Investigating the relationship between obsessive-compulsive symptomatology and executive functions.

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Abstract

This thesis aimed to investigate the relationship between obsessive-compulsive symptoms (particularly obsessive intrusive thoughts) and executive functions (particularly working memory). Previous research had demonstrated executive function (EF) deficits in individuals with OCD. Executive functions are those cognitive mechanisms that help to control and regulate thoughts and behaviour. However, several questions remained unanswered: 1) do individuals with subclinical OCD also demonstrate EF deficits? 2) Are those EF deficits found in individuals with OCD trait in nature, or caused by state factors? 3) Are EFs implicated in OCD-relevant processes, such as thought control strategies? Three studies were conducted to help investigate these questions further. The study presented in chapter two found no difference between individuals with subclinical OCD and nonclinical individuals on a range of executive function tasks. The study presented in chapter three found that an increase in obsessive intrusive thoughts did not lead to impairments in working memory. The study presented in chapter four found no relationship between working memory and an individual’s ability to dismiss obsessive intrusive thoughts. The implications of the results from this thesis are discussed and future directions are suggested.

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Chapter 1 – Introduction to obsessive-compulsive disorder, obsessive intrusive thoughts and executive functions.

1.1: Chapter overview

In this chapter, I will first introduce obsessive-compulsive disorder (OCD) and focus particularly on one core symptom – obsessive intrusive thoughts (OITs). I will then introduce current cognitive theories of OCD, and describe the factors that these theories posit are important in the development and maintenance of OCD. I will also introduce the continuum model of OITs; the idea that OITs are experienced by all individuals but vary in some fundamental ways, such as frequency and associated distress. Those with OCD experience OITs at the clinical extreme end of the continuum. I will then describe some contested claims of cognitive theories of OCD and list some unanswered questions. Following this, I will introduce "subclinical obsessive-compulsive disorder" and explain how research into such samples can increase our understanding of OCD. Next, I will introduce executive functions in OCD and subclinical OCD, and explain how they may help to answer some unresolved questions in OCD research. Executive functions are those cognitive mechanisms that control and manage other lower-level cognitive processes and thereby facilitate self-directed behaviour toward a goal (Banich, 2009). Finally, I will describe an alternative possibility, that EFs are simply a consequence of OCD phenomena and may not provide any useful information about the development and maintenance of OCD.

1.2: Obsessive-compulsive disorder, obsessive intrusive thoughts and cognitive theories of OCD

Obsessive compulsive disorder (OCD) is a mental health disorder characterized by unwanted thoughts, images or impulses alongside ritualistic mental or behavioural acts (American Psychiatric Association [APA], 2013). These characteristics of OCD can vary significantly between individuals and as a result, OCD is considered a heterogeneous condition (e.g. Markarian et al., 2010; McKay et al., 2004). Obsessive compulsive disorder affects 1-3 percent of the population at some point in their life time (Rasmussen & Eisen, 1994; Kessler et al., 2005; Torres et al., 2006) and is associated with significant impairments in functioning and quality of life (Eisen, Stouf, & Rasmussen, 2006; Markarian et al., 2010). For example, individuals with a diagnosis of OCD may experience disturbed sleep and disrupted occupational functioning (such as loss of work; Markarian et al., 2010) and symptom severity has been found to negatively correlate with quality of life (Eisen et al., 2006). In addition to this, 60-90% of individuals with OCD present with at least one other psychological disorder, such as depression or anxiety (Ruscio, Stein, Chiu, & Kessler, 2010; Torres et al., 2006).

Defining obsessive intrusive thoughts

The unwanted thoughts, images and impulses that are characteristic of OCD are often referred to as obsessive intrusive thoughts (OITs). However, currently there is no universally accepted definition of OITs, which is problematic for assessing and understanding OITs (Julien, O'Connor, & Aardema, 2007). This lack of a universal definition of OITs ultimately has a negative impact on understanding the development and maintenance of OCD. It is therefore important to define OITs in the most accurate way. One of the difficulties with forming a definition of OITs is that within the literature the terms “intrusive thoughts”, “intrusions”, “cognitive intrusions”, “unwanted intrusive thoughts” and “obsessive intrusive thoughts” are often used interchangeably (Julien et al., 2007). In addition, there are a range of similar types of thought which are often confused with OITs, such as negative automatic thoughts, worry, and task-unrelated thoughts. In order to form an accurate and universally acceptable definition of OIT, it is therefore important to consider the commonalities between current definitions, as well as the differences between OITs and other types of thought.

One way of assessing commonalities between OIT definitions, and a way of helping to form a precise definition, is to consider *both* process characteristics and content (Clark & Purdon, 1995). Process characteristics refer to the form that the thoughts take; for example, repetitiveness. Content refers to thematic characteristics of the OIT; for example, aggression. In terms of process characteristics, most definitions describe OITs as presenting not only in the form of thoughts, but also in the form of images (e.g. the image of carrying out a repulsive sexual act) or impulses (e.g. the impulse to jump from a great height). Obsessive intrusive thoughts are also often described as being unwanted, due to the anxiety-provoking content of the thoughts, and the negative impact that the thoughts can have on day-to-day life (Clark & Rhyno, 2005). The spontaneous nature of the thoughts is also captured by most definitions, as OITs appear suddenly into conscious awareness. In addition, OITs are often described as recurrent or repetitive, and difficult to control

(Clark & Rhyno, 2005; Julien et al., 2007). Finally, OITs are frequently described as interrupting the task at hand, often because they are discordant with what a person is thinking or doing at the time of the thought (Clark & Rhyno, 2005; Julien et al., 2007).

Whereas process characteristics have been captured by most definitions of OITs, content has generally been ignored. In a study which used the most comprehensive measure of OITs ("Inventario de Pensamientos Intrusos Obsesivos"), García-Soriano, Belloch, Morillo, and Clark (2011) found that OITs frequently cover the themes of aggression, sex, religion, symmetry, doubts, contamination and superstition. However, OITs can be highly idiosyncratic and cover a range of themes (Rachman, 1981), and so it is important that definitions of OITs do not include strict content boundaries. Indeed, García-Soriano et al. (2011) found that 10% of participants indicated that their most upsetting OIT was not from the list of OITs provided, suggesting that it covered a different theme. Definitions of OITs, therefore, should state some of the most common OIT themes, whilst also making it clear that OITs can cover a range of different themes.

In order to further our understanding of OITs, it is important to consider the distinction between these cognitions and other, similar, types of cognition – in other words, to be clear on what OITs are *not*. Although information on the differences between OITs and other types of thought is likely excessive for OIT definitions, it remains a useful way of understanding more clearly what OITs are and are not. Four similar types of thought that are often confused with OITs are worry, negative automatic thoughts, rumination (Clark and Rhyno, 2005), and task-unrelated thoughts. Worry has been described as a "chain of thoughts and images, negatively affect-laden and relatively uncontrollable" (Borkovec, Robinson, Pruzinsky, & DePree, 1983, p. 10). Both OITs and worry interrupt ongoing activities, are difficult to control, and are subjectively unpleasant. However, compared to OITs, worry tends to take a verbal or linguistic form (as compared to in the form of thoughts, images, or impulses); tends to be more realistic, more unpleasant, more voluntary, of a longer duration, and tends to cause a greater interference in functioning (Clark & Rhyno, 2005). In terms of content, worry tends to relate more closely to every day concerns than OITs (Turner, Beider & Stanley, 1992), and the content of worry is more acceptable (Julien et al., 2007). Although worry is characteristic of a range of anxious states, it is typically found in generalized anxiety disorder (GAD; APA, 2013).

Negative automatic thoughts are recurring, disapproving comments about oneself (e.g. "I am useless") (Ingram, Atkinson, Slater, Saccuzzo, & Garfin, 1990). Both negative automatic thoughts and OITs tend to share several process characteristics: repetitiveness and intrusiveness (Clark & Rhyno, 2005). However, negative automatic thoughts tend to be more volitional and self-directed than OITs, they are predominately verbal or linguistic in form (as compared to in the form of thoughts, images or impulses), and less disruptive of ongoing activity than OITs (Clark & Rhyno, 2005). In addition, negative automatic thoughts tend to be experienced as longer chains of related thoughts, whereas OITs are more likely to be experienced as short bursts of thought. In terms of content, negative automatic thoughts typically relate to themes of loss or failure, whereas OITs tend to relate to themes of aggression, sex, religion, symmetry, doubts, contamination and superstition (García-Soriano et al., 2011;

Julien et al., 2007). Finally, negative automatic thoughts are likely to be perceived as more rational and ego-syntonic (in line with an individual's self-image) than OITs. Negative automatic thoughts are typically found in depression (Beck, 1967), although they are associated with range of mental health disorders.

Rumination has been described as "repetitive and passive thinking about one's symptoms of depression and the possible causes and consequences of these symptoms" (Nolen-Hoeksema, 2004, p. 107). In terms of process characteristics, rumination and OITs are both recurrent and repetitive; however, rumination tends to be longer in duration, more ego-syntonic (in line with a person's self-image), volitional and directed by the individual, than OITs (Clark & Rhyno, 2005). In terms of content, rumination is more likely to be past-orientated and self-focussed than OITs. Although rumination is associated with range of mental health disorders, it is typically found in depression (Beck, 1967).

Task-unrelated thoughts (sometimes referred to as 'mind wandering') is a broad term given to any thoughts that are not relevant to the task at hand (e.g. Smallwood & Schooler, 2006). Task-unrelated thoughts can include fantasies, future concerns, or past mistakes, amongst many others. In terms of process characteristics, OITs differ from task-unrelated thoughts in that OITs are spontaneous, whereas task-unrelated thoughts are sometimes deliberate (Seli, Risko, Purdon, & Smilek, 2016). In terms of content, OITs are negative and unwanted, whereas task-unrelated thoughts are sometimes positive (e.g. fantasising about winning the lottery; Seli et al., 2016). However, there are many process and content overlaps with OITs and task-unrelated thoughts, and in this respect OITs are most accurately thought of as a type of task-unrelated thought. In other words, all OITs are task-unrelated thoughts, but not all task-unrelated thoughts are OITs.

In summary, OITs are those thoughts, images or impulses that are unwanted, spontaneous, repetitive, difficult to control, that interrupt the task at hand, and broadly cover the themes of aggression, sex, religion, symmetry, doubts, contamination and superstition. Indeed, this is the OIT definition that will be used throughout this thesis. Examples of OITs may include an individual imagining themselves carrying out an unprovoked aggressive act on another individual as they walked down the street, or suddenly doubting whether they locked the front door of their house as they arrived at work. These OITs differ from worry, negative automatic thoughts, rumination, and task-unrelated thoughts in terms of process characteristics and content.

Understanding the development and maintenance of obsessive-compulsive disorder

Current understanding of the development and maintenance of OCD is best informed by a range of cognitive theories (Clark & Purdon, 1993; Clark & Purdon, 2016; Rachman, 1997, 1998, 2003; Salkovskis, 1985, 1989, 1999; Salkovskis & Millar, 2016). There is a significant degree of overlap between each of these cognitive theories, and many include elaborations on previous theories, rather than opposing or contradictory ideas. Indeed, because of this significant overlap, these theories are often referred to collectively as “cognitive theories of OCD”. Understanding what cognitive theories can and cannot tell us about the development and maintenance of OCD is crucial for informing future theoretical developments. Indeed, there are likely to be important factors that influence the development and maintenance of OCD, but have not yet been considered by cognitive theories of OCD.

The central claim of cognitive theories of OCD is that OITs become problematic (more frequent, intense, and distressing) when appraised or interpreted in negative ways (Clark & Purdon, 1993; Rachman, 1997, 1998, 2003; Salkovskis, 1985, 1989, 1999). Although OITs are a central symptom of OCD (American Psychiatric Association [APA], 2013) they are also experienced by the general population (e.g. Abramowitz et al., 2014; Radomsky, Rachman, Shafran, Coughtrey, & Barber, 2014). In other words, it is not OITs themselves that are problematic, because many people experience them without experiencing any significant distress or dysfunction. Instead, it is the way that individuals evaluate the OITs that is important in determining whether they become more frequent and distressing. More specifically, individuals with OCD may feel that an OIT is an indication that they are personally responsible for preventing some anticipated harm from occurring to the self or others (Salkovskis, 1985, 1989, 1999). In addition, individuals with OCD may misintrerpret the significance of their OITs, or believe that OITs are equal to actions (Rachman, 1997, 1998, 2003).

Cognitive theories of OCD also provide an explanation for why these negative appraisals occur in the first place; they are said to be a product of dysfunctional beliefs that an individual may hold about their thoughts and the world around them (Obsessive Compulsive Cognitions Working Group - OCCWG, 1997; 2001; 2003; 2005). More specifically, it has been demonstrated that that individuals with OCD are likely to 1) feel responsible for the thoughts they experience; 2) overrate the importance of their thoughts;

3) feel the need to control their thoughts; 4) overestimate threats; 5) be intolerant to uncertainty; and 6) be prone to perfectionism (OCCWG, 1997; 2001; 2003; 2005). Understandably, these dysfunctional beliefs have a direct impact on the way that individuals think about their OITs.

Finally, cognitive theories of OCD highlight the importance of an individual's response to OITs (often referred to as compulsions) in the development and maintenance of OCD. Negative beliefs and interpretations of OITs lead to an individual becoming distressed and anxious by the OITs that they experience; often believing that they are "mad, bad or dangerous" (Rachman, 2003, p.6). In an attempt to reduce anxiety caused by the OITs, individuals may respond by carrying out covert or overt compulsive acts, such as repeated checking of a door, or washing their hands (Rachman, 1997, 1998, 2003; Salkovskis, 1985, 1989, 1999). Although these compulsive acts may reduce anxiety in the short-term, in the long-term they prevent individuals from disconfirming the faulty appraisals associated with OITs, and ultimately cause distressing OITs to persist (Rachman, 1997). Individuals with OCD are also more likely to suppress OITs than nonclinical individuals (Morillo, Belloch, & García-Soriano, 2007; García-Soriano & Belloch, 2013; suppression refers to the effortful process of trying to remove a thought; Wegner, 1989). However, most of these suppression attempts are unsuccessful at removing OITs (Purdon, Rowa, & Antony, 2007).

