it may be more useful to treat OCD as a heterogeneous disorder, whereby each sub-type has different psychological impairments. The present research sought to evaluate the role of memory deficits, executive function deficits, memory confidence and perceived responsibility in checking, through a series of three studies. One further study examined the role of cognitive impairments in

obsessive and compulsive behaviours, whilst also taking in to account the role of anxiety. Each of the experimental chapters in this thesis contains a discussion (see chapters 3, 4, 5 & 6). This section will attempt to integrate these discussions. Limitations and directions for future work will also be discussed.

7.1. A summary of chapter findings

This section will briefly summarise the methodology, findings and conclusions drawn from chapters 3, 4, 5 and 6.

7.1.1. Chapter 3. Checking behaviours, prospective memory and executive functions.

The study reported in chapter 3 set out to examine whether impairments in prospective memory and executive function predicted checking behaviours in a sample of 106 adults. Furthermore, the relationship between memory and executive deficits was investigated. Checking symptoms were assessed using the Padua Inventory. The prospective memory questionnaire (PMQ) was used to assess self-reports of prospective memory. The Cambridge Neuropsychological Test Battery (CANTAB) was used to measure inhibition, planning, set-shifting and working memory. Findings showed that prospective memory and inhibition predicted checking symptom severity. Specifically, internally cued prospective memory and prospective memory aiding strategies were shown to predict checking symptoms. Importantly, there were no correlations between internally cued prospective memory and inhibition or between prospective memory aiding strategies and inhibition. These variables were shown to independently contribute to checking symptoms. Long-term episodic prospective memory was shown to predict checking symptoms when examined alone but not when combined with other variables.

This suggests that it may not be an independent predictor of checking symptoms. The findings from this study highlight the role of prospective memory and inhibition as key contributors to the checking symptom profile and support cognitive deficit models. This study is also the first to suggest that these cognitive processes may play independent roles in predicting checking symptoms. A model in which memory deficits are thought to be secondary to executive impairments is not supported. Examination of both memory deficits and executive deficits in single studies may help us better understand the development and variance shown in checking symptoms. It appears appropriate to examine memory and executive function as involving several independent processes rather than classing them as unitary processes.

7.1.2 Chapter 4. Checking behaviours, prospective memory and memory confidence.

Chapter 4 expanded on the prospective memory findings reported in chapter 3 by using a task analogous to everyday contexts. A sample of 72 adults, including those with sub-clinical checking symptoms took part. The Padua Inventory was used to assess checking symptoms. The Edinburgh Virtual Errands Task (EVET) was used which requires individuals to detect and respond to cues without any instruction. In addition, we examined confidence as a function of memory within the EVET environment. This was measured using a self report method whereby individuals were asked to rate their confidence in completed EVET tasks. Results indicated that higher checking symptoms were related to greater prospective memory errors. Participants assigned to high and medium checking groups had more prospective memory errors compared to those in a low checking group. Confidence in completed tasks did not differ between the three

checking groups, thus not providing support for low confidence in those with greater checking symptoms. These findings add weight to previous work by reporting objective prospective memory errors in individuals with greater checking symptoms using a virtual environment task. In light of the results obtained, it can be concluded that the memory deficits predicted checking symptom severity. These findings support the examination of memory as involving independent memory processes (e.g. prospective memory). The finding of no difference in confidence ratings between checking groups does not provide support for belief and appraisal accounts of checking (see chapter 4 for further discussion).

7.1.3 Chapter 5. Predicting checking symptoms: The independent contribution of familiarity, inhibition and perceived responsibility.

Chapter 5 examined the memory-deficits in the context of episodic memory recollection. 108 adults participated and checking symptoms were assessed using the checking sub-scale from the Yale Brown Obsessive Compulsive scale. A Remember/Know (R/K) paradigm was used to examine familiarity biases in checkers. Additionally, the relative contribution of inhibitory control, as measured using the Stop Signal Task (SST) was investigated. The relationship between memory and executive deficits was then studied. Furthermore, the relative contribution of memory confidence and perceived responsibility taken as part of belief and appraisal models was examined. Memory confidence was measured using the Memory and Cognitive Confidence Scale (MACCS) and perceived responsibility was measured using the Responsibility Attitudes Scale (RAS). Findings showed that familiarity, inhibition and perceived responsibility were all independent predictors of checking. Memory confidence predicted checking symptom

severity when investigated alone but not when combined with other variables, suggesting that it is not an independent predictor of checking symptoms. The relationship between inhibition and checking was not mediated by familiarity responses. Each of these cognitive variables had an independent role in predicting checking symptoms. Overall, these findings highlight the role of familiarity, inhibition and perceived responsibility in predicting checking symptom severity. They do not provide support for a model in which memory deficits are thought to be secondary to executive impairments. Cognitive deficit models in terms of memory and inhibition and the belief appraisal models relating to perceived responsibility are supported. Importantly, the findings suggest that examination of a combination of factors from different models can help to explain the onset and maintenance of checking behaviours.

7.1.4 Chapter 6. Obsessive Compulsive Disorder and inhibitory impairment: The role of anxiety and compulsions.

Chapter 6 had two main objectives. Firstly, to examine whether inhibitory impairments were related solely to OCD symptoms, or if they arise more generally from the presence of comorbid anxiety. Secondly, to investigate whether inhibitory impairments were specific to certain symptom profiles (e.g. obsessions and/or compulsions) when examining the role of anxiety. In experiment 1, 14 OCD participants, 11 anxiety controls and 15 healthy controls completed the Stop Signal Task (SST) to measure inhibition. Inhibition was reported to be poorer in the OCD group and anxiety group when compared to healthy controls. No performance differences were reported between the OCD group and the anxiety group. This suggests that inhibitory impairments may not be solely related to the presence of OCD symptoms. In experiment 2, the SST was used to

examine inhibition, anxiety symptoms were measured using the anxiety sub-scale from the Depression and Anxiety Stress Scale (DASS) and obsessions and compulsions were measured using the Yale-Brown Obsessive and Compulsive Scale (Y-BOCS). 294 adults participated. Findings from experiment 2 showed that anxiety, but not inhibition, was an independent predictor of obsessive symptoms. Furthermore, inhibition and anxiety were independent predictors of compulsive symptoms. These findings highlight the role of inhibition and anxiety in predicting compulsive symptoms. The results demonstrate that inhibition may independently contribute to compulsive but not obsessive symptoms. This builds on previous reports of inhibitory impairments in OCD, emphasising a relationship between inhibition and compulsive behaviours. Findings from experiment 1 and 2 highlight the role of anxiety and inhibition in relation to compulsive symptoms in OCD. It can be concluded that inhibitory impairments reported in OCD may arise more generally from the presence of anxiety symptoms. Additionally, inhibitory impairments appear to relate more closely to compulsive rather than obsessive symptoms, when taking anxiety into account.