To give hypothetical example of how an OIT may become problematic for an individual, based on cognitive theories of OCD: an individual may suddenly have the thought of shouting out something offensive during a church service. This thought is ego-dystonic (conflicts with the individual's self-image) and therefore unwanted, as the individual considers themselves to be very polite and religious. The thought interrupts what the individual was previously doing – reading a prayer. As the individual often feels the need to control their thoughts and feels responsible for the thoughts that they experience, they become anxious and distressed and feel compelled to act in order to remove the thought and prevent the thought from becoming a reality. As a result, they repeat the phrase "I am a good person" alongside a Hail Mary (an example of a compulsion), three times, which reduces their feelings of anxiety for a short period of time.

Obsessive intrusive thoughts: The continuum model

Cognitive theories of OCD rest on the premise that OITs are experienced by everybody and exist on a continuum of severity (Abramovitch et al., 2014; Berry & Laskey, 2012). This continuum of OIT severity is sometimes referred to as the "continuum model" (Berry & Laskey, 2012). From a diagnostic perspective, severity corresponds closely to diagnosis, such that individuals who experience more severe OITs are more likely to be diagnosed with OCD, and individuals who experience less severe OITs are more likely to be from the general population. The continuum model posits that everybody experiences OITs of the same content, but they vary based on a range of associated variables (e.g. frequency, distress, intensity). Severity can therefore be thought of as a term used to describe these associated variables collectively. As with cognitive theories more generally, identifying any inaccuracies, or potential areas for development, of the continuum model is important for furthering our understanding of OCD. In addition, the continuum model posits that all individuals experience OITs of the same kind, and this has important methodological implications for research into OCD. More specifically, it suggests findings from OIT research which recruits nonclinical individuals is generalizable to understanding OITs in individuals with OCD (Abramowitz et al., 2014).

A large body of literature currently supports the continuum model of OITs, by demonstrating that OITs of a similar content are experienced by all individuals (e.g. Rachman & de Silva, 1978; Abramovitch et al., 2014; Radomsky et al., 2014). Some of the earliest research in support of the continuum model came from a study by Rachman and de Silva (1978), who interviewed 124 individuals from the general population and found that 80% of the sample experienced OITs which were similar in content to individuals with a diagnosis of OCD. This was a seminal finding as it had previously been thought that OITs were pathological and not experienced by most people (e.g. Black, 1974; Lewis, 1936). Since 1978, this finding has been replicated many times, with reports of between 70% and 100% of the general population experiencing OITs (Belloch, Morillo, Lucero, Cabedo, & Carrió, 2004; Langlois, Freeston, & Ladouceur, 2000; Purdon & Clark, 1993; Radomsky, Alcolado, et al., 2014; Salkovskis & Harrison, 1984). In addition, it has also been demonstrated that OITs are common across cultures, when 84%-100% (average 94.3%) of students from 15 cities, in six different continents, reported experiencing at least one OIT in the past three months (Radomsky et al., 2014).

Further evidence for the continuum model of OITs comes from questionnaire studies which demonstrate differences between nonclinical individuals and those with OCD on a range of OIT variables. In comparison to nonclinical individuals, those with a diagnosis of OCD report that their OITs are more frequent, distressing, unacceptable and uncontrollable (Clark & Rhyno, 2005). In addition, thoughts at the severe end of the continuum are more likely to be resisted, neutralized (a voluntarily initiated activity which aims to reduce discomfort associated with OIT; Salkovskis, 1989; e.g. internally repeating that you are not a bad person) and be accompanied by maladaptive thought-control strategies (e.g. thought suppression) (Clark & Rhyno, 2005). Individuals with OCD also report that their OITs are more intense and more difficult to dismiss than nonclinical individuals (Rachman & de Silva, 1978). Each of these variables are thought to vary continuously across the continuum; such that, for example, one individual may experience only a few OITs each month, barely resist them, and find them only slightly distressing – whereas a second individual may experience many OITs each month, heavily resist them, and find them extremely distressing. A third individual may exist somewhere in between these two individuals, in terms of frequency, resistance and distress.

The idea that all individuals experience OITs of the same kind, but differing based on a range of associated variables, has important implications for research into OCD. More specifically, it suggests that research into nonclinical individuals can reveal important information about the development and maintenance of OCD. Indeed, a wealth of research has been conducted with nonclinical participants and this has greatly increased our understanding of OCD (Abramowitz et al., 2014). Moreover, there are even several advantages to using nonclinical individuals (compared to individuals with OCD) in OCD research. Research with nonclinical individuals is cheaper and more convenient than research with samples with OCD (Abramowitz et al., 2014). In addition, putative developmental and maintenance factors of OCD can be induced and manipulated in nonclinical participants, meaning they offer a more precise experimental control than individuals with OCD (who may already have been affected by such factors) (Abramowtiz et al., 2014). Research with nonclinical samples is also less likely to be prone to the influence of confounding variables (e.g. medication) (Gibbs, 1996) and provides opportunity to conduct longitudinal research to determine developmental factors of OCD (Abramowitz et al., 2014). Finally, research with nonclinical samples may be particularly useful for conducting preliminary research, to determine whether a particular line of research is worth pursuing in individuals with OCD (Abramowitz et al., 2014).

Criticisms of cognitive theories of obsessive-compulsive disorder

Cognitive theories currently offer the best scientific framework for understanding OCD, and this is reflected by the development of effective treatments that have been built upon these theories, such as cognitive-behavioural therapy (CBT) (Freeston, Rheaume, & Ladouceur, 1996; Wilhelm et al., 2005). However, despite the large body of evidence that supports the cognitive theories of OCD, and the continuum model on which it is based, more recent reviews have challenged the ideas (e.g. Berry & Laskey, 2012; Cougle & Lee, 2014; Julien et al., 2007), suggesting revisions to the ideas may be necessary. In further support of the idea that revisions to current theories of OCD may be necessary, cognitive interventions are unhelpful for around half of individuals (Fisher & Wells, 2005), suggesting new interventions are needed to help these individuals. In order for new interventions to be developed, and for our understanding of OCD to increase, new theoretical models, or elaborations on current cognitive theories, are needed (Kyrios, 2011).

In a review of the literature, Cougle and Lee (2014) challenged a core claim of cognitive theories of OCD; that more frequent OITs are the result of negative appraisals and dysfunctional control strategies. Rather, the reviewers argued that that causality is in the opposite direction, such that individuals who experience more frequent OITs are more likely to negatively appraise, and attempt to control, OITs. In support of this position, Cougle and Lee (2014) cited evidence which demonstrated that a stress management intervention (which was not designed to alter an individual's OIT appraisals) was just as effective at reducing symptoms of OCD as a cognitive intervention designed to target faulty appraisals (Whittal, Woody, McLean, Rachman, & Robichaud, 2010). In addition, analysis of weekly assessments in the same trial demonstrated that the reduction of OITs predicted the subsequent reduction of negative appraisals, but the reduction of negative appraisals did not predict the reduction of OITs (Woody, Whittal, & McClean, 2011). If negative appraisals and dysfunctional control strategies do not lead to an increased frequency of OITs, the question remains as to what does cause the increase. In other words, why do some people experience more OITs than others? Further elaborations to cognitive theories of OCD must consider this question.

A further question that is unanswered by cognitive theories of OCD is why particular control strategies, such as suppression, are often unsuccessful. For example, in a diary study, Purdon et al. (2007) found that individuals with OCD were only able to suppress thoughts on 11% of occasions. In addition, it is currently unclear why individuals vary in their ability to suppress OITs (e.g.

both nonclinical; Purdon & Clark, 2001; and those with OCD; Abramowitz, Tolin, Street, 2001). There is some evidence to suggest that ability to suppress OITs depends upon how upsetting the OIT is (Ólafsson et al., 2014; Edwards & Dickerson, 1987). In other words, individuals who experience more upsetting OITs (e.g. those with OCD) find them more difficult to suppress than individuals who experience less upsetting OITs. However, contrary to this, there is evidence to suggest that individuals with OCD have difficulty suppressing neutral thoughts, in comparison to nonclinical individuals and anxious controls (Tolin, Abramowitz, Przeworski, & Foa, 2002), suggesting some other mechanism is needed to explain variations in suppression ability. Future attempts to improve cognitive theories of OCD must therefore consider other explanations for variations in suppress ability.

The continuum model has also received criticism and suggested improvements have been put forward (Berry & Laskey, 2012). In a review of the literature on OITs in the general population, Berry and Laskey (2012) argued that the continuum model does not account for differences in OIT content, trigger (what, if anything, elicits the OIT) and response strategy (how somebody reacts to the OIT once it has occurred). More specifically, Berry and Laskey (2012) presented research demonstrating that individuals with OCD were less likely to have an identifiable trigger for their OITs than individuals from the general population; in that the thoughts are less likely to be directly linked to their environment. Berry and Laskey (2012) also argued for some content differences; that individuals with OCD are more likely to experience bizarre or aggressive OITs than nonclinical individuals. Finally, Berry & Laskey (2012) argued that individuals with OCD are more likely to seek reassurance for their OITs than individuals from the general population. Crucially, Berry & Laskey (2012) conclude that there still remains much overlap in each of these areas (e.g. individuals from the general population can still experience very bizarre or aggressive OITs), and so the continuum model should not be discarded. Rather, a renewed continuum model should be adopted which accounts for these further complexities. An important implication of this conclusion is that research with nonclinical individuals can still reveal important information about the development of OCD.

A further variable that has not yet been considered by the continuum model of OITs is dismissibility; an individual's ability to remove an OIT from consciousness. Dismissibility can be thought of as a form of thought suppression and has been measured in two ways: subjectively and objectively. First, *subjective* dismissibilty has been measured through the use of self-report questionnaires, which ask participants "how difficult is it for you to dismiss OITs"? (Rachman & de Silva, 1978; Salkvoskis & Harrison, 1984; Ólafsson et al. 2014). Second, *objective* dismissibility has been measured through experimental studies, which ask participants to dismiss OITs and indicate (e.g. using a keyboard) when they have dismissed the thought (Ólafsson et al. 2014; Purdon, Gifford, McCabe, & Antony, 2011). Overall, very little research has explored OIT dismissibility, but the limited findings suggest that symptoms of OCD are related to subjective OIT dismissibility (Rachman & de Silva, 1978; Salkvoskis & Harrison, 1984; Ólafsson et al. 2014) rather than objective OIT dismissibility (Ólafsson et al. 2014; Purdon et al., 2011). In other words, dismissing OITs may be a problem of perception of how difficult it is to remove thoughts, rather than actual difficulty removing them. However, this finding is surprising, as it is unclear why subjective and objective dismissibility would not align. Due to the limited research in this area, further research is needed to clarify the relationship between symptoms of OCD and both subjective and objective dismissibility. Finding a relationship between symptoms of OCD and objective dismissibility would suggest that the continuum model needs to be updated further to account for differences in dismissibility.

Subclinical obsessive-compulsive disorder

The majority of current research into OCD is conducted on nonclinical individuals and those with a diagnosis of OCD. However, there are a lesser-studied group of individuals who could reveal important information about the development and maintenance of OCD; those described as having “subclinical levels of obsessive-compulsive symptomatology”. Individuals with subclinical levels of obsessive-compulsive symptomatology may experience unpleasant OCD symptoms (such as upsetting OITs), but not to the same extent as individuals with a diagnosis of OCD (e.g. Gibbs, 1996; Goracci et al., 2007; Grabe et al., 2001). These individuals are sometimes described as having “subclinical OCD” (e.g. Grabe et al., 2001) or “subthreshold OCD” (e.g. Goracci et al., 2007). It is important to note that none of these subclinical labels are official diagnostic categories; rather, they are terms used in research to operationalise a broad set of obsessive-compulsive characteristics. Operationalising subclinical OCD in this way is useful for learning more about OCD. Indeed, it has been demonstrated that individuals with subclinical levels of obsessive-compulsive symptomatology are at increased risk of developing OCD (Black, Gaffney, Schlosser, & Gabel, 2003; Fullana et al., 2009). Further research is therefore needed into this under-studied group of individuals.

A clearer picture of subclinical OCD is created when considering how it fits within the continuum model of OITs. Based on this model, the experience of OITs varies from nonclinical individuals, through to individuals with subclinical levels of obsessive-compulsive symptomatology, and further to individuals with clinical levels of OCD symptomatology (Abramowitz et al., 2014). In other words, those individuals who fall into the category of subclinical OCD may score higher than nonclinical individuals on a range of OIT variables (e.g. more OIT frequency, intensity, distress etc.), but score lower than individuals with a diagnosis of OCD. Of course, the specific area on the continuum where subclinical OCD lies is best viewed as being approximate, rather than precise, and may vary between studies dependent upon the way that subclinical OCD has been operationalised. Indeed, this is the case with individuals with OCD; their experiences of OITs exist in an approximate area at the most severe end of the continuum. In other words, whilst it may look like operationalising subclinical OCD conflicts with the continuum model of OITs (as it is attempting to turn a dimensional experience into a discrete category), this is not the case, as the category lies in an approximate area of the continuum, and mainly serves as a useful descriptive tool in research.

There is large variation in how subclinical OCD is operationalised, which makes it difficult to draw conclusions about what subclinical OCD is, and what it can tell us about OCD. Some studies have employed a diagnostic interview, where an individual's obsessive-compulsive symptoms are assessed in relation to pre-defined criteria for subclinical OCD (e.g. Angst, 1993; Grabe et al., 2000). Other studies have categorised participants based on their scores on a self-report OCD symptom questionnaire (e.g. Obsessive-Compulsive

Inventory – Revised – OCI-R; Foa et al., 2002). Within these studies, there is variation in the cut-off scores used to operationalise subclinical OCD. Some studies employ a conservative cut-off score, such as describing the highest 3% of scorers on an OCD measure as having subclinical OCD (e.g. Kim, Jang, Kim, 2009). Other studies have employed a more liberal cut-off score, such as conducting a median split on questionnaire scores and dividing the group into a “low OCD” and “subclinical OCD” group, based either on overall symptoms or a specific symptom subtype (e.g. checking; Harkin & Kessler, 2012; Harkin, Rutherford, & Kessler, 2011; Riskind, Abreu, Strauss, & Holt, 1997). Other studies have employed a cut-off score somewhere in between these liberal and conservative examples, such as recruiting participants who score within the top 25% of an OCD symptom measure (Frost & Shows, 1993), or recruiting participants who score 1 S.D above the sample mean on an OCD symptom measure (Abramovitch, Shaham, Levin, Bar-Hen, & Schweiger, 2015).

Currently there is no universally agreed upon method of how to operationalise subclinical OCD using self-report questionnaires, and each method has its own advantages and disadvantages. Liberal cut-off scores make the recruitment of larger sample sizes easier, but are less sensitive to OCD symptomatology and may therefore include many individuals who would more accurately be described as nonclinical (Mataix-Cols, Vallejo, & Sa, 2000). Conservative cut-off scores are more sensitive to OCD symptomatology, but increase the likelihood that individuals with undiagnosed OCD may be included in the sample (Mataix-Cols et al., 2000). Indeed, previous studies that have conducted diagnostic interviews following a conservative cut-off allocation have found that many of these participants meet clinical OCD diagnostic criteria (Lee, Yost, & Telch, 2009 – 73%; Lee & Telch, 2010 – 75%). Recently Abramowitz et al. (2014) suggested a method for decreasing the likelihood of including individuals with undiagnosed OCD; that is, using pre-determined empirically derived cut-off scores for OCD questionnaires. For example, the OCI-R (Foa et al., 2002) is able to distinguish between individuals with and without OCD using a cut-off score of 21 (those who score 21 or higher are likely to have OCD). Excluding individuals who score over the clinical cut-off score greatly decreases the likelihood of including individuals with undiagnosed OCD.

Summary

To summarise this chapter so far, cognitive theories of OCD argue that it is not OITs themselves that are problematic, but rather the way that they are appraised and responded to (Clark & Purdon, 1993; Rachman, 1997, 1998, 2003; Salkovskis, 1985, 1989, 1999). Negative appraisals of OITs lead to dysfunctional control attempts, which increase the severity of OITs. Cognitive theories of OCD are based on the premise that OITs exist on a continuum, similar in content but varying in terms of a range of associated variables, such as frequency, distress, resistance, intensity, and perceived dismissibility (Clark & Rhyno, 2005). Nonclinical individuals may experience less frequent, distressing, and intense OITs than individuals with subclinical levels of obsessive-compulsive symptomatology, who in turn may experience less frequent, distressing, and intense OITs than individuals with clinical OCD. This continuum model has important implications for research into OCD, as it suggests findings from nonclinical samples, and individual with subclinical levels of obsessive-compulsive symptomatology, can provide useful information about the development and maintenance of OCD (Abramowitz et al., 2014).

More recently, cognitive theories of OCD have been challenged, and modifications have been suggested (e.g. Berry & Laskey, 2012; Cougle & Lee, 2014). More specifically, Cougle and Lee (2014) argued that negative appraisals and dysfunctional response strategies do not lead to an increase in the number of OITs experienced, leaving the question open as to what does lead to an increase in OITs. It is also unclear why OIT suppression is often unsuccessful, and why individuals vary in their ability to suppress OITs (Abramowitz, Tolin, Street, 2001; Purdon et al., 2007; Purdon & Clark, 2001). Finally, there are reasons to believe that the continuum model should account for differences in objective dismissibility, as well as subjective dismissibility (Purdon et al., 2011). In order to increase our understanding of the development and maintenance of OCD, research should aim to investigate these contested claims.

1.3: The role of executive functions in obsessive-compulsive disorder and subclinical obsessive-compulsive disorder

Research that integrates neuropsychological findings with cognitive theories of OCD may help to resolve some of the current contested issues in OCD research (Kyrios, 2011). Increasingly, the role of executive functions (EFs) in OCD is being investigated and offers potential for increasing our understanding of OCD. Broadly speaking, there are two lines of evidence that suggest that research into EFs may help to increase our understanding of the disorder, and, more specifically, resolve some of the contested issues within cognitive theories of OCD. First, there is evidence that demonstrates that individuals with OCD have poorer EF than nonclinical individuals (Abramowitz, & Mittelman, 2013; Shin, Lee, Kim, & Kwon, 2014; Snyder, Kaiser, Warren, & Heller, 2014). Second, there is evidence that links EFs with OCD-relevant mechanisms, such as thought suppression (e.g. Brewin & Beaton, 2002; Brewin & Smart, 2005), suggesting a direct role of EF in the experience of OITs. Although the empirical evidence linking EFs to OCD-relevant mechanisms is sparse, there are also theoretical reasons to suggest that EFs may play a role in OCD.

Defining and measuring executive functions

Currently there is a lack of consensus within the literature as to how many EFs there are, however, Miyake, Friedmann, Emerson, Witzki, & Howerter’s (2000) 3-factor model is the most widely used and influential model. Miyake et al.’s (2000) model posits that there are three related but separable EFs: information updating and monitoring (often referred to as working memory), inhibition of prepotent responses (often referred to as inhibition) and mental set-shifting (often referred to as cognitive flexibility).

Working memory involves updating and monitoring relevant information; this includes replacing non-relevant information with relevant information, where appropriate (Morris & Jones, 1990). As a real world example, working memory is required when an individual attempts to remember a phone number that someone has told them, whilst they look for a pen to write it down. Some of the most frequently used measures of working memory are the n-back task (Kirchner, 1958) and the Backward Digit Span

Task (BDS; Wechsler Adult Intelligence Scale, 3rd edition; WAIS III; The Psychological Corporation, 1997). For the n-back task, participants are presented with a sequence of letters or shapes. Participants are required to indicate when the relevant stimulus matches the stimulus n-trials before (e.g. 2 trials previous). For the BDS task, participants are required to remember a list of numbers, which increases in length, and recall the numbers in reverse order. In both of these tasks, participants are required to hold, manipulate and update information.

Inhibition refers to the ability to deliberately suppress dominant, automatic, or prepotent responses (Heeren, Van Broeck, & Philippot, 2009; Miyake et al., 2000). The children's game "Simon says" provides a real-world example of a task, in which success requires inhibition. In this game, instructions are to be followed *only* if preceded by "Simon says". Hearing an instruction, such as "touch your nose", often causes participants to touch their nose; inhibition is required to stop this action. Inhibition is often measured using the Stroop task (Stroop, 1935) and the Flanker task (Eriksen & Eriksen, 1974) . For the Stroop task, participants are presented with a range of colour words (e.g. blue) which are displayed in a range of different colours (e.g. the word "blue" is in red font/ink). Participants are required to indicate what the word says, and not the colour of which the word is presented. For the Flanker task, participants are presented with a row of arrows and they are required to indicate the direction of the central arrow. For some of these trials, the central arrow is pointing in the opposite direction to the surrounding arrows. In both of these tasks, participants are required to stop, or inhibit, a prepotent response.

Cognitive flexibility refers to the process of changing behaviour based on alterations in, and feedback from, the environment (Vriend & Wit, 2013). This process includes attention-switching; the ability to disengage from irrelevant stimuli and attend to relevant stimuli. As a real world example, cognitive flexibility is involved in an individual's ability to switch between using a PC and a Mac. Some examples of tasks used to measure cognitive flexibility, include the Wisconsin Card Sorting Test (WCST; Heaton, 1981) and the Switching Inhibition and Flexibility Task (SwIFT; FitzGibbon, Cragg & Carroll, 2014). For the WCST, participants are given cards which vary based on three characteristics; colour (e.g. red), shape (e.g. triangle), and number (e.g. two). Participants are required to sort the cards based on an unknown rule (e.g. colour), by deducing the correct answer from "correct" or "incorrect" responses from the experimenter. The sorting rule is changed frequently by the experimenter, without warning. For the SwIFT, participants are presented with bivalent stimuli which vary based on colour and shape. Participants are also presented with a rule (typically either "Sort by colour" or "Sort by shape") and are required to sort the bivalent stimuli based on the rule. Both of these tasks require participants to switch their attention based on different rules/criteria.

Executive functions in obsessive-compulsive disorder

Individuals with OCD have poorer EF than nonclinical individuals; reflected by poorer performance on a range of tasks measuring working memory, inhibition, and cognitive flexibility (amongst other cognitive variables; Abramovitch et al. 2013; Shin et al. 2014; Snyder et al. 2014). In other words, individuals with OCD demonstrate EF deficits. However, the literature is not consistent, and often studies utilising the same task and sample-type find contradictory results (Abramovitch & Cooperman, 2015). The evidence for EF deficits in individuals with OCD comes from three separate meta-analyses, which found broadly similar results (Abramovitch et al. 2013; Shin et al. 2014; Snyder et al. 2014). In their review, Abramovitch et al. (2013) presented effect sizes based on EF domains (e.g. cognitive flexibility) rather than on EF tasks (e.g. WCST), whereas Shin et al. (2014) presented effect sizes for EF tasks rather than EF domains. Snyder et al (2014) presented both task and domain effect sizes. Individuals with OCD performed significantly worse than nonclinical controls on tasks measuring visuospatial working memory (Shin et al., 2014; g = -.45 to -.74; Abramovitch et al., 2013; d = -.37; Snyder et al., 2014; d = .47), inhibition (Shin et al., 2014; g = -.45 to -.55; Abramovitch et al., 2013; d = -.49; Snyder et al., 2014; d = .40), and cognitive flexibility (Shin et al., 2014; g = -.31 to -.49; Abramovitch et al., 2013; d = -.51; Snyder et al., 2014; d = .49). However, findings related to verbal working memory were mixed, with two meta-analyses finding small differences between the two groups (Abramovitch et al., 2013; d = -.34; Snyder et al., 2014; d = .22) and one meta-analysis finding no significant difference (Shin et al., 2014; g = .11). This difference is likely due to variation in tasks included in the meta-analyses, as Shin et al (2014) only included one verbal working memory task (digit span). These reviews suggest that individuals with OCD have deficits in the areas of working memory, inhibition, and cognitive flexibility. Differences in verbal working memory, however, appear small or non-existent.

The finding that individuals with OCD demonstrate EF deficits has led to the suggestion that EF deficits may be endophenotypes of OCD; that is, trait markers that links genes to symptoms of OCD (Taylor, 2012; Gottesman &

Gould, 2003). Clarifying whether EF deficits are endophenotypes of a disorder is crucial for several reasons. First identifying endophenotypes can help improve current diagnostic classification systems, by offering a further variable to assess (Lilienfeld, 2014). In addition, identifying endophenotypes can reveal important information about the causes and mechanisms of a disorder. There are five criteria used to define endophenotypes: i) associated with causes of the disorder, ii) trait-like (i.e. state independent; occurs in the individual even if they do not display the disorder) iii) heritable iv) co-segregation between the endophenotype and illness within families v) presence in unaffected relatives at a higher rate than the general population (Gottesman & Gould, 2003; Gould & Gottesman, 2006).

If EF deficits were endophenotypes of OCD, this would have important implications for our understanding of OCD. More specifically, it could suggest that symptoms of OCD (e.g. obsessions and/or compulsions) are caused directly by EF deficits. If this is the case, research into EFs may help resolve some of the contested issues with cognitive theories of OCD, such as helping to explain why some individuals experience more OITs than others, and why individuals vary in their suppression success. Alternatively, it could be that EF deficits, and symptoms of OCD are caused by a shared third factor (which could be a neurobiological factor, such as pre-frontal cortex dysfunction) which leads to both EF deficits *and* OCD symptoms (Snyder et al., 2014). In support of the idea that EF deficits are endophenotypes of OCD is evidence demonstrating that EFs do not change after receiving treatment for OCD (e.g. Kim et al., 2002; Nielen & Den Boer, 2003; Roh et al., 2005). In addition, unaffected first degree relatives of individuals with OCD also demonstrate EF deficits (e.g. Cavedini, Zorzi, Piccinni, Cavallini, & Bellodi, 2010; Chamberlain & Menzies, 2009; Rajender et al., 2011). In other words, these findings suggest that EF deficits are heritable and trait-like, two of the previously discussed criteria used to define endophenotypes (Gottesman & Gould, 2003; Gould & Gottesman, 2006).

Executive functions in subclinical obsessive-compulsive disorder

Finding EF deficits in individuals with subclinical OCD would support the view that EFs deficits are endophenotypes of OCD. Alternatively, not finding EF deficits in individuals with subclinical OCD may suggest either that EF deficits are not endophenotypes of OCD, or that intact EFs represent a protective factor against the development of OCD. Research investigating the role of EFs in subclinical OCD is extremely sparse, with varied methodologies, and inconsistent findings, making it difficult to draw strong conclusions. Surprisingly, individuals with subclinical OCD have been found to have *better* working memory than nonclinical individuals (on the Spatial Working Memory Task; SWMT - Johansen & Dittrich, 2013). Whereas individuals with subclinical OCD have been found to have poorer inhibition than nonclinical individuals (Go/No Go Task, Abramovitch et al., 2015). Finally, those with subclinical OCD have been found to have poorer cognitive flexibility than nonclinical individuals (WCST, Kim et al. 2009; Goodwin & Sher, 1992; Berg Card Sorting Task; BCST, Berg, 1948; Sternheim, Van Der Burgh, Berkhout, Dekker & Ruitter, 2014) and not different from nonclinical individuals (Intra/Extradimensional Shift Test, Sahakian and Owen, 1992; Johansen & Dittrich, 2013; WCST, Mataix-Cols, Barrios, Sánchez-Turet, Vallejo, Junqué, 1999).