7.2 Memory deficits in checking

The first objective of this thesis was to investigate memory deficits, with particular emphasis on prospective memory and episodic memory recollection. It is proposed that individuals with OCD may have memory impairments leading to difficulties in remembering whether they have completed a task (Sher, Frost, & Otto, 1983). Impairments in memory may contribute to and maintain checking symptoms. Memory deficits in checking were examined in chapters 3, 4 and 5 of the current work. Firstly, findings from chapter 3 and 4 investigating the relationship between prospective

memory and checking will be reported. Next, we will consider the findings from chapter 5 where a relationship between familiarity biases (episodic retrospective memory) and checking was examined. Previous literature will be reported and the findings from each chapter will be discussed in relation to this. This should help to inform our understanding of the role of memory deficit models in checking.

7.2.1 Do prospective memory deficits underlie checking?

Researchers have indicated that prospective memory may be closely linked to checking symptoms (Cuttler & Graf, 2007). Previously, researchers have provided evidence based on subjective measures, of prospective memory impairments in checkers (Cuttler & Graf, 2007, 2008). Individuals assigned to a high checking group reported more long-term episodic, short-term habitual and internally-cued prospective memory errors than those assigned to a medium checking group. Those reporting high checking symptoms also reported using more prospective memory aiding strategies than those in the medium checking group (Cuttler & Graf, 2007). In addition, prospective memory deficits have been reported in studies using objective event-based tasks in non-clinical (Cuttler & Graf, 2007, 2008) and clinical samples (Harris, Vaccaro, Jones, & Boots, 2010; Racsmany, Demeter, Csigo, Harsanyi, & Nemeth, 2011).

Chapter 3 examined prospective memory using a subjective measure whilst examining the contribution of other cognitive factors (see section 6.4.1 for further discussion of the relationship between prospective memory and other cognitive factors). In addition, chapter 4 investigated prospective memory using a virtual environment whilst examining confidence as a function of memory performance within that environment (see section 6.5 for further discussion of memory confidence).

A self-report measure was used in chapter 3 to examine prospective memory in checkers. The findings demonstrated that self-reports of prospective memory failures predicted checking severity. More specifically, higher internally cued prospective memory failures and higher prospective memory aiding strategies predicted higher checking symptoms. This finding supports previous work using subjective measures to examine prospective memory deficits in checkers (Cuttler & Graf, 2007, 2008). Long-term episodic prospective memory was reported to be a predictor of checking symptoms when examined alone, but it was no longer a predictor when combined with other variables, suggesting that it may not be an independent predictor of checking symptoms.

Results in chapter 3, using a subjective measure of prospective memory, did not show impairments in short-term habitual prospective memory. This is contrary to previous work (Cuttler & Graf, 2007, 2008). Differences in results could relate to the subjective nature of the questionnaires used. Subjective measures are open to response biases and some individuals may not be fully aware of their cognitive processes or symptoms. Previously, Harris et al. (2010) reported that checkers clinically diagnosed were less accurate than controls on an objective task. No differences were reported in subjective reports of prospective memory failures. The results from this study suggest that clinically diagnosed individuals may have a less accurate perception of their own prospective memory performance.

In order to avoid the issues of subjective memory biases, chapter 4 employed an objective, virtual, prospective memory task. It was expected that the use of the EVET in chapter 4 would provide a further test of prospective memory impairments under simulated natural conditions. Although laboratory tasks can provide a means of

controlling factors theorised to be influential such as self-report biases, often the experimenter determines when potential cues are encountered and when the participant is prompted to check. In spontaneous behaviour, actions and reflections in the course of ongoing events are likely to bear substantially on the manifestations of symptoms. For example, when individuals move around the home, significant objects have the potential to cue prospective memories ("I must close that window", "I have to take that package when I leave"). In the EVET, participants are responsible for exploiting available cues in the absence of extrinsic reminders or direct instructions to check, and performance in such a task is analogous to much everyday activity.

Findings from chapter 4 indicated that higher checking symptoms were related to greater prospective memory errors. Medium and high checkers had more prospective memory errors when compared to low checkers. This finding is supportive of previous work in which event-based prospective memory was investigated in clinical samples using objective tasks (Harris et al., 2010; Racsmany et al., 2011). Previous work and results reported in chapters 3 and 4 provide support for memory deficits in relation to prospective memory. Prospective memory impairments have been reported in both clinical and non-clinical samples whilst using subjective and objective tasks. The current findings extend previous work by reporting greater prospective memory impairments in those with higher checking symptoms, in a task analogous to everyday contexts. As far as the researchers are aware, this is the first study to examine prospective memory using a virtual environment task. These findings also support the concept of memory as involving several independent processes (Müller & Roberts, 2005).

7.2.2 Do episodic memory impairments underlie checking?

Proponents of dual process models argue that episodic retrieval involves two distinct processes (Yonelinas, 2002), familiarity and recollection. Episodic memory familiarity biases have been implicated in checking in a small number of previous studies (Coles, Radomsky, & Horng, 2006; Radomsky & Alcolado, 2010; van den Hout & Kindt, 2003a, 2003b, 2004). By this account, individuals who feel the need to check whether a cooker is turned off may feel a sense of familiarity with turning it off, rather than specifically recollecting that it has been turned off. Familiarity based remembering does not rely on contextual processing, merely involving a feeling that an action (or more generally an event) has been encountered before. Less detailed and vivid source memories may encourage individuals to continue checking in order to gain a more concrete memory of having completed an action.

Evidence suggests that familiarity biases may be evident in circumstances where checking is induced in OCD threat-relevant circumstances (Coles, Radomsky & Horng, 2006; Radomsky & Alcolado, 2010; van den Hout & Kindt, 2003a, 2003b, 2004). Whether these biases extend to non-threat relevant circumstances is uncertain. Irak and Flament (2009) examined attention in checkers using recall and recognition performance measures, where OCD threat-relevant and neutral stimuli were presented. Findings from this study showed that across attention tasks, recall and recognition were higher in checkers for OCD threat-relevant stimuli but lower for neutral stimuli, when compared to non-checkers. Although familiarity was not measured directly in this study, these findings suggest that with better recollection for OCD threat-relevant information, familiarity biases (thus poorer recollection) may be evident in non-threat relevant

contexts. Klumpp, Amir, and Garfinkel (2009) however, reported that OCD washers gave more familiarity responses for false memories relating to OCD threat-relevant words, but not positive or neutral words. It was suggested that OCD threat-relevant material may lead to a greater reliance on familiarity for remembering events. The difference in samples between these two studies, checker vs washers, may contribute to the contrary findings. Findings with regards to whether familiarity biases extend to non-threat relevant contexts in checking samples are inconclusive. Chapter 5, therefore, aimed to determine the role of familiarity biases in non-threat relevant contexts. Knowledge as to whether there are general familiarity biases or whether they are specific to OCD threat-relevant contexts will help researchers to further understand the role of episodic memory recollection biases in checking symptoms.

In chapter 5, a non-threat relevant R/K task was used to examine familiarity biases in checkers. Familiarity responses were shown to predict higher checking symptom severity. This supports previous studies showing familiarity biases in checkers (Coles, Radomsky, et al., 2006; Radomsky & Alcolado, 2010; van den Hout & Kindt, 2003a, 2003b, 2004). The finding also extends work reported by Irak and Flament (2009) as these researchers did not specifically measure recollection biases. The current result expands previous findings of familiarity biases in checking samples to non-threat relevant contexts. Familiarity biases have been reported across contexts (OCD threat-relevant and non-threat relevant). This has important implications for future research, as familiarity biases may be global in checkers. Researchers and/or therapists may need to concentrate on general recollection deficits. The memory deficits are supported in

relation to episodic memory recollection biases. This finding supports the investigation of the memory deficits as involving independent memory processes.

7.2.3 Memory deficit summary

Findings reported in chapters 3, 4 and 5 are supportive of the memory deficits in compulsive checking (Muller & Roberts, 2005). Prospective memory deficits and episodic memory biases were reported in the current work. A consequence of having prospective memory impairments is that checkers doubt their ability to successfully complete a task. This doubt leads to greater checking. Recognition biases may add to the checking cycle. It is possible that prospective memory and retrospective episodic memory work together to generate and maintain checking compulsions. For example, impairments in prospective memory will result in prospective memory failures. In order to compensate for these failures, individuals may rely on retrospective memory recollection in order to establish whether tasks have been completed or not. If individuals experience retrospective recollection failures or recognition biases, this will perpetuate memory impairments (Cuttler & Graf, 2007).

7.3 Executive dysfunction in checking.

Cognitive-behavioural models of OCD have proposed that individuals with OCD may exhibit impairments in executive functions, namely inhibition, planning, set-shifting and working memory. It is possible that some executive functions impact more substantially on checking behaviours than others but, at present, we lack evidence. Identifying the relative importance of each of these variables will help contribute to our understanding of checking.

Executive processes were investigated in chapter 3 along with prospective memory deficits. Further to this, chapter 5 specifically examined inhibition deficits in a checking sample whilst investigating the relationship with episodic memory. Chapter 6 examined inhibition deficits in more detail. Based on previous literature, it was unclear as to whether inhibitory deficits are solely related to OCD symptoms or if they arise more generally from the presence of anxiety symptoms. It was also uncertain as to whether inhibitory impairments are specific to certain symptoms (obsessive and/or compulsive symptoms). Both of these aspects were investigated in chapter 6 in two separate experiments. Previous literature will be reported, and the findings from each chapter will be discussed in relation to this. This will help to inform our understanding of the role of executive dysfunction in checking.

7.3.1 Do inhibitory deficits underlie checking?

The most consistent evidence for executive dysfunction with respect to OCD indicates a deficit in inhibition, the ability to suppress irrelevant or interfering stimuli (Abramovitch, Dar, Schweiger, & Hermesh, 2011; Aycicegi, Dinn, Harris, & Erkmen, 2003; Bannon, Gonsalvez, Croft, & Boyce, 2002; Bohne, Keuthen, Tuschen-Caffier, & Wilhelm, 2005; Chamberlain, Fineberg, Blackwell, Robbins, & Sahakian, 2006; Chamberlain, Fineberg, Menzies, et al., 2007; Morein-Zamir, Craig, et al., 2010; Page et al., 2009; Penades et al., 2007; Sottocorno, Martoni, Galimberti, Fadda, & Bellodi, 2011). A small number of studies have also provided support for impairments in inhibitory control in checkers (Omori et al., 2007; Van der Linden, Ceschi, Zermatten, Dunker, & Perroud, 2005). Chapter 3 aimed to examine inhibitory control in checkers whilst examining the contribution of other executive variables and memory deficits.

In chapter 3, inhibition (as measured using the SST), but not planning, set-shifting or working memory, was shown to predict checking symptom severity. The SST was administered in chapter 5 and results showed that inhibitory impairments predicted checking symptom severity. The finding of specific executive deficits, namely inhibitory deficits in chapter 3, and support for inhibition deficits in chapter 5 is supportive of previous work using checking samples (Omori et al., 2007; Van der Linden et al., 2005). These findings provide support for cognitive deficit models and suggest that inhibitory dysfunction is a key contributor to the checking symptom profile.