A large contributing factor to the inconsistent findings in studies looking at EF in subclinical OCD is likely due to variations in how researchers have operationalised subclinical OCD. Indeed, this variation is made apparent by the large differences in OCD symptom severity of samples with subclinical levels of obsessive-compulsive symptoms. Sternheim et al. (2014) and Abramovitch et al. (2015) both used the Obsessive-Compulsive Inventory-Revised (OCI-R; Foa et al., 2002) to measure symptom severity in their sample of individuals with subclinical OCD. However, the mean OCD symptom score in Sternheim et al. (2014) was 24.4 (out of a total score of 72) the mean symptom score in Abramovitch et al (2015) was 36.6. Here, two studies have both recruited samples of individuals with subclinical OCD, but one of the samples is experiencing a much more severe level of symptomatology. A related (and previously discussed) issue here is that previously individuals with OCD generally score around 28.00 on the OCI-R (e.g. Foa et al., 2002). Sample means higher than 28.00 (e.g. in Abramovitch et al., 2015) are therefore likely to have included individuals with undiagnosed OCD. In other words, EF deficits in some studies may be representative of deficits in OCD, rather than subclinical OCD (Lee et al., 2009; Lee & Telch, 2010).

Further research is needed to clarify whether individuals with subclinical levels of obsessive-compulsive symptomatology demonstrate EF deficits, whilst taking care not to include individuals with undiagnosed OCD (this is the aim of chapter two).

Executive functioning and obsessive intrusive thoughts

If EF deficits do represent endophenotypes of OCD, one possibility is that the deficits directly cause the symptoms of OCD. If it was shown that EFs are related to symptoms of OCD in this way, this would help to resolve some of the issues surrounding cognitive theories of OCD (e.g. why are OITs more frequent in some individuals than others? And why do people vary in their suppression ability?). Although there is little empirical research exploring the link between EFs and symptoms of OCD, there has been some speculation on the relationship. Executive functions help to direct the thoughts that we experience and the behaviours we conduct, and so it seems reasonable to hypothesise that they may have an impact upon the symptoms of OCD. Working memory involves monitoring and updating information, and the removal of unwanted material (Rosen & Engle, 1998). Inhibition is the ability to inhibit a prepotent motor or attentional response. Poor working memory and inhibition, therefore, may prevent an individual from successfully suppressing OITs or inhibiting behavioural compulsions, causing symptoms to persist (Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005; Grisham & Williams, 2013). Cognitive inflexibility, or an inability to switch attention from one stimulus (e.g. an OIT) to another (e.g. the task at hand), may partially explain the repetitive OITs found in individuals with OCD (Abramovitch & Cooperman, 2015). In other words, individual differences in EFs may explain differences in suppression success and in the number of OITs experienced by different individuals.

In support of the idea that working memory may be implicated in the successful suppression of OITs, Brewin and Smart (2005) found that better working memory predicted fewer OITs in a suppression task, in a nonclinical student sample. Similarly, a nonclinical student sample who completed a working memory training intervention experienced fewer OITs during a suppression task than participants who did not complete the intervention (Bomyea & Amir, 2011). These findings offer preliminary evidence for the idea that individual differences in working memory may explain differences in suppression success, an idea not currently accounted for by cognitive theories of OCD. Further research is needed to investigate this relationship between working memory and suppression success. An interesting extension on these studies would be to investigate whether working memory is related to the dismissal of OITs, rather than in preventing them from occurring in the first place (this is the aim of chapter 4).

Are executive function deficits epiphenomena of obsessive-compulsive disorder?

An alternative explanation for EF deficits in individuals with OCD, is that they represent epiphenomena of OCD, rather than endophenotypes of the disorder. In other words, rather than EF deficits causing the symptoms of OCD, it may be the symptoms of OCD that are causing apparent EF deficits. Showing that EF deficits are epiphenomena of obsessive-compulsive symptoms, such as OITs, has important implications for our understanding of OCD. More specifically, it suggests that individual differences in EFs cannot explain differences in an individual's ability to suppress OITs. If EF deficits are the result of symptom interference, this also has important implications for the treatment of OCD, as it suggests that treating the symptoms would also alleviate the EF deficits (rather than teaching compensatory strategies for the EF deficits, Snyder et al., 2014).

Three lines of research support the idea that EF deficits may be epiphenomena of OCD. First, there is evidence that state factors, such as anxiety, have a negative impact on cognitive performance (e.g. Eysenck, Derakshan, Santos & Calvo, 2007). Second, individuals with OCD are more likely to report interference from a range of OCD symptoms (e.g. obsessions or compulsions) during a range of neuropsychological tasks, than nonclinical controls (Moritz, Hottenrott, Jelinek, Brooks, & Scheurich, 2012). Third, research has found improvements in EF test performance following treatment for OCD (Kuelz et al., 2006; Moritz, Kloss, Katenkkamp, Birkenr, & Hand, 1999; Nakao et al., 2005). Overall, it seems plausible that state factors, including OITs or compulsions, could account for the EF deficits found in individuals with OCD.

The Executive Overload Model of OCD was developed to explain the impact of state factors on EFs (Abramovitch, Dar, Hermesh & Schweiger, 2012). This model posits that an "overflow" of OITs in individuals with OCD, consumes cognitive resources and impairs performance on EF tasks. However, the model is in its infancy and to date, no studies have tested the claims of the model. Further research is therefore needed to test the Executive Overload Model of OCD, and to assess the impact of state variables on EF performance more generally (this is the aim of chapter three).

1.4: Thesis overview

This thesis investigates how EFs relate to obsessive-compulsive symptomatology. Three unresolved questions are addressed that may help to elucidate the relationship between EFs and OCD, and provide information which can be used to update cognitive theories of OCD: 1) Do individuals with subclinical OCD demonstrate EF deficits? (*chapter two*) 2) Can OITs lead to observable deficits in EFs? (*chapter three*) 3) Do individual differences in EF predict an individual's ability to dismiss OITs? (*chapter four*).

Chapter 2: Executive functioning in subclinical obsessive-compulsive disorder

Chapter two presents an experimental study which investigates the EF profile of individuals with subclinical OCD. Nonclinical individuals and individuals with subclinical OCD performed a range of EF tasks. To ensure the sample represented individuals with *subclinical* levels of obsessive-compulsive symptomatology, individuals who may have had undiagnosed OCD were carefully excluded using empirically derived clinical cut-off scores on a measure of OCD symptomatology (OCI-R). No differences were found between individuals with subclinical OCD and nonclinical individuals on tasks measuring working memory, inhibition, or cognitive flexibility. One possible explanation for these findings is that EF deficits found previously in individuals with OCD may be caused by symptom interference. Symptoms experienced by individuals with subclinical OCD, in the current study, may not have been severe enough to cause interference in the EF tasks.

Chapter 3: Mechanisms of OCD: Do obsessive-intrusive thoughts impair working memory?

Chapter three reports an experimental study which investigates whether OCD symptom interference (particularly OITs) can lead to deficits in EF (specifically, in working memory). This study was designed to investigate whether EF deficits are epiphenomena of OCD symptoms. More specifically, the study was designed to test a key prediction of the Executive Overload Model of OCD: does an increase in OITs lead to working memory deficits? A nonclinical sample was recruited; one group were primed with OITs and another group were not. Following this, all participants completed a working memory task. No differences were found in working memory between the two groups. These findings do not support the Executive Overload Model of OCD, and suggest that an increase in OITs does not lead to working memory deficits.

Chapter 4: The relationship between working memory and obsessive intrusive thought dismissibility.

Chapter four presents a study which investigates the mechanism that may link EF deficits (specifically working memory) to OCD symptoms. More specifically, the study aimed to investigate whether individual differences in working memory explained differences in an individual's ability to dismiss OITs. Participants completed a working memory task and a thought dismissibility task, where they were asked to dismiss OITs by replacing them with neutral thoughts. Based on limited previous research it was predicted that OIT dismissal would be related to working memory capacity; however, this hypothesis was not supported. This finding suggests that working memory is not implicated in an individual's ability to dismiss OITs.

Chapter 5: General discussion

Chapter 5 provides a summary and discussion of the results from this thesis. In particular, the lack of support for both the trait and state account of EF deficits on OCD is discussed. Future directions are suggested and include further testing of the Executive Overload Model of OCD, and the investigation of EFs in individuals with different sub-types of OCD.

Chapter 2: Executive functioning in subclinical obsessive-compulsive disorder

The current chapter aims to investigate the question of whether individuals experiencing subclinical levels of obsessive-compulsive symptomatology (or subclinical OCD, for short) demonstrate executive function (EF) deficits. First I will describe why it is important to find out more about the EF profiles of individuals with subclinical OCD. Next, I will present evidence which has investigated EFs in individuals with subclinical OCD, and explain why it is difficult to draw strong conclusions from the available evidence. Finally, I will introduce the present study, and describe how it will overcome some methodological issues found in previous studies.

The importance of investigating executive functioning in subclinical obsessive-compulsive disorder

Research into subclinical OCD is important as it can reveal information about the development and maintenance of OCD. There is a small amount of evidence to suggest that individuals with subclinical OCD are at increased risk of developing OCD (Black, Gaffney, Schlosser, & Gabel, 2003; Fullana et al., 2009). Based on this, it would be expected that any proposed endophenotypes of OCD would also be found in individuals with subclinical OCD. Endophenotypes are any variable that links genes to symptoms of a given disorder, and could be biochemical, neuropsychological, neuroanotomical, or cognitive variables, amongst others (Cannon & Keller, 2006; Gottesman & Gould, 2003). In other words, endophenotypes of OCD are variables that increase an individual's risk of developing OCD. Identifying endophenotypes of OCD, therefore, has important implications for early intervention into OCD. Research which finds proposed endophenotypes for OCD in individuals with subclinical OCD would support the idea that proposed endophenotypes are in fact endophenotypes whereas research which does not demonstrate the presence of proposed endophenotypes of OCD in individual with subclinical OCD would suggest that they are not endophenotypes.

Importantly, the evidence suggesting individuals with subclinical OCD are at increased risk of developing OCD is weak and has mainly looked at subclinical obsessive-compulsive symptoms in children (Black et al., 2003; Fullana et al., 2009). It therefore cannot be concluded, with confidence, that those with subclinical OCD are at increased risk of developing clinical OCD. It may be that in those with subclinical OCD, symptoms either persist at a subclinical level, or reduce further to a nonclinical level over time. If individuals with subclinical OCD are not at increased risk of developing OCD, then this would have important implications for research looking for candidate endophenotypes in those with subclinical OCD. More specifically, it would suggest that *not* finding a candidate endophenotype of OCD in those with subclinical OCD does not necessarily mean that it is not an endophenotype. It may suggest, for example, that a lack of the candidate endophenotype in individuals with subclinical OCD serves as a protective factor from developing the disorder. Identifying such protective factors could help inform interventions designed to prevent the development of OCD.

Executive function deficits have been proposed as candidate endophenotypes of OCD, and would therefore be useful to investigate in individuals with subclinical OCD (e.g. Chamberlain, Blackwell, Fineberg, Robbins, Sahakian, 2005; Taylor, 2012). Executive functions (EFs) are a set of cognitive control abilities that allow individuals to regulate their thoughts and behaviours (e.g. Miyake & Friedman, 2012). In support of the idea that EFs are endophenotypes of OCD is a large body of research that has demonstrated EF deficits in individuals with OCD (Abramovitch, Abramowitz, & Mittelman, 2013; Shin, Lee, Kim, & Kwon, 2014; Snyder, Kaiser, Warren, & Heller, 2014). Further support for this idea comes from the finding that EF deficits do not improve after treatment for OCD (e.g. Kim et al., 2002; Nielen & Den Boer, 2003; Roh et al., 2005). If it was the case that EF deficits were also found in individuals with subclinical OCD, this would add further weight to the idea that EF deficits are endophenotypes of OCD.

In contrast to this, if EF deficits were not found in individuals with subclinical OCD, then the interpretation of the finding is more difficult, as it could suggest one of (at least) two things. First, that EF deficits are not endophenotypes of OCD. If EF deficits are not endophenotypes of OCD, it may be that they are caused by severe symptom interference, which would be present in clinical OCD but not subclinical OCD. In other words, troublesome symptoms, such as OITs, may interfere with EF task performance (e.g. by increasing anxiety), leading to apparent EF deficits. An alternative explanation would be that EF deficits are endophenotypes of OCD, but they are not present in individuals with subclinical OCD, as intact EFs serve as protective factors from the development of OCD. In other words, although individuals with subclinical OCD experience troubling symptoms of OCD, these symptoms either persist, or improve, due to better EFs (compared to those who develop OCD).

Clarifying the EF profile of individuals with subclinical OCD clearly has important implications for our understanding of the development and maintenance of OCD. However, relatively little research has investigated EFs in those with subclinical OCD. Studies in this area are generally conducted in a similar manner; two groups of participants are recruited (nonclinical and subclinical OCD) and their performance on a range of EF tasks is compared. Despite these similarities, the method of measuring EF varies between studies, as does the method of operationalising OCD. As a result, it is currently difficult to draw strong conclusions about the EF profiles of individuals with subclinical OCD. There are theoretical reasons to expect that individuals with subclinical OCD would demonstrate EF deficits. More specifically, although not an official diagnostic category, subclinical OCD can be thought of as a milder form of OCD (e.g. Gibbs, 1996; Grabe et al., 2000), and so it would be surprising if the cognitive profiles of individuals with subclinical OCD and clinical OCD differed. Indeed, there is evidence demonstrating a range of OCD-relevant variables exist on a continuum, rather than as discrete categories (e.g. OCD vs nonclinical) (e.g. Abramovitch et al., 2014; Berry & Laskey, 2012; Clark & Rhyno, 2005). Despite these theoretical reasons to expect individuals with subclinical OCD would demonstrate EF deficits, findings from this area are largely inconsistent and contradictory.

Are there executive function deficits in subclinical obsessive-compulsive disorder?

In support of the idea that individuals with subclinical OCD demonstrate EF deficits, Abramovitch, Shaham, Levin, Bar-hen, and Schweiger (2015) compared inhibition abilities of twenty-seven individuals with subclinical OCD and twenty-seven nonclinical individuals. Individuals allocated to the subclinical OCD group were those who scored more than one standard deviation above the sample mean on an OCD symptom measure (Obsessive-Compulsive Inventory-Revised, OCI-R; Foa et al., 2002). Individuals in the nonclinical group were those who scored less than one standard deviation below the sample mean score on the OCI-R. Inhibition was measured using the Expanded Go/No Go Task (Neurotrax, 2003), whereby participants were required to respond as quickly as possible to a sequence of coloured squares by clicking a mouse button. Participants were also given a rule that instructed them *not* to click on a particular coloured square, and therefore had to inhibit this prepotent response. Individuals with subclinical OCD performed poorer on the Expanded Go/No Go task than nonclinical indivuals. This finding suggests that, similarly to individuals with OCD, individuals with subclinical OCD have inhibitory deficits.