Evidence to support inhibitory deficits in OCD as well as in specific sub-types such as checking is convincing. What is less certain is whether inhibitory deficits are solely related to OCD symptoms or if they arise more generally from the presence of anxiety symptoms. Previous studies have reported that an OCD group had poorer inhibitory performance compared to a group with panic disorder (Bannon, Gonsalvez, & Croft, 2008; Bannon et al., 2002) and a group with social phobia (Van der Linden et al., 2005). Little research however, has compared inhibitory control between those with OCD and specific anxiety groups. Previous work comparing inhibitory performance between OCD groups and clinical groups that include a specific anxiety component to the disorder (for example; trichotillomania) was examined. It was anticipated that examination of these findings may help to facilitate evaluation of the specificity of inhibition to OCD symptoms. These studies reported that inhibitory control was poorer in both the OCD and anxiety groups (trichotillomania and anorexia nervosa) compared to controls (Chamberlain et al., 2006; Sottocorno et al., 2011). The results are mixed and inconclusive.

Chapter 6 aimed to further examine inhibitory impairments between three specific groups. SST performance was compared between an OCD group (with high anxiety), an anxiety group (who scored low on OCD symptoms) and a control group (who scored low on OCD and anxiety symptoms). Results in chapter 6 indicated that inhibition was poorer in the OCD and anxiety groups when compared to healthy controls. Inhibitory performance was not shown to differ between the OCD and anxiety group. This finding raises the possibility that the presence of anxiety symptoms contributes to inhibitory impairments. This is supportive of previous work comparing inhibitory control between OCD groups and groups with a specific anxiety component (Chamberlain et al., 2006; Sottocorno et al., 2011). This work demonstrated that there were no differences in inhibitory performance between the OCD and anxiety groups. Nonetheless, findings from chapter 6 are contrary to work where inhibitory performance deficits were reported to be poorer for OCD groups when compared with anxiety disorders (Bannon et al., 2008; Bannon et al., 2002; Van der Linden et al., 2005). Group differences may have contributed to these contradictory findings, as chapter 6 used a general anxiety group in comparison to a specific anxiety group used in previous research. Clinical severity of the samples may account for differences in findings. Although participants in the anxiety group in chapter 6 reported high levels of anxiety on the DASS-anxiety sub-scale, all participants confirmed that they did not have a clinical diagnosis. Participants in the studies conducted by Bannon et al. (2002); Bannon et al. (2008) and Van der Linden et al. were recruited based on their clinical diagnosis for anxiety (see chapter 6 for further discussion). OCD tends to be highly co-morbid

with anxiety, thus an understanding of what symptoms contribute to impairments may help researchers to develop and improve interventions.

Inhibitory impairments have been reported in general OCD and checking samples. What is less certain is whether inhibition is related to all OCD symptoms and sub-types, or if it is more closely linked to obsessive and/or compulsive symptoms. Some researchers have reported that compulsions but not obsessions are related to inhibitory control (Morein-Zamir, Fineberg, Robbins, & Sahakian, 2010; Van der Linden et al., 2005). Contrary to this, other researchers have suggested that poor inhibitory control is related to both obsessions and compulsions (Coles, Schofield, & Pietrefesa, 2006). Findings are contradictory. Experiment 2 (chapter 6) examined the relationship between obsessions and inhibition and compulsions and inhibition in a sample of 294 participants. Based on the finding from experiment 1 (chapter 6), which suggested that anxiety symptoms may contribute to inhibitory deficits seen in OCD, experiment 2 took into account the role of anxiety.

Results from experiment 2 (chapter 6), showed that obsession symptom severity was predicted by higher anxiety symptoms. This is supportive of findings showing that OCD is highly comorbid with anxiety symptoms (Ruscio, Stein, Chiu, & Kessler, 2010). Inhibition was a significant predictor of obsessions when investigated alone, but no longer predicted obsessions when combined with anxiety. The former finding supports previous work showing a relationship between obsessions and inhibition (Coles, Schofield, et al., 2006). The latter finding suggests that inhibitory control is not an independent contributor to obsessive symptom severity. It may be important for

researchers to take into account anxiety when examining the relationship between inhibition and obsessions.

Results from chapter 6 demonstrated that inhibition and anxiety predicted compulsive symptoms. This finding suggests that each of these variables contribute independently to compulsions, supporting previous research showing a relationship between compulsions and inhibition (Morein-Zamir, Fineberg, et al., 2010; Van der Linden et al., 2005). The greatest predictor of compulsive symptoms (as assessed by the standardised beta and R^2 change) was anxiety. This suggests that anxiety provides a greater contribution to compulsive symptoms than inhibitory control. Overall, the findings from experiment 2 suggest that inhibitory function may play an independent role in predicting compulsions but not obsessions, when taking anxiety into account. These findings provide support for cognitive deficit models, in particular for inhibitory dysfunction. They suggest that researchers should make a distinction between compulsive and obsessive behaviours in the investigation of inhibition whilst taking into account the role of anxiety

7.3.2 Do planning deficits underlie checking?

In addition to impairments in inhibition, it was suggested that planning impairments may contribute to checking symptoms. Previous work has reported planning impairments in clinical checking samples using the Stockings of Cambridge task (SOC) (Chamberlain, Fineberg, Blackwell, et al., 2007; Nedeljkovic et al., 2009). Contrary to this, other researchers have reported no planning deficits in OCD samples when using the SOC task (Purcell, Maruff, Kyrios, & Pantelis, 1998a, 1998b; Veale, Sahakian, Owen, & Marks, 1996). With mixed findings, there is still uncertainty as to the relative

contribution of planning impairments to checking symptoms when considering other cognitive processes (e.g. memory, inhibition, attention set-shifting and working memory).