Further support for the idea that individuals with subclinical OCD demonstrate EF deficits comes from a range of studies demonstrating poorer cognitive flexibility in individuals with subclinical OCD than nonclinical individuals (Wisconsin Card Sorting Task, WCST; Kim et al. 2009; Goodwin & Sher, 1992; Berg Card Sorting Task; BCST, Berg, 1948; Sternheim, Van Der Burgh, Berkhout, Dekker & Ruitter, 2014). For example, Kim, Jang, and Kim (2009) recruited twenty-one individuals with subclinical OCD and twenty nonclinical individuals. Individuals allocated to the subclinical OCD group were those who scored in the top three percent on two OCD symptom measures (Padua Inventory, PI, Sanavio, 1998; Maudsley Obsessive Compulsive Inventory, MOCI, Hodgson & Rachman, 1977) out of a sample of 670 students.

Those allocated to the nonclinical group were those who received “average” scores on the two measures. Cognitive flexibility was measured using the WCST (Kim et al., 2009); whereby participants were required to sort cards based on an unknown rule. Each card varied based on shape, colour, and number, and participants were required to deduce the currently appropriate sorting rule based on “correct” or “incorrect” feedback from the experimenter. Those with subclinical OCD performed poorer than the nonclinical individuals on the WCST. This finding suggests that, similarly to individuals with OCD, those with subclinical OCD demonstrate cognitive flexibility deficits.

In contrast to the research demonstrating EF deficits in individuals with subclinical OCD, there is evidence suggesting no differences between EFs in those with subclinical OCD and nonclinical individuals (Johansen & Dittrich, 2013; Mataix-Cols, et al., 1999, Sahakian and Owens, 1992; Spitznagel & Suhr, 2002). Further to this, there is some evidence, surprisingly, demonstrating *superior* EF in those with subclinical OCD than nonclinical individuals (Johansen & Dittrich, 2013; Soref et al., 2008). Johansen and Dittrich (2013) administered a working memory task (Spatial Working Memory Task; SWMT from the Cambridge Neuropsychological Test Automated Battery; CANTAB) to twenty-six individuals with subclinical OCD and twenty-three nonclinical individuals. Individuals were allocated to the subclinical OCD group if they had scored above the sample mean on a measure of OCD symptomatology (Yale-Brown Obsessive-Compulsive Scale, Y-BOCS; Goodman et al., 1989) and a measure of cognitive and executive impairments associated with OCD (Cognitive Assessment Instrument of Obsessions and Compulsions, CAOIC; Dittrich, Johansen, & Fineberg, 2011). Individuals with subclinical OCD performed better on the SWMT than the nonclinical individuals. This finding suggests that individuals with subclinical OCD have superior working memory to nonclinical individuals. Such a finding differentiates those with subclinical OCD from those with clinical OCD, as those with clinical OCD demonstrate working memory deficits (e.g. Snyder et al., 2014).

In contrast to evidence demonstrating inhibition deficits in individuals with subclinical OCD (Abramovitch et al., 2015), there is evidence demonstrating individuals with subclinical OCD have *better* inhibitory abilities than nonclinical individuals. Soref, Dar, Argov, and Meiran (2008) recruited ten individuals with subclinical OCD and ten nonclinical individuals. All participants were administered the letter version of the flanker task (Eriksen & Eriksen, 1974). Participants were allocated to the subclinical OCD group if they had scored within the top quartile of scores on an OCD symptom measure (the OCI-R; Foa et al., 2002), from a sample of 171 students. Nonclinical individuals had all scored within the bottom quartile of scores on the same OCD symptom measure. For the flanker task, participants were required to classify a letter (H or S) which was flanked by compatible (e.g. HHHHH) or incompatible (e.g. SSHSS) letters. Individuals with subclinical OCD performed better on the flanker task than nonclinical individuals, reflected by lower inhibition interference costs (i.e. response time of incompatible trials minus response time of the compatible trials). This finding suggests that individuals with subclinical OCD demonstrate superior inhibitory abilities than nonclinical individuals. Such a finding differentiates those with subclinical OCD from those with clinical OCD, as those with clinical OCD demonstrate inhibitory deficits (e.g. Snyder et al., 2014).

There is also evidence demonstrating no difference between nonclinical individuals and those with subclinical OCD in cognitive flexibility, contradicting the previously discussed findings which showed a deficit in those with subclinical OCD (Intra/Extradimensional Shift Test, Sahakian and Owens, 1992; Johansen & Dittrich, 2013; WCST, Mataix-Cols, Barrios, Sánchez-Turet, Vallejo, Junqué, 1999, Spitznagel & Suhr, 2002). For example, Mataix-Cols et al. (1999) administered the WCST (Heaton, 1981) to thirty-five individuals with subclinical OCD and thirty-six nonclinical individuals. Individuals were included in the subclinical OCD group if they scored more than one standard deviation above the sample mean on a measure of OCD (PI, Sanavio, 1998) and were included in the nonclinical group if they scored more than one standard deviation below the sample mean on the same measure. There was no difference on the WCST performance between the two groups. This finding suggests that individuals with subclinical OCD do not demonstrate cognitive flexibility deficits. Such a finding differentiates those with subclinical OCD from those with clinical OCD, as those with clinical OCD demonstrate cognitive flexibility deficits (e.g. Snyder et al., 2014)

Evidently, the state of EF profiles in individuals with subclinical OCD is currently unclear, reflected by a range of contradictory findings. Methodological variations within the literature make it even more difficult to draw strong conclusions about the state of EFs in subclinical OCD. Interpreting the available research whilst accounting for these variations in methodology is crucial for gaining a deeper understanding of executive functioning in individuals with subclinical OCD.

One factor that may explain some of the contradictory findings in this area is that some groups with subclinical OCD may have included individuals with undiagnosed OCD. In other words, it may well be that individuals with subclinical OCD do *not* demonstrate EF deficits, but they sometimes appear to show EF deficits due to the inclusion of large numbers of individuals with OCD. In support of this idea, Kim et al. (2009) found individuals with subclinical OCD performed poorer on the WCST than nonclinical individuals, but Mataix-Cols et al. (1999) did not find such a difference when using the same task. However, Kim et al. (2009) operationalised subclinical OCD using a more conservative cut-off score than Mataix-Cols et al. (1999) (top 3% of scorers on two OCD measures: MOCI; Hodson & Rachman, 1977, & PI; Sanavio, 1998 vs one standard deviation above sample mean on the PI). It is therefore highly likely that Kim et al. (2009) included many more individuals with undiagnosed OCD than Mataix-Cols et al. (1999), thus potentially skewing the results to more closely reflect EF profiles in OCD than subclinical OCD. Indeed, previously it has been found that around three-quarters of individuals, who fall in the top three percent of scorers on a measure of OCD, have OCD (Lee, Yost, & Telch, 2009; Lee & Telch, 2010). To the author's knowledge, no studies investigating the executive functioning of individuals with subclinical OCD have attempted to exclude individuals with undiagnosed OCD. Future research investigating EFs in subclinical OCD, therefore, needs to carefully exclude individuals with undiagnosed OCD.

To summarise the evidence so far, the relatively small number of studies that have investigated EFs in subclinical OCD have produced a range of contradictory findings, making it impossible to draw strong conclusions. One strong possibility is that individuals with subclinical OCD do not demonstrate EF deficits, and this would become apparent if individuals with undiagnosed OCD were excluded from studies. If this were the case, it would suggest that intact EFs serve as a protective factor against the development of OCD, or that previous EF deficits found in OCD were caused by severe symptom interference (e.g. a large number of OITs; Abramovitch, Dar, Hermesh, & Schweiger, 2012). However, another strong possibility is that individuals with subclinical OCD do demonstrate EF deficits, and findings which demonstrate otherwise are spurious. Indeed, there are many other similarities between subclinical OCD and clinical OCD (e.g. appraisals, OIT frequency, etc. Abramowitz et al., 2014) and it would be plausible that there are also similarities in EF profiles. If individuals with subclinical OCD do demonstrate deficits, this would support the idea that EF deficits are endophenotypes of OCD. Further research is clearly needed to investigate the EF profiles of individuals with subclinical OCD.

Important methodological considerations

Given the lack of consistency concerning EFs in subclinical OCD, it is particularly important that studies in this area carefully consider a range of methodological factors, which have varied significantly throughout the literature. One such consideration is how best to operationalise OCD (as previously discussed). More specifically, it is important that studies exclude individuals with undiagnosed OCD, so that the samples more accurately represent subclinical OCD. One convenient method of doing this is to exclude individuals who score over empirically derived clinical cut-off scores of questionnaire measures (Abramowitz et al., 2014). These clinical cut-off scores have been empirically derived and are able to distinguish between individuals with OCD and the rest of the general population. For example, individuals who score 21 or over on the OCI-R (Foa et al., 2002) are likely to have OCD. Future studies, therefore, could quickly exclude individuals with OCD by excluding all individuals who score 21 or over on the OCI-R.

A second methodological consideration for future studies investigating the EF profiles of individuals with subclinical OCD is choosing accurate and stringent EF measures. Some of the tasks used previously to measure EFs are broad in measurement, capturing several EFs in the same task, and making it difficult to draw conclusions about specific EFs. Of note, is the commonly used WCST, which not only requires cognitive flexibility, but also abstract thinking and concept formation (Barcelo, 2001) as well as working memory and inhibition (Cinan & Tanör, 2002). Based on this, it cannot be concluded whether individuals with subclinical OCD who perform poorer on the WCST than nonclinical individuals (e.g. Kim et al., 2009), are demonstrating cognitive flexibility deficits, or deficits in some other area, such as working memory. A more stringent measure of cognitive flexibility is the Switching, Inhibition and Flexibility Task (SwIFT; FitzGibbon, Cragg & Carroll, 2014). For this task, participants are required to sort stimuli by either shape or colour, on a computer**.** This task differs from the WCST, in that participants do not have to infer the rule by which they are required to sort; they are told what the rule is. This reduces ambiguity and incidental demands of the task, and means that it is a more stringent measure of cognitive flexibility than the WCST. Future studies looking to measure cognitive flexibility, therefore, should use a more stringent task such as the SwIFT.

A third consideration for future studies in this area is the impact of confounding variables. In particular, depression and anxiety have been found to moderate neuropsychological test performance (e.g. Basso, Bornstein, Carona, & Morton, 2001; Moritz, Fricke & Hand, 2001; Bédard, Joyal, Godbout, & Chantal, 2009; Eysenck, Derakshan, Santos & Calvo, 2007) and should therefore be accounted for when comparing EFs between two groups. However, a recent review of the literature concluded that there are no factors which have reliably demonstrated a confounding effect on EFs (Abramovitch & Cooperman, 2015). In addition, those studies that have controlled for depression when comparing EFs in individuals with subclinical OCD and nonclinical individuals, *have* found significant differences between the groups, suggesting depressive symptoms do not explain the differences (Abramovitch et al., 2015; Kim et al., 2009). Due to the lack of clarity surrounding the impact of depression and anxiety on EF performance, it is vital that future research takes full account of depressive and anxious symptomatology.

The present study

The present study aims to investigate the EF profiles of individuals with subclinical OCD. The key question of the present study, therefore, is whether individuals with subclinical OCD demonstrate poorer EFs than nonclinical individuals. This question will be answered by comparing individuals with subclinical OCD, and a group of nonclinical individuals, on tasks assessing working memory, inhibition, and cognitive flexibility. Efforts were made to exclude individuals with undiagnosed OCD. Executive function tasks were carefully selected to represent stringent measures of each construct, and confounding variables (depression and anxiety) were measured and controlled for.

Working memory was assessed by the Digit Span Backward Subscale of WAIS (WAIS DSB - The Psychological Corporation, 1997). For this task, participants are required to remember a list of numbers and then recall the same list, backwards. Although individuals with OCD generally demonstrate working memory deficits (e.g. Snyder et al., 2014), no differences in performance between individuals with OCD and nonclinical individuals have repeatedly been found on the WAIS DSB (e.g. Snyder et al., 2014; Segalas et al., 2008; Krishna et al., 2011). Due to the similarities between subclinical OCD and clinical OCD, it was therefore hypothesised that there would be no differences between individuals with subclinical OCD and nonclinical individuals on the WAIS DSB.

Inhibitory control was assessed by the arrow version of the flanker task (Eriksen & Eriksen, 1974). This task differs slightly to the flanker task used by Soref et al. (2008), in that the central stimuli is an arrow (rather than a letter), flanked by arrows either facing in the same direction or in the opposite direction. Based on the wealth of evidence that individuals with OCD demonstrate inhibition deficits (Abramovitch et al., 2013; Shin et al., 2014; Snyder et al., 2014), it was hypothesised that individuals with subclinical OCD would perform poorer than nonclinical individuals on the flanker task.

Cognitive flexibility was assessed using the Switching, Inhibition and Flexibility Task (SwIFT; FitzGibbon, Cragg & Carroll, 2014). This task has not yet been used with individuals with OCD or those with subclinical OCD.

Based on the wealth of evidence demonstrated cognitive flexibility deficits in individuals with OCD (Abramovitch et al., 2013; Shin et al., 2014; Snyder et al., 2014), it was hypothesised that individuals with subclinical OCD would perform poorer than nonclinical individuals on the SwIFT task.

To summarise the study's hypotheses:

Hypotheses:

There will be no difference in working memory between individuals with subclinical OCD and nonclinical individuals.

Individuals with subclinical OCD will demonstrate poorer inhibition than nonclinical individuals.

Individuals with subclinical OCD will demonstrate poorer cognitive flexibility than nonclinical individuals.

2.1: Method

Design

The experiment had a one-way, independent samples design. The independent variable was obsessive-compulsive symptom group, with two levels: nonclinical and subclinical. There were five primary dependent variables: one working memory variable (total score on the Digit Span Backward Subscale of WAIS: WAIS DSB; The Psychological Corporation, 1997), two cognitive flexibility variables (reaction time and accuracy scores on the Switching Inhibition and Flexibility Task, SwIFT; FitzGibbon, Cragg & Carroll, 2014), and two inhibition variables (reaction time and accuracy scores on the flanker task; Eriksen & Eriksen, 1974). Control variables were depression and anxiety scores (as measured on the Depression Anxiety and Stress Scale, DASS; Lovibond & Lovibond, 1995).

Participants

Staff and students from The University of Sheffield were invited to take part in the study via e-mail. Three hundred and four participants showed interest in participating in the study. Before the study began, all participates were screened for the study based on their scores on the Obsessive-Compulsive Inventory-Revised (OCI-R; Foa et al., 2002). Individuals were invited to participate in the study if they scored below the empirically derived clinical cut-off of 21 on the OCI-R (Foa et al., 2002) and reported no previous diagnosis of OCD. This exclusion criterion was used to ensure that the sample represented subclinical OCD and nonclinical samples, and not samples of individuals with OCD. As a result of the screening procedure 195 were invited to participate in the study. Of these participants, 54 (19 males, 34 females, 1 'other' but did not specify; mean age = 24 years; age range = 18-48 years) agreed and completed the study. A median split of OCI-R scores created two groups (based on a median OCI-R score of 11): a subclinical OCD group (n = 27; mean age = 22 years; 14 males, 12 females, 1 other) and a nonclinical group (n = 27; mean age = 26 years; 5 males, 22 females). See table 1 for further comparisons between the two groups. Participants provided informed consent and received either course credits or £5 cash reimbursement for their time.

Materials

Questionnaires

The *Obsessive Compulsive Inventory – Revised* (OCI-R; Foa et al., 2002) is an 18-item measure used to assess OCD symptoms. The OCI-R comprises a list of symptoms (e.g. "I check things more often than necessary") for which participants indicate on a scale from 0 ("not at all") to 4 ("extremely") how distressed the symptoms have made them in the past month. Items cover six sub-scales: (a) washing, (b) checking/doubting, (c) obsessing, (d) mental neutralizing, (e) ordering, and (f) hoarding. Total score of the OCI-R was calculated by summing all the items. Scores on the OCI-R range from 0-72 with higher scores indicating higher levels of OCD symptomatology. The recommended cut-off score for the OCI-R is 21, with scores at or above this level indicating the likely presence of OCD (Foa et al., 2002). The OCI-R has demonstrated good psychometric properties in nonclinical participants; excellent internal consistency ($\alpha = .89$), good test-retest reliability (1 week – $r = .84$), and convergent validity (significant positive correlations were found with the OCI-R and a range of OCD measures; Foa et al., 2002). Discriminant validity was mixed, with high correlations between the OCI-R and Beck Depression Inventory (BDI; $r = .7$); however, this is common across all OCD symptom measures (Foa et al., 2002). The internal consistency of the OCI-R, in this study, was $\alpha = .48$. The internal consistency of the OCI-R subscales was: washing, $\alpha = .61$; checking/doubting, $\alpha = .53$; obsessing, $\alpha = .88$; mental neutralizing, $\alpha = .47$; ordering, and hoarding, $\alpha = .77$.

The *Depression Anxiety and Stress Scale* (DASS; Lovibond & Lovibond, 1995) is a 42-item measure of depression, anxiety and stress. Participants were presented with statements (e.g. "I found myself getting upset by quite trivial things") and were required to indicate how much each statement applied to them in the past month, on a scale from 0 ("did not apply to me at all") to 3 ("applied to me very much or most of the time"). Scores for depression, anxiety, and stress are calculated by summing the items for each subscale, with higher scores indicating higher levels of each construct. Scores on the depression subscale range from 0-42 (0-9 = normal; 10-13 = mild; 14-20 = moderate; 21-27 = severe; 28-42 = very severe), scores on the anxiety subscale range from 0-42 (0-7 = normal; 8-9 = mild; 10-14 = moderate; 15-19 = severe; 20-42 = very severe), and scores on the stress subscale range from 0-42 (0-14 = normal; 15-18 = mild; 19-25 = moderate; 26-33 = severe; 34-42 = very severe). The DASS has demonstrated excellent internal consistency (α =.92 -.97 for a sample of individuals with OCD and nonclinical individuals; Antony, Bieling, Cox, Enns, & Swinson, 1998), and good convergent and divergent validity (when compared with other measures of depression and anxiety in nonclinical individuals and those with OCD; Antony et al., 1998). In this study, the internal consistency for each subscale was: depression (α = .95), anxiety (α = .91), & stress (α = .94).

Executive function tasks

A computerised version of the flanker task (Eriksen & Eriksen, 1974) was used to measure inhibition. The flanker task was completed on a computer with a 17-inch monitor and running E-Prime 2.0 software (Psychology Software Tools, Inc., Pittsburgh, PA). Participants were required to indicate the direction that a central arrow was pointing in (either left or right), by pressing a key. The arrow was surrounded by either 1) four arrows pointing in the same direction (congruent trials), 2) four arrows pointing in the opposite direction (incongruent trials), or 3) four Xs (neutral trials). Participants completed 18 practice trials followed by 144 experimental trials (48 congruent, 48 incongruent, 48 neutral). Stimuli were presented in a pseudorandomized order. Two dependent variables were computed for the flanker task: reaction time interference cost, and accuracy interference cost. Interference costs were calculated as the difference in reaction times between congruent and incongruent flanker trials. This interference cost reflects an individual's ability to inhibit a prepotent response to the distractor arrows, such that a higher interference cost represents poorer inhibition.

The Switching, Inhibition and Flexibility Task (SwIFT; FitzGibbon, Cragg & Carroll, 2014) was used to measure cognitive flexibility. The SwIFT was completed on a computer with a 17-inch monitor and running E-Prime 2.0 software (Psychology Software Tools, Inc., Pittsburgh, PA). Participants were required to sort bivalent stimuli by one of two rules (colour or shape) by pressing one of two keys. The rules were pseudo-randomized so that on 50% of trials participants would have to match stimuli on the same rule as the previous trial (e.g. "shape" then "shape") and on 50% of trials participants would have to match stimuli on a different rule to the previous trial (e.g. "colour" then "shape"). Participants completed three mixed blocks of 48 trials each. Two dependent variables were computed for the SwIFT: reaction time switch cost and accuracy switch cost. Switch costs were calculated as the difference between non-switch trials and switch trials. This switch cost reflects an individual's ability to adapt to the changing rules of the task, such that a higher switch cost represents poorer cognitive flexibility.

The Digit Span Backward Subscale of WAIS (WAIS DSB - The Psychological Corporation, 1997) was used to assess working memory. The experimenter read out a series of short strings of digits to the participant (e.g. 3, 8, 4) who was then required to repeat back each string in a backwards order (e.g. 4, 8, 3). Participants were presented with seven blocks of two trials each. The length of the strings of digits increased throughout each block, beginning with two digits and finishing with eight digits. The task ended when participants made two errors on a single block. Participants scored 1 mark for each trial that they answered correctly. The maximum possible score was 14.

Procedure

Individuals were first screened online, using the survey platform Qualtrics, where they completed the OCI-R (Foa et al., 2002) and the DASS (Lovibond & Lovibond, 1995). Individuals who were eligible, and willing, to participate in the study (those who scored lower than the clinical cut-off on the OCI-R) attended the laboratory to complete the flanker task, followed by the SwIFT and WAIS DSB. The order of the tasks was the same for all participants. Participants sat approximately 80 cm from the screen.

2.2: Results

Demographic characteristics

Demographic and clinical characteristics of the nonclinical and subclinical OCD groups are provided in Table 1. Between-group differences in demographic information were examined with analysis of variance (ANOVA; age, OCI-R score, DASS depression score, DASS anxiety score, DASS stress score) or Pearson's chi-square analysis (gender), as appropriate. The subclinical OCD group scored significantly higher on the OCI-R than the nonclinical group, demonstrating that the groups differed significantly in their OCD symptoms. The nonclinical group were significantly older than the subclinical OCD group and had significantly fewer males than the subclinical

OCD group. In addition, the subclinical OCD group scored significantly higher on the depression subscale of the DASS. No significant differences were found between the two groups on the anxiety or stress subscales of the DASS.

Table 1 - Demographic and clinical characteristics

	Nonclinical (*n* = *27*)	**Subclinical OCD (*n* = *27*)**	**Analysis**
	Mean (SD)	Mean (SD)	
Age (years)	25.85 (7.87)	22.15 (4.06)	$F(1, 52) = 4.72$, $p = 0.03$, $\eta^2 = .083$
Male: Female	5: 22	14: 12[a]	$\chi^2(1) = 7.18$, $p = -.007$[b]
OCI-R Total (Max score 72; clinical cut-off < 21)	7.86 (1.75)	15.4 (2.25)	$F(1, 52) = 189.1$, $p < 0.001$, $\eta^2 = .78$
DASS Depression Total (Max score 42; normal; 0-9; moderate 14-20; extremely severe 28+)	11.56 (7.32)	17.04 (10.41)	$F(1, 52) = 5.01$, $p = 0.03$, $\eta^2 = .088$

DASS Anxiety Total (Max score 42 normal 0-7 moderate 10-14; extremely severe 20+)	9.7 (6.78)	12.26 (8.16)	$F(1, 52) = 1.57, p = .216, \eta^2 = .029$
DASS Stress Total (Max score 42; normal 0-14; moderate 19-25; extremely severe 34+)	13.41 (7.59)	18.26 (10.83)	$F(1, 52) = 3.64, p = .062, \eta^2 = .065$

* = significant at $p = 0.05$ level

[a] = 1 participant stated gender as “other” (not specified)

[b] = excluded “other” as this participant does not identify as a male or female and therefore cannot be included in the gender comparison analysis.

Relationship between depression, anxiety, gender and executive functions

As differences were found in depression, age, and gender scores between those in the subclinical OCD group and the nonclinical group, a series of Pearson’s correlation analyses and point-biserial correlation analyses were run to explore the relationships between depression, anxiety, gender, age, and cognitive flexibility (SwIFT reaction time switch cost and SwIFT accuracy switch cost), inhibition (flanker reaction time interference cost and flanker reaction time interference cost), and working memory (BDS total score). No significant relationships were observed between any of the variables. More specifically, no significant relationships were observed between depression and SwIFT reaction time switch cost ($r[54] = .26$, $p = .054$); depression and SwIFT accuracy switch cost ($r[54] = -.06$, $p = .666$); depression and flanker reaction time interference ($r[54] = -.09$, $p = .497$); depression and flanker accuracy interference cost ($r[54] = .01$, $p = .922$); or depression and BDS total score ($r[54] = -.17$, $p = .22$).

As with depression, no significant relationships were found between anxiety and SwIFT reaction time switch cost ($r[54] = .09$, $p = .521$); anxiety and SwIFT accuracy switch cost ($r[54] = -.18$, $p = .19$); anxiety and flanker reaction time interference ($r[54] = -.16$, $p = .244$); anxiety and flanker accuracy interference cost ($r[54] = .11$, $p = .44$); or depression and BDS total score ($r[54] = -.16$, $p = .25$).

As with depression and anxiety, no significant relationships were found between gender and SwIFT reaction time switch cost ($r_{pb} = -.01$, $n = 54$, $p = .93$); gender and SwIFT accuracy switch cost ($r_{pb} = .06$, $n = 54$, $p = .66$); gender and flanker reaction time interference ($r_{pb} = .01$, $n = 54$, $p = .92$); gender and flanker accuracy interference cost ($r_{pb} = .03$, $n = 54$, $p = .83$); or depression and BDS total score ($r_{pb} = -.18$, $n = 54$, $p = .19$).

Finally, no significant relationships were found between age and SwIFT reaction time switch cost ($r[54] = -.23$, $p = .095$); age and SwIFT accuracy switch cost ($r[54] = .21$, $p = .121$); age and flanker reaction time interference ($r[54] = .01$, $p = .94$); age and flanker accuracy interference cost ($r[54] = -.21$, $p = .13$); or age and BDS total score ($r[54] = -.17$, $p = .209$). Due to the lack of relationships between depression, anxiety, gender, and age, and each of the EF measures, none of the variables were controlled for in the following analyses.

Are there working memory differences between individuals with subclinical obsessive-compulsive disorder and nonclinical individuals?

In order to explore whether there were any differences in working memory between the subclinical OCD group and the nonclinical group, a one-way ANOVA was conducted. Backward digit span total score was entered as a dependent variable. ANOVA confirmed no significant differences in BDS scores between the subclinical OCD group ($M = 7.74$, $SD = 2.10$) and the nonclinical group ($M = 7.52$, $SD = 2.23$), $F(1, 52) = .142$, $p = 0.708$.

Are there inhibition differences between individuals with subclinical obsessive-compulsive disorder and nonclinical individuals?

In order to explore whether there were any differences in inhibition between the subclinical OCD group and the nonclinical group, a MANOVA was conducted. Flanker reaction time interference cost and flanker accuracy interference cost were entered as dependent variables. Using Pillai’s trace, there were no significant inhibition differences between individuals with subclinical obsessive-compulsive disorder and nonclinical individuals, V = .022, F (2, 51) = .583, $p = .56$.

Are there cognitive flexibility differences between individuals with subclinical obsessive-compulsive disorder and nonclinical individuals?

In order to explore whether there were any differences in cognitive flexibility between the subclinical OCD group and the nonclinical group, a MANOVA was conducted. SwIFT reaction time switch-cost scores and SwIFT accuracy switch-cost were entered as dependent variables. Using Pillai's trace, there were no significant cognitive flexibility differences between individuals with subclinical obsessive-compulsive disorder and nonclinical individuals, V = .101, F (2, 51) = 2.86, p = .07.

Are there any relationships between obsessive-compulsive symptoms and executive functions?