In chapter 3, planning was not found to predict checking symptoms. No relationship was shown between planning and checking symptoms when using the SOC task. This is supportive of some previous work using the same task in clinical OCD samples (Purcell et al., 1998a, 1998b; Veale et al., 1996) and contrary to research using the SOC task in clinical checking samples (Chamberlain, Fineberg, Blackwell, et al., 2007; Nedeljkovic et al., 2009). Sample differences may help to explain the discrepancy in findings. Nedeljkovic et al. reported that OCD checkers and those with mixed symptom profiles had poorer performance on movement times compared to washers, indicating that checkers were slower in cognitive speed. Although at first this may appear contrary to the planning findings in chapter 3, it is important to mention that planning accuracy was not reported by Nedeljkovic et al. The current study reported planning accuracy as the main outcome measure for planning, and thus we cannot reasonably compare between these studies. Contradictory findings could also link to symptom severity, particularly since Nakao et al. (2009) indicated that severity may affect neuropsychological functioning.

7.3.3 Do attention set-shifting deficits underlie checking?

Previous researchers have reported that attention set-shifting is impaired in checking samples (Goodwin & Sher, 1992; Omori et al., 2007). Goodwin and Sher reported that non-clinical checkers had poorer set-shifting abilities on the Wisconsin Card Sort Task (WCST) compared to a non-checking group. Omori et al. reported significant attention

set-shifting impairments in clinical checkers compared to washers on the category and letter fluency tasks and the digit symbol test. Contrary to this Nielen and Den Boer (2003) examined attention set-shifting using the Intra-Dimensional/Extra-Dimensional task (ID/ED) in a general OCD sample. Here, no set-shifting deficits were reported in the OCD group when compared to a healthy control group before and after medication treatment. Based on these findings, it is unclear as to whether deficits in set-shifting are evident in OCD and/or checking samples. In chapter 3, the relationship between set-shifting and checking symptoms was examined, whilst taking account of possible impairments in other areas of cognitive function.

Findings from chapter 3 showed that set-shifting deficits, as measured using the ID/ED task, did not predict checking symptoms. This work is supportive of previous research also using the ID/ED task to investigate attention set-shifting in an OCD sample (Nielen & Den Boer, 2003). The finding however, is contrary to previous work investigating set-shifting in checkers (Goodwin & Sher, 1992; Omori et al., 2007). Differences in task sensitivity may help to explain the discrepancy in findings. Goodwin and Sher used the WCST and Omori et al. used a letter fluency and digit symbol test to measure attentional flexibility compared to the ID/ED task in chapter 3. In a review, it was noted that set-shifting was most consistently impaired in samples using the ID/ED set-shifting task (Olley, Malhi, & Sachdev, 2007). Clinical severity is likely to play a major role in the expression of these deficits (Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005).

7.3.4 Do working memory deficits underlie checking?

The final executive function examined in chapter 3 was working memory. Nedeljkovic et al. (2009) used the Spatial Working Memory (SWM) task and reported working memory impairments for checkers when compared to healthy controls. Dittrich, Johansen, Fineberg, and Landro (2011) and Nielen and Den Boer (2003) did not report working memory impairments, when comparing performance accuracy on the SWM task between a clinical OCD group and a healthy control group. Working memory was examined in a checking sample using the reading and backward location span tests (Jaafari et al., 2013). It was reported here that checking behaviour in OCD was linked to a reduction in working memory. Evidence relating to working memory impairments in OCD and checking samples is contradictory. Chapter 3 aimed to further examine the relationship between working memory and checking, whilst measuring the relative contribution of other executive functions thought to relate to checking symptoms.

In chapter 3, working memory was not shown to predict checking symptoms, supporting previous work using the SWM task (Dittrich et al., 2011; Nielen & Den Boer, 2003). This finding is contrary to work reported by Nedeljkovic et al. (2009). The current finding also differ from work reported by Jaafari et al. (2013). Overall, it appears that SWM findings in OCD and checking samples are unresolved and this may be attributable to symptom severity and sub-type (Nakao et al., 2009). Harkin and Kessler (2011) suggested that some working memory tasks may be more sensitive to impairments in checkers, thus task sensitivity may help to explain the discrepancy in findings.

7.3.5 Executive dysfunction summary

The current research showed that executive function impairments were not uniformly associated with checking symptom severity. Out of the four executive functions measured (inhibition, planning, set-shifting and working memory), only inhibition was shown to be related to checking symptoms, with poorer inhibitory control predicting higher checking symptoms. Difficulties of individuals with this compulsion cannot be explained in terms of a pervasive and unified deficit in executive function, but relate to a specific dimension of cognitive regulation. Findings from experiments 1 and 2, in chapter 6, highlight the role of anxiety and inhibition in relation to compulsive symptoms in OCD. It can be concluded, that inhibitory impairments reported in OCD may arise more generally from the presence of anxiety symptoms. Furthermore, inhibitory impairments appear to relate more closely to compulsive rather than obsessive symptoms when taking the role of anxiety into account. Findings of consistent inhibitory impairments across this thesis, provide support for cognitive deficit models of OCD.

7.4 Memory deficits and executive dysfunction.

It has been suggested that memory impairments may be part of a more general pattern of executive function impairment (McDaniel & Einstein, 2000; Omori et al., 2007; Savage et al., 1999). Evidence suggests that both memory impairments and inhibition predict checking symptoms. In a review conducted by Muller and Roberts (2005), it was suggested that a combination of cognitive deficits may contribute to the OCD profile. Furthermore, it was suggested that there may be a central deficit of inhibition in OCD. Chapter 3 and 5 in this thesis sought to examine the interrelations among these variables. Previous literature will be reported and the findings from each

chapter will be discussed in relation to this. This should help to inform our understanding of the relationship between memory and executive deficits in checking.