Relationships between OCD symptoms and each of the EF tasks were explored using Pearson's correlation analysis. No significant relationships between OCD symptoms and any of the EF variables were found. A Bonferroni correction was made to correct for multiple comparisons, and P-values of <.0125 (.05/4) were considered to be significant. No significant relationships were found between OCI-R score and SwIFT reaction time switch cost (r[54] = .28, p = .04), SwIFT accuracy switch cost (r[54] = -.14, p = .28), flanker reaction time interference cost (r[54] = .14, p = .31), flanker accuracy interference cost (r[54] = .09, p = .54), or Backward Digit Span (r[54] = .03, p = .82). See Appendix A for scatter plots of the relationships between OCD symptoms and executive functions.

Relationships between OIT frequency (as measured by the INPIOS) and each of the EF tasks were explored using Pearson's correlation analysis. No significant relationships were found between INPIOS total score and SwIFT reaction time switch cost ($r[54] = .048$, $p = .73$), SwIFT accuracy switch cost ($r[54] = -.114$, $p = .41$), flanker reaction time interference cost ($r[54] = -.125$, $p = .37$), flanker accuracy interference cost ($r[54] = -.192$, $p = .16$), or Backward Digit Span ($r[54] = .176$, $p = .20$).

Are there any executive function differences between individuals with subclinical obsessive-compulsive disorder and nonclinical individuals when grouped based on a more reliable scale?

All previous analyses were carried out on individuals with subclinical OCD and nonclinical individuals who had been grouped based on their total score of the OCI-R. However, in the current study, the internal consistency of the OCI-R was low ($\alpha = .48$). A second set of analyses was therefore conducted whereby individuals were grouped based on their scores on an OCI-R subscale (obsessing) which had demonstrated a high internal consistency in the current study ($\alpha = .88$). A median split of OCI-R obsessing scores created two groups (based on a median score of 2): a subclinical OCD group ($n = 25$; mean age = 25 years; 10 males, 15 females) and a nonclinical group ($n = 29$; mean age = 23 years; 9 males, 19 females, 1 other). The previously conducted analyses (ANOVA, MANOVA, Pearson's correlation) were carried out on the new groups. However, again, no significant differences or relationships were found. ANOVAs and MANOVAs revealed no significant differences between individuals with subclinical OCD and nonclinical individuals in working memory ($p = .59$), inhibition ($p = .09$), or cognitive flexibility ($p = .82$). In addition, no significant relationships were found between total scores on the obsessing subscale and working memory ($p = .40$), inhibition ($p = .36$, $p = 44$), or cognitive flexibility ($p = .06$, $p = 94$).

2.3: Discussion

The present study aimed to determine whether individuals with subclinical OCD demonstrate EF deficits. In order to determine this, a group of individuals with subclinical OCD and a group of nonclinical individuals completed three EF tasks. Care was taken to overcome methodological issues that had previously been found in research in this area. Specifically, individuals who may have had OCD were excluded, stringent tests of each EF were chosen, and potential confounding variables were accounted for. Results across three separate measures of EF performance indicated that there were no differences in EFs between nonclinical and subclinical groups. In contrast to the study predictions, no differences were found between individuals categorised as having subclinical OCD and nonclinical controls in the areas of cognitive flexibility or inhibition. In line with predictions, no differences were found between individuals categorised as having subclinical OCD and nonclinical controls in working memory. In addition, no relationships were found between symptoms of OCD and any of the EF tasks.

The lack of difference in inhibition between individuals with subclinical OCD and nonclinical individuals is contrary to previous research in the area (Abramovitch et al., 2015; Soref et al., 2008). Abramovitch et al. (2015) found poorer inhibition with individuals with subclinical OCD (compared to nonclinical individuals), Soref et al (2008) found superior inhibition in individuals with subclinical OCD (and also used the flanker task). These contradictory findings create a complicated picture of inhibition in subclinical OCD. However, the findings from the current study are arguably more reliable than those found previously, as the sample recruited in the current study is more representative of individuals with subclinical OCD than the samples recruited previously. In support of this idea, the mean OCD symptom scores in Abramovitch et al. (2015) and Soref et al. (2008) are much higher than the clinical cut-off for each measure (36.6 and 31.3 respectively, vs 21) and even higher than mean symptom scores of individuals with OCD (28.01; Foa et al., 2002). In other words, the sample of individuals with subclinical OCD in Abramovitch et al. (2015) and Soref et al. (2008) were conceivably much more likely to have included individuals with undiagnosed OCD than the present study. Their findings should therefore be interpreted in that light. In addition, the sample size of the present study was substantially larger than use in Soref et al.'s (2008) study (*n* = 20), meaning the present finding is less likely to be a spurious result.

The finding that individuals with subclinical OCD do not have cognitive flexibility deficits is contrary to some previous research (Goodwin & Sher, 1992; Kim et al., 2009; Sternheim, et al., 2014). As with the case of inhibition in subclinical OCD, this is likely due to the inclusion of many individuals with clinical OCD, rather than subclinical OCD. Indeed, none of these studies attempted to exclude individuals with undiagnosed OCD from the subclinical OCD sample. In fact, Sternheim et al. (2014) *only* included individuals if they scored over the clinical cut-off on an OCD symptom measure (OCI-R). In a study which operationalised subclinical OCD using a liberal cut-off criterion (i.e. there were likely fewer individuals with undiagnosed OCD included), Johansen and Dittrich's (2013) findings aligned with those of the present study. In other words, it seems that individuals with subclinical obsessive-compulsive symptoms do not demonstrate cognitive flexibility deficits, and the findings from some previous studies may have been due to the inclusion of individuals with undiagnosed OCD.

Further indications that the current findings accurately represent the state of cognitive flexibility in subclinical OCD comes from the fact that the current study used a more stringent measure of cognitive flexibility (the SwIFT) than several of the previous studies in this area (e.g. the WCST, which assesses a number of cognitive abilities in addition to cognitive flexibility). As a result, more confidence can be placed in the finding that individuals with subclinical OCD do not demonstrate cognitive flexibility deficits. Previous findings demonstrating deficits on the WCST in individuals categorised as having subclinical OCD (e.g. Kim et al., 2009), may in fact represent deficits in another area, such as concept formation (Barcelo, 2001), as the task is broad in measurement (Snyder et al., 2014).

In summary, it would appear that the EF deficits that characterise clinical OCD (Abramovitch et al., 2013; Shin et al., 2014; Snyder et al., 2014) are not present in those categorised as having subclinical OCD. Although EF deficits have previously been found in subclinical OCD, the samples in these studies – intended to reflect *subclinical* OCD – may conceivably have included large numbers of individuals with undiagnosed clinical OCD. In contrast, the present study deliberately sought to recruit a sample specifically representative of individuals with subclinical obsessive-compulsive symptoms (individuals who score highly on measures of OCD but do not meet diagnostic criteria for clinical OCD), in order to address previous problems of unrepresentative sampling.

The finding that individuals with subclinical OCD do not demonstrate EF deficits could plausibly suggest one of two things. First, that EF deficits are endophenotypes of OCD, but individuals with subclinical OCD are not at increased of developing OCD, and therefore do not show EF deficits. Although there is some evidence that individuals with subclinical levels of obsessive-compulsive symptomatology are at increased risk of developing OCD, this has only been found in children (Black et al., 2003; Fullana et al., 2009). In other words, children with subclinical OCD may be at increased risk of developing OCD, but not adults. Indeed, the average age of the sample with subclinical OCD in the current study was 22, and most individuals with OCD develop the disorder much earlier than this (e.g. Millet et al., 2004). If this is the case, the lack of EF deficits in adults with subclinical OCD may serve as a protective factor from the development of OCD. Intact inhibition and working memory may help an individual suppress upsetting OITs (e.g. Brewin & Smart, 2005). Intact cognitive flexibility may help an individual re-direct their attention from an upsetting OIT to a less upsetting thought.

A second, and arguably more plausible, possibility is that EF deficits do not represent endophenotypes of OCD. Rather, EF deficits found in OCD may have been caused by state factors relating to clinical OCD, such as the experience of OITs (Abramovitch et al., 2011; Abramovitch et al., 2014; Snyder et al., 2014). For example, repeated checking of task responses may lead to underperformance on such tasks (Moritz, Hottenrott, Jelinek, Brooks, & Scheurich, 2012) and experiencing distressing OITs during an EF task may lead to impaired performance in those with OCD (Abramovitch et al., 2012; Teasdale, Proctor, Loyd, & Baddeley, 1993). Indeed, experiencing task-unrelated thoughts during an EF task can also lead to impaired performance (Cheyne, Solman, Carriere, & Smilek, 2009; Smallwood & Schooler, 2006; Smallwood et al., 2004). Individuals with subclinical OCD experience less functional impairment than individuals with OCD (de Bruijn et al., 2010) and may therefore be less vulnerable to symptom interference whilst completing an EF task. If EF deficits were the result of symptom interference, this could explain the consistent finding that individuals with OCD do not underperform on the WAIS DSB (The Psychological Corporation, 1997; Snyder et al., 2014), as the task is much shorter than other working memory tasks, leaving little time for symptom interference. However, whether EF deficits are the cause or consequence of OCD cannot be determined with confidence from cross-sectional studies, and would instead require longitudinal or experimental designs. Future studies could begin to address this question directly, for example, by inducing OITs in participants to determine whether it causes interference with EF task performance. Finding task underperformance on individuals who were induced with OITs would suggest that apparent EF deficits are caused by state factors.

There are several limitations of the current study that should be considered. First, there were differential methods of reimbursement; some participants received course credit and others received £5 cash. However, the data on which participants received which form of reimbursement was not recorded, meaning comparisons between the two methods of reimbursement cannot be made. It may be, for example, that those who are paid cash perform better on the EF tasks, as the cash reimbursement increases motivation more than course credit. There may have been more cash payments made to those with subclinical OCD, thus increasing their motivation and EFs in turn.

Second, although care was taken to recruit a sample with subclinical obsessive-compulsive symptoms, and to exclude those with undiagnosed OCD, it is possible that the sample may have more closely represented a nonclinical sample. Indeed, the OCI-R score of the subclinical OCD group is only marginally higher than nonclinical participants, found previously (15.4 vs 14.9; Abramowitz et al., 2014). Future studies may take care to recruit participants who score under, but closer to, the clinical cut-off for OCD (21 on the OCI-R; Foa et al., 2002), in order to more closely represent individuals with subclinical obsessive-compulsive symptoms. While this would be methodologically challenging and labour intensive, it would nevertheless increase confidence in the representativeness of the experimental sample. Alternatively, studies could recruit individuals who score highly on measures of OCD symptomatology, and then exclude individuals with OCD via diagnostic interviews.

Third, a priori power analysis was not conducted, meaning the study may have been underpowered to detect EF differences between individuals with subclinical OCD and nonclinical individuals. Although executive function differences have been found in studies of a similar sample size (e.g. n = 52 in Abramovitch et al., 2015; n = 43 in Kim et al., 2009 vs n = 54 in the current study), such a sample size is only adequately powered to detect large effect size differences. As moderate effect size EF differences are generally found between individuals with OCD and nonclinical individuals (e.g. Snyder et al., 2014), future studies investigating EFs in subclinical OCD should ensure that they are adequately powered to also detect moderate, or small, effect sizes.

Finally, in the current study individuals were not screened for clinical DSM disorders, psychotropic medication, or neurological disorders and it was therefore not possible to check for the effect of these variables. Each of these other variables has been linked to underperformance on EF tasks (Abramovitch & Cooperman, 2015). Future research should control for these variables.

In conclusion, the present study shows that individuals with subclinical OCD do not demonstrate EF deficits. Previous research has demonstrated EF deficits in those with OCD, and so a lack of EF deficits appears to be a differentiating factor between those with OCD and those with less severe, subclinical symptoms. It is plausible that previously found deficits in EF in individuals with OCD may be caused by state factors, such as OIT interference. Future research would benefit from finding out whether state factors can interfere in EF task performance. Indeed, this is what the study presented in the next chapter aims to test.

Chapter 3: Mechanisms of OCD: Do obsessive-intrusive thoughts impair working memory?

The overarching question of the current chapter is whether a range of OCD-relevant state factors (e.g. obsessive intrusive thoughts; OITs, excessive checking, poor effort, etc.) have a negative impact on working memory. This research question was generated from the findings of the previous chapter. One explanation for why individuals with subclinical OCD do not demonstrate executive function (EF) deficits (chapter 2) but individuals with OCD do demonstrate EF deficits (e.g. Snyder, Kaiser, Warren, & Heller, 2014), is that the deficits are the result of OCD-relevant state factors, of which individuals with OCD are more prone to. The focus of this chapter is on working memory, rather than EFs more generally, as it appears to be particularly relevant to OCD (Snyder et al., 2014).

In this chapter, first, I will introduce two accounts of working memory deficits in OCD: the trait account and the state account. Next I will provide evidence for both accounts, and describe how there is a growing body of evidence in favour of the state account. I will then introduce The Executive Overload Model of OCD, created to explain the impact of OITs on working memory. Next, I will explain how state factors are likely to have a larger impact on particular types of working memory task than others. Finally, I will introduce the current study, and explain how i) it aims to provide the first empirical test of The Executive Overload Model of OCD and ii) it also aims to investigate the role of a range of other state factors on working memory performance.

Executive function deficits have been demonstrated in individuals with OCD (Abramovitch, Abramowitz, & Mittelman, 2013; Shin, Lee, Kim, & Kwon, 2014; Snyder et al., 2014), the largest of which appears to be in working memory (Snyder et al., 2014). Working memory is a temporary storage system that allows for the manipulation of verbal and visual information (Baddeley, 2000; Baddeley & Hitch, 1974), and that underpins a range of goal-oriented behaviours. According to the influential Baddeley and Hitch model, working memory comprises a central executive, episodic buffer and two sub-domains: verbal working memory and visuospatial working memory. The central executive is responsible for controlling and regulating other cognitive processes. Verbal working memory is responsible for the storage and manipulation of verbal information; for example, when manipulating numbers for mental arithmetic. Visuospatial working memory is responsible for the storage and manipulation of visual and spatial information; for example, remembering a route through a maze. The episodic buffer is responsible for integrating information from the verbal and visuospatial domains. In support of the idea that the largest EF deficit in OCD is in working memory, Snyder et al. (2014) conducted a meta-analysis which compared performance between individuals with OCD and nonclinical individuals on a range of EF tasks. The largest deficit found in the meta-analysis was on a working memory task (the n-back task; d = .71).