7.4.1 Is there a relationship between prospective memory and inhibition in checking?

The relationship between prospective memory and inhibition has been examined in a limited number of studies. Shimamura, Janowsky, and Squire (1991), first proposed that prospective memory and inhibition may share commonalities. Further to this, some theoretical accounts suggest that at some stage prospective memory requires resource demanding processes (Marsh & Hicks, 1998; McDaniel & Einstein, 2000; Smith, 2003; Smith & Bayen, 2004). One account in particular, the multi-process model of prospective memory, identifies two possible retrieval routes. One suggests retrieval to be an automatic process and the other requires voluntary, controlled retrieval of intentions and is suggested to involve planned processes (McDaniel & Einstein, 2000). Support for both of these routes was reported by McDaniel, LaMontagne, Beck, Scullin, and Braver (2013). A few studies have indicated that if prospective memory cues occur while individuals are engaged in other activity, they have to inhibit that activity to meet the predetermined obligation (Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013; West & Craik, 2001). The extent to which prospective memory impairments are secondary to other cognitive functions was examined in a sample of individuals diagnosed with schizophrenia (Henry, Rendell, Kliegel, & Altgassen, 2007). Results from this study showed that both prospective memory and inhibition deficits were evident in schizophrenia. Furthermore, after controlling for cognitive and executive functions (inhibition) and retrospective memory, significant impairments were still evident in

prospective memory in individuals with schizophrenia. This finding suggests that prospective memory may represent a distinct deficit in individuals with schizophrenia, beyond inhibitory dysfunction. It was thought that this may apply to checkers and was investigated in chapter 3.

Chapter 3 aimed to examine the relationship between prospective memory and inhibition using a checking sample. No relationship was found between prospective memory and inhibition. Prospective memory did not mediate the relationship between inhibition and checking. Based on this finding, prospective memory and inhibition are suggested to be independent predictors of checking symptoms. This finding is supportive of work conducted by Henry et al. (2007). The findings from chapter 3 imply that particular aspects of prospective memory (specifically internally cued memory and prospective memory aiding strategies) may be associated with checking symptoms, but not sufficiently to mediate the relationship between inhibition and checking symptoms. In summary, the findings do not provide support for a model in which memory deficits in checking are thought to be secondary to executive dysfunction.

7.4.2 Is there a relationship between episodic memory and inhibition in checking?

Few researchers have examined the relationship between episodic memory and inhibition in OCD. One study which attempted to examine this relationship in a clinical OCD sample reported that memory processes were mediated by organizational strategies and it was concluded that differences in memory performance were secondary to impairments in executive processes (Savage et al., 1999). In addition, Omori et al. (2007) reported a relationship between poor inhibitory control and general memory

impairments. With evidence to suggest that there may be a relationship between aspects of memory and inhibitory impairments, chapter 5 examined whether a relationship was evident between inhibition and episodic memory biases.

Findings from chapter 5 showed no relationship between inhibition and familiarity biases. Familiarity responses did not mediate the relationship between inhibition and checking. These variables were suggested to play independent roles in checking. This finding is contrary to that expected based on findings reported by Savage et al. (1999) and Omori et al. (2007). The relationship shown by Omori et al, however, was between general memory and inhibitory functioning. The current findings suggest that this relationship does not extend to other aspects of memory. In conclusion, the findings from chapter 5 indicate that familiarity biases shown in checkers cannot be fully explained by inhibitory impairments. Rather, both appear to be independent predictors in the checking symptom profile.

7.4.3 Memory deficits and executive function summary

Results from chapters 3 and 5 indicate that there was no relationship between memory deficits and inhibitory impairments. Specifically, prospective memory and familiarity responses did not mediate the relationship between inhibition and checking. These findings imply that prospective memory and familiarity responses may be associated with checking, however not sufficiently to mediate the relationship between inhibition and checking compulsions. As far as the current author is aware, this is the first study to examine the interrelations among memory deficits and executive processes in a checking sample. The findings have implications for a model in which the relationship between executive functions and checking is thought to be mediated by memory impairments. In

summary, the findings indicate that impairments in memory and checking behaviours cannot be explained primarily on the basis of executive functioning deficits. A combination of cognitive deficits appears to independently contribute to the checking symptom profile.

7.5 Memory confidence in checking

Researchers examining belief and appraisal models have suggested that low memory confidence, a construct relating to meta-cognitive processing, may contribute to and maintain checking symptoms (Tolin et al., 2001; Wells, 2008). Memory confidence was examined in chapters 4 and 5 whilst examining the contribution of other cognitive factors thought to predict checking symptoms (e.g. memory deficits and/or executive function deficits).

7.5.1 Does low memory confidence underlie checking?

The impact of confidence in memory was examined in chapters 4 and 5, in the context of measuring other variables, such as memory deficits, executive deficits and perceived responsibility. The importance of confidence in checking symptoms seems likely. Individuals who have check that doors and windows are locked should have a clear memory representation of locking them. Mistrust in memory for the event/s, can result in repeated checking to ensure safety (Rachman, 2002). Researchers have reported diminished memory confidence when individuals were asked to repeat 'relevant' checking, but not when they were asked to repeat 'irrelevant' checking on a virtual kitchen cooker (van den Hout & Kindt, 2003a, 2003b, 2004) and real kitchen cooker (Coles, Radomsky, et al., 2006; Radomsky, Gilchrist, & Dussault, 2006). Furthermore, Nedeljkovic and Kyrios (2007) reported that general confidence in memory, as

measured using MACCS, predicted OCD and checking symptoms over and above perceived responsibility. Chapters 4 and 5 aimed to further examine the role of memory confidence in predicting checking symptoms.

In chapter 4, outcome confidence was measured using a subjective measure, with participants asked to complete a subjective rating after completing a virtual environment task. Confidence was not shown to differ between individuals assigned to low, medium and high checking groups. This finding is contrary to expectations based on previous findings (Coles, Radomsky, et al., 2006; Radomsky et al., 2006; van den Hout & Kindt, 2003a, 2003b, 2004).

In order to develop our understanding for the role of confidence in checking, it is important to assess why findings from chapter 4 differ from previous work. The way in which confidence was measured may play a key role in apparent differences between the current findings and previous literature. It is important to note that van den Hout and Kindt (2003a, 2003b, 2004) and Radomsky et al. (2006) took two measurements of confidence. Firstly 'confidence in memory accuracy' was assessed. Participants were shown a schematic drawing of six cooker rings and asked to indicate which three they checked in their last checking event, and how confident they were in their answer. The second measure relied on 'outcome confidence' and participants were asked to specify how confident they were that the cooker rings had been turned off. Both studies showed that relevant checking resulted in a reduction in the former confidence in memory accuracy. There were no differences in outcome confidence between the relevant and irrelevant checking groups. This indicates that all participants tended to be highly confident in having turned off the cooker. In chapter 4, participants were asked to rate

how confident they were in their performance. This measurement of confidence appears similar to outcome confidence measures used in previous literature, and may explain why confidence in the current study was not shown to be related to checking symptoms (see chapter 4 for further discussion).

Chapter 5 contrasted with chapter 4 in that subjective memory confidence was measured as opposed to outcome confidence. MACCS, a self-report measure of general memory confidence, was used to examine whether memory confidence predicted checking symptom severity. Findings demonstrated that when entered into a regression model alone, self-reported memory confidence predicted checking symptoms. Individuals recruited from non-clinical samples may, therefore have some awareness with regards to their low memory confidence. The current study extended previous work by examining the predictive power of memory confidence when investigated with other variables thought to be implicated in the onset and maintenance of checking symptoms. Confidence no longer predicted checking symptoms when included with familiarity, inhibition and perceived responsibility. This suggests potential suppressor effects and that confidence in memory may not be an independent predictor of checking symptoms.

7.5.2 Memory confidence summary

The current research showed that not all aspects of memory accuracy and/or memory confidence are uniformly associated with checking symptom severity. Outcome confidence appears to be intact in checkers. Low self-reported memory confidence was shown to be related to checking symptoms, but only when other variables such as memory deficits, executive deficits and perceived responsibility were not taken into account. This finding has implications for belief and appraisal models which suggest a

role for memory confidence in checking. The finding suggests that the relationship between memory confidence and checking may be suppressed by other cognitive factors such as memory deficits, inhibitory deficits and heightened perceived responsibility. Memory confidence, therefore, may not be an independent predictor of checking symptoms. The ability of memory confidence to influence checking symptom may be controlled or influenced by other cognitive variables.

7.6 Perceived responsibility in checking

Researchers examining belief and appraisal models have suggested that dysfunctional beliefs such as heightened perceived responsibility may contribute to and maintain checking symptoms (Rachman, 2002). Perceived responsibility was examined in chapter 5, whilst examining the contribution of other cognitive factors thought to predict checking symptoms (e.g. memory deficits and executive function impairments).

7.6.1 Does heightened perceived responsibility underlie checking?

Perceived responsibility has been reported to be related to checking symptoms in non-clinical (Coles, Radomsky, et al., 2006; Mancini, D'Olimpio, & D'Ercole, 2001; Smari, Gylfadottir, & Halldorsdottir, 2003; van den Hout & Kindt, 2004) and clinical samples (Boschen & Vuksanovic, 2007; Cougle, Salkovskis, & Wahl, 2007; Foa, Sacks, Tolin, Prezworski, & Amir, 2002; Lopatka & Rachman, 1995). Evidence to support heightened perceived responsibility in checkers is persuasive. What is uncertain is the relationship between perceived responsibility and checking, when examined with other variables suggested to be impaired in checkers (e.g., memory and executive deficits and memory confidence).

Chapter 5 set out to examine the predictive power of perceived responsibility whilst investigating episodic memory recollection, inhibitory impairments and memory confidence in the same analysis. Perceived responsibility was shown to predict checking symptom severity and continued to predict checking symptoms when investigated with familiarity and inhibition. This finding led the author to suggest that these variables may contribute independently to checking symptoms. The finding that perceived responsibility predicted checking symptoms supports previous work (Boschen & Vuksanovic, 2007; Coles, Radomsky, et al., 2006; Cougle et al., 2007; Foa et al., 2002; Lopatka & Rachman, 1995; Mancini et al., 2001; Smari et al., 2003; van den Hout & Kindt, 2004). The greatest predictor of checking symptoms in chapter 5 was perceived responsibility. The consistent findings for heightened perceived responsibility in checkers, therefore, offers strong support for the dysfunctional belief theory of compulsive checking (Rachman, 2002).

7.6.2 Perceived responsibility summary

Findings to support heightened perceived responsibility in checking, when other variables thought to contribute to checking are taken into account, are convincing. When perceived responsibility was investigated with familiarity and inhibition in a single model, the greatest predictor of checking symptoms was perceived responsibility. These findings are consistent with a cognitive view that perception of responsibility is a key determinant in the checking profile. Importantly, the findings also encourage the examination of a combination of variables taken from different cognitive-behavioural models. Determining the specificity of the relationship between particular beliefs and

cognitive functions may lead to an improved understanding of the processes involved in the onset and maintenance of OCD.

7.7 General limitations and suggestions for future research

In the current work, cognitive dysfunctions and dysfunctional beliefs were reported to predict checking symptom severity using samples that included participants with sub-clinical symptoms. Individuals with sub-clinical OCD show clinical features and personality traits similar to individuals with clinical OCD (Frost, Steketee, Cohn, & Griess, 1994; Gershuny & Sher, 1995; Mataix-Cols et al., 1999). In particular, checking compulsions have been commonly shown in non-clinical populations (Sher et al., 1983) and the content of checking compulsions does not appear to differ between clinical and non-clinical populations. Individuals experiencing checking compulsions in non-clinical populations, (termed 'sub-clinical') may find it easier to dismiss compulsive tendencies than individuals clinically diagnosed, as compulsions are experienced less frequently and intensely (Gibbs, 1996). Researchers expect that impairments reported in sub-clinical populations will be higher in clinical samples (Cuttler & Graf, 2007). Nonetheless, there are limitations to the use of a non-clinical population to explore clinical phenomena. Non patient samples are unlikely to compare qualitatively to clinical OCD samples. For example, participant anxiety and distress is important to the clinical OCD profile, yet these symptoms are less likely to be an important component in sub-clinical samples. Furthermore the impact of alternative comorbid diagnoses can not be evaluated using a non-clinical sample. Future research therefore, should use clinical samples to examine the relative contribution of these variables, the interrelationship between them and the impact of clinically relevant symptoms and related diagnoses.

Examination of both cognitive dysfunction and dysfunctional beliefs will help researchers to further understand what contributes to and maintains OCD checking symptoms.

The current findings are limited in the extent to which we can draw conclusions relating to anxiety. Findings from chapter 6 suggest that future work considering cognitive-behavioural models, should compare performance between an OCD group, anxiety control group and healthy control group. These groups were not taken into account in chapters 3, 4 and 5. We know that OCD tends to be highly comorbid with anxiety and depressive symptoms (Nestadt et al., 2009; Ruscio et al., 2010). The extent to which we can separate these symptoms is questionable and it would appear unrealistic to control for these comorbidities (D'Argembeau, Van der Linden, d'Acremont, & Mayers, 2006; Miller & Chapman, 2001). Future research should examine cognitive deficit models and belief and appraisal models whilst comparing performance between an OCD group, anxiety and/or depression control group and health control group. This will allow researchers to assess whether deficits are specific to individuals with OCD symptoms or if they relate more generally to the presence of anxiety and/or depressive symptoms.

One further limitation concerns the way in which checking symptoms were measured using a subjective self-report measure. Researchers report that self-report measures are reliable (Steketee, Frost, & Bogart, 1996), however there is the possibility that self-report measures are open to response biases. Respondents may not be fully aware of all of their symptoms or cognitive processes, particularly individuals with greater symptom severity (Müller & Roberts, 2005). The use of a clinical sample where

individuals have been diagnosed with OCD by a trained clinician, psychiatrist or psychologist may help to validate the current findings.

Self-report methods were also used to measure memory confidence in the current work. Despite findings that general memory confidence predicted checking symptom severity when investigated alone, future studies should confirm this finding using objective measures (e.g. EVET task). Examination of confidence as a function of memory performance within a virtual environment, would allow researchers to further understand the relative contribution of these variables in everyday contexts. Similarly, regression findings reported by Cuttler, Alcolado, and Taylor (2013) assessing the relationship between doubt and memory confidence, suggest that it may be important for future research to incorporate a measure of doubt. It was shown in this study that memory confidence (measured using the Memory and Cognitive Confidence Scale - MACCS) failed to account for any variance in checking symptoms, however doubt predicted checking symptoms in a non-clinical sample (Cuttler et al).

A limitation in chapter 5 is that familiarity biases were only examined using non-threat stimuli. Research shows that individuals with higher checking symptoms are likely to have higher rates of anxiety (Ruscio et al., 2010). It is possible that higher anxiety in checkers enables them to perceive and respond better to threat material. Recollection resources may be focused on threat information to reduce anxiety and thus recollection is poorer (familiarity responses are higher) for non-threat material. In order to confirm this and expand on work reported in chapter 5, future research should compare recollection biases for threat and non-threat material in a single study using a clinical checking sample.

Both prospective memory deficits and episodic memory biases have been reported in the current research. Researchers have suggested that these processes may work together to generate and maintain checking compulsions (Cuttler & Graf, 2007). Future research should examine prospective memory and retrospective episodic memory in a single study, in order to examine the relationship between these variables. A clearer understanding of the relationship between variables will help researchers to further comprehend the development of OCD and hopefully enable advances in the treatment process.

7.8 Concluding remarks

Prospective memory impairments and familiarity biases were reported in the current work. These findings provide support for cognitive deficit models of checking in relation to memory deficits. Findings of both prospective memory deficits and familiarity biases in checkers suggest that it is important to examine independent memory processes rather than treating memory as a unitary process. Future research examining memory deficits would benefit from examining different aspects of memory, recall and recognition.

Support for inhibitory deficits in OCD and checking in the current work is convincing. No deficits, however, were reported in planning, set-shifting or working memory. These findings have implications for a model proposing that checking may be related to executive dysfunction. Difficulties of individuals with checking compulsions cannot be explained in terms of a persuasive and unified deficit in executive function, but relate to a specific dimension of cognitive regulation. Furthermore, the current work suggests that inhibitory impairments reported in OCD may arise more generally from the

presence of anxiety symptoms. Inhibitory impairments appear to relate more closely to compulsive rather than obsessive symptoms when taking the role of anxiety into account. Findings of consistent inhibitory impairments across this thesis, provides support for cognitive deficit models of OCD. They also suggest that future research should concentrate on examining inhibitory impairments in compulsive sub-types, whilst taking anxiety into account.

The current work examined the relationship between memory and inhibitory deficits and reported no relationship between these variables. Each deficit was reported to independently contribute to compulsive checking symptoms. These findings do not provide support for a model in which memory impairments in checking are thought to be secondary to executive dysfunction. Findings of both memory and inhibitory deficits suggest that no single deficit can explain checking symptom severity. A combination of cognitive deficits appears to contribute to the checking symptom profile.

Memory confidence was reported to predict checking symptom severity when examined alone. When examined within the context of other variables that were thought to contribute to checking symptoms, memory confidence no longer related to checking. This finding has important implications for belief and appraisal models, as it may suggest that memory confidence effects could be suppressed by other factors such as memory deficits, executive deficits and perceived responsibility. Nonetheless, perceived responsibility was reported to be the strongest predictor of checking symptom severity, over and above memory and executive deficits. These findings provide support for the belief and appraisal model of checking in relation to dysfunctional beliefs.

In conclusion, this thesis demonstrates that prospective memory, familiarity biases, inhibitory control, memory confidence and perceived responsibility are related to checking symptom severity. Importantly, memory deficits (prospective memory and episodic recollection) inhibitory dysfunction and perceived responsibility are shown to contribute independently to checking symptoms. It was shown that cognitive impairments may relate to the presence of anxiety symptoms rather than solely to OCD symptoms. Additionally, anxiety and inhibition played an independent role in predicting compulsion severity. Rather than controlling for anxiety, it may be important for researchers to account for the impact of anxiety, when examining cognitive-behavioural models of OCD and checking. The findings demonstrate that there is no single deficit or model sufficient to explain checking symptoms in OCD. Checking etiology appears to be a complex process and the findings provide support for the contribution of a combination of deficits. Support for both cognitive deficit models and belief and appraisal models lead the current author to suggest that these two models are inter-related. Memory deficits, reduced memory confidence and heightened perceived responsibility are likely to lead to doubt and thus encourage repetitive checking. It is hoped that experimental investigations will help to improve our understanding of the most important variables that contribute to and maintain checking symptoms.

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