Are executive function deficits caused by state factors?

Broadly, there are three accounts to explain working memory deficits in OCD: the trait account, and the state account, or a combination of the trait and state account. The trait account posits that working memory deficits are endophenotypes of OCD; trait markers that link clinical symptoms with genetic contributions (Gottesman & Gould, 2003). In other words, individuals will demonstrate EF deficits before developing OCD, and these deficits will remain after treatment for OCD. The trait view of OCD is supported by research demonstrating unchanged working memory performance after treatment for OCD (e.g. on the Spatial Span task of the Wechsler Memory Scale - III, or WMS-III: Rao, Reddy, Kumar, Kandavel, & Chandrashekar, 2008). According to trait view of EF deficits, OCD symptoms are caused by either deficits in working memory (alongside other EF deficits), or a shared third factor, such as pre-frontal cortex dysfunction, that leads to both working memory deficits *and* OCD symptoms (Snyder et al., 2014).

More recently, evidence has been building for an alternative account of working memory deficits in OCD; the state account. According to this idea, working memory deficits are epiphenomena, rather than endophenotypes, of OCD. Symptoms of OCD, such as OITs or compulsive checking, may be a cause of working memory impairments rather than a consequence. For example, an individual may underperform on a working memory task because OITs are distracting them, or increasing anxiety. According to this idea, individuals with OCD do not have an underlying, persistent deficit in working memory. Rather, they *appear* to have deficient working memory, due to the task interference caused by state factors (e.g. OITs).

If working memory deficits in individuals with OCD are caused by state factors, this would have important implications for the treatment and understanding of OCD. More specifically, it would suggest that interventions designed to improve EFs, such as cognitive remediation, are unnecessary for individuals with OCD. Rather, treating the symptoms of OCD would lead to improvements in executive functioning. In addition, if it could be demonstrated that EF deficits were caused by state factors, this could reduce the stigma experienced by individuals with OCD. Biogenetic explanations of mental health issues (such the trait account of EF deficits in OCD) increase the perception that individuals with mental health issues are dangerous and less likely to recover (Kvaale, Haslam, & Gottdiener, 2013). Finding that EF deficits are caused by state factors, therefore, may increase optimism regarding treatment, and self-esteem, in individuals with OCD.

Several lines of research support the state account of working memory deficits in OCD. First, although several meta-analyses have demonstrated EF deficits in individuals with OCD (Abramovitch et al., 2015; Shin et al., 2014; Snyder et al., 2014); for many domains (including working memory), the evidence is mixed and deficits are not consistently demonstrated (Abramovitch & Cooperman, 2015). If working memory deficits were a trait marker of OCD, it would be expected that deficits would be consistently found in individuals with OCD. However, if working memory deficits were caused by state factors, then it is plausible that the findings would vary dependent upon a variety of incidental factors such as the testing environment, the attitude of the experimenter (e.g. strict vs empathetic), the framing of the study (e.g. participant motivation may be lower if they are told beforehand that individuals with OCD demonstrate EF deficits) (Moritz, Hottenrott, Jelinek, Brooks, & Scheurich, 2012) etc. Each of these factors may impact on anxiety and OCD symptoms, thus leading to variable task interference.

In further support of the state account of working memory deficits is evidence that demonstrates that symptoms of depression and anxiety have a negative impact on cognitive performance (e.g. Basso, Bornstein, Carona, & Morton, 2001; Moritz, Fricke & Hand, 2001; Bédard, Joyal, Godbout, & Chantal, 2009; Eysenck, Derakshan, Santos & Calvo, 2007). Higher levels of depression and anxiety have been found in individuals with OCD (e.g. Grisham & Williams, 2013; Yap, Mogan, & Kyrios, 2012), and these symptoms may interfere with working memory. In other words, symptoms of depression and anxiety found in individuals with OCD may explain why these individuals demonstrate poorer EFs than nonclinical individuals.

Further evidence to suggest that working memory deficits may be caused by state factors comes from a study which demonstrated OCD symptoms directly interfered in neuropsychological task performance (Moritz et al., 2012). Moritz et al. (2012) asked sixty individuals with OCD and thirty nonclinical controls to complete a range of neuropsychological tasks (including a working memory task, the Corsi Block Tapping Task). Following this, all participants were asked to complete a questionnaire which assessed interference from a range of OCD-relevant symptoms; for example, whether touching the keyboard bothered the participant (due to contamination fears), whether OITs interfered in performance, or whether the participant exerted a lot of effort into task. Individuals with OCD were more likely to report interference from a range of OCD symptoms during the neuropsychological tasks than nonclinical individuals. Poor effort during the task, in particular, had a negative impact on working memory. This study highlights how OCD-relevant state factors can interfere in working memory task performance and lead to apparent EF deficits.

In further support of the state account of working memory deficits in OCD is evidence which suggests working memory resources are required for the processing of OITs (e.g. Eysenck, 1992; Levinson, Smallwood, & Davidson, 2012; Teasdale, Proctor, Lloyd, & Baddeley 1993; Teasdale et al., 1995). According to this idea, individuals with OCD experience more OITs than nonclinical individuals, and experiencing more OITs during a working memory task is likely to consume (finite) working memory resources. If fewer working memory resources are available for the task at hand, this will inevitably lead to poorer task performance. Evidence for this idea comes mainly from research into task-unrelated thoughts (a broad term for spontaneous thoughts, which may include OITs). It has been demonstrated that when working memory load is high, fewer task-unrelated thoughts are experienced in nonclinical individuals (Teasdale et al., 1993; Teasdale et al., 1995). Memory load refers to the task difficulty, such that higher-load tasks require the maintenance and manipulation of larger amounts of information (e.g. letters). Higher memory load is associated slower reaction times and poorer accuracy (e.g. Jonides et al., 1997). When task-unrelated thoughts do occur during a task that relies on working memory, performance declines (Cheyne, Solman, Carriere, & Smilek, 2009; Smallwood et al., 2004), suggesting that maintaining task-unrelated thoughts consumes working memory resources.

In an attempt to extend these findings on task-unrelated thoughts, and to account for the impact of OITs on working memory, Abramovitch, Dar, Hermesh and Schweiger (2012) developed the Executive Overload Model of OCD. The model posits that an "overflow", or excessive number of OITs, accompanied by constant control attempts, consume working memory (and other EF resources) and thus impairs performance on working memory (and other EF) tasks. More specifically, the model suggests that an overflow of OITs, which is associated with hyperactivity of the frontostriatal system, is a result of repeated attempts to control automatic processes. These OITs overload the executive system and, in doing so, lead to EF impairments. The model also posits that individuals with OCD possess a general fear of impulsivity, which leads them to increase their attempts to control behaviour, which in turn leads to an increase in OITs, resulting in a vicious cycle of more OITs and poorer EFs. The model does not offer any further theoretical detail on how OITs may impact upon specific EFs, such as working memory. However, as an analogy, the model suggests that "an overflow of OITs overloads the executive system in a way which is similar to having numerous open programs on a personal computer that overloads the RAM memory and causes the primary program to operate more slowly… resulting in neuropsychological deficits" (Abramovitch & Cooperman, 2015, pp. 31).

One further possible explanation for working memory deficits in OCD is a combination of both the trait and the state account. In other words, small working memory deficits may be a trait marker of OCD. This working memory deficit may, in turn, make individuals with OCD more susceptible to state factors, such as OITs, as posited by the Executive Overload Model of OCD (Abramovitch et al., 2012; Abramovitch & Cooperman, 2015). However, evidence for this dual state-trait of working memory deficits in OCD is lacking.

In addition, this account does not explain why task-unrelated thoughts, which include OITs, lead to poorer working memory performance in nonclinical individuals (Cheyne et al., 2009; Smallwood et al., 2004).

Differential effects of state factors on working memory

The evidence presented so far suggests that state factors could plausibly lead to working memory deficits in all cases. However, there are reasons to believe that state factors may have differential effects on working memory, dependent upon the task and load. If the impact of state factors on working memory does vary, then recognising the conditions under which state factors will have an impact is an important methodological consideration for future studies to address. In support of the idea that state factors may have differential effects on working memory, deficits appear to be larger in individuals with OCD on high (vs low) memory load working memory tasks (Abramovitch & Cooperman, 2015). More specifically, several studies have demonstrated reduced performance on the n-back task in individuals with OCD, but only on higher memory load trials, and particularly on visuospatial tasks (3-back; de Vries et al., 2013; van der Wee et al., 2003) and several reviews have argued for the same pattern (Abramovitch & Cooperman, 2015; Harkin & Kessler, 2011). If working memory deficits are caused by state factors, then this finding would suggest that state factors have a disproportionately negative impact on high-load, visuospatial working memory tasks.

An experimental study confirmed that OCD-relevant state factors (anxiety) can have a larger impact on visuospatial working memory than verbal working memory. Vytal, Cornwell, Letkiewicz, Arkin and Grillon (2013) asked twenty-seven nonclinical individuals to complete both a verbal and a visuospatial n-back task. For the n-back task, participants are presented with a sequence of stimuli (letters for the verbal version of the task, and shapes for the visuospatial version of the task) on a computer screen, and must indicate when the currently displayed stimulus matches the stimulus presented *n* trials ago. For half of the trials, anxiety was induced in participants, by putting them at risk of receiving an electrical shock. Performance during the shock trials was significantly lower than the no-shock trials on the verbal 1-back and 2-back tasks, and for the visuospatial 1-back, 2-back, *and* 3-back tasks. The authors concluded that these results not only demonstrate the negative impact of anxiety on cognitive performance, but also that visuospatial working memory is more vulnerable to the negative effects of anxiety than verbal working memory.

It is conceivable from the evidence presented that OCD-relevant state factors lead to the largest working memory deficits on high-load, visuospatial working memory tasks. However, the question remains as to why that may be the case. Research into task-unrelated thoughts provides one possible explanation. Levinson, Smallwood & Davidson (2012) argued that that if a working memory task is demanding (e.g. if it has a high memory load) and prioritised (i.e. OITs are experienced and are more salient and emotional valent than the task), fewer task-unrelated thoughts are experienced, as working memory helps to maintain task focus and inhibit task-unrelated thoughts. However, if the task is not demanding (e.g. it has a low memory load) or prioritised then working memory resources allow the task and task-unrelated thoughts to co-occur. Support for this idea comes from the finding that participants report more frequent intrusive cognitions during low-difficulty and high-difficulty (but not medium-difficulty) cognitive tasks (Hyman et al., 2013). When task-unrelated thoughts are experienced at the same time as the task, the thoughts are likely to distract from the task and lead to poorer performance, particularly on difficult (high-load) tasks, where even small distractions may lead to problems. In the context of OCD, according to this idea, individuals may experience more OITs during low-load (e.g. 1-back task) and high-load (e.g. 3-back task) visuospatial tasks. As OITs are often considered threatening, they are likely to be prioritised over the task, due to their salience and emotional valence. Therefore, experiencing OITs during high-load (but not low-load) tasks may have a negative impact on task performance.

In summary, there is a range of evidence that supports the state account of working memory deficits in OCD. First, there is evidence that a range of symptoms relevant to OCD (e.g. OITs, contamination fears, depression, anxiety, etc.) have a negative impact on neuropsychological task performance (e.g. Basso et al., 2001; Bédard et al., 2009; Eysenck et al., 2007; Moritz et al., 2001; Moritz et al., 2012). Second, there is evidence to suggest that OITs consume working memory resources, leaving fewer resources available to complete the task at hand, leading to poorer performance (e.g. Eysenck, 1992; Levinson, et al., 2012; Teasdale, et al., 1993; Teasdale et al., 1995). The Executive Overload Model of OCD was developed to account for the impact of OITs on working memory (and other EFs), positing that an increase in OITs will lead to a decrease in working memory (Abramovitch et al., 2012).

Despite the promising evidence in support of the state account of working memory deficits, there are several reasons to suggest further investigation is required. First, the evidence regarding the impact of anxiety and depression on neuropsychological task performance is inconsistent, with many studies showing no negative impact (Abramovitch & Cooperman, 2015). Second, only one study has investigated the impact of OCD-specific phenomena on neuropsychological task performance, and of all the state factors measured, only poor effort was associated with poorer working memory (Moritz et al., 2012). Third, much of the evidence to suggest working memory resources are consumed by OITs comes from research into task-unrelated thoughts, rather than OITs specifically. The Executive Overload Model of OCD provides an invaluable extension of these task-unrelated thought findings into the domain of OCD (Abramovitch et al., 2012). However, this model is currently in its infancy and no known studies have been conducted to directly test its predictions. If OITs do impact upon working memory, the largest negative impact is likely on high-load visuospatial tasks (e.g. Levison et al., 2012).

The present study

The main aim of the current study, therefore, is to test a key prediction of The Executive Overload Model of OCD: whether an increase in OITs will impair working memory. Demonstrating that an increase in OITs leads to an increase in working memory deficits would increase confidence in the state account of working memory deficits, and in the Executive Overload Model itself. For this study, nonclinical participants were recruited and completed the n-back task. Half of participants were primed with OITs before the task; half were not. Priming OITs is a widely used experimental method of inducing OITs (e.g. Purdon, 2001; Purdon & Clark, 2001; Purdon, Rowa & Anthony, 2005).

Participants were first asked to think in detail about an upsetting OIT; this is known to lead to an increase in OIT frequency in the minutes following the prime. Priming OITs allows for the measurement of OIT responses in real-time. It was predicted that those participants in the primed condition would perform poorer on the 3-back task than those in the non-primed condition; but that there would be no difference between the two conditions on the 1-back task.

Secondary aims of the current study are to test the relationship of other state variables to working memory. More specifically, depressive and anxious symptoms will be controlled for. In addition, the impact of a range of OCD-relevant phenomena on working memory (e.g. self-reported OIT interference, excessive checking, effort, etc.) will be measured. It is expected that depressive and anxious symptoms will be negatively related to working memory. In addition, it is expected that self-reported effort will be related to working memory (i.e. replication the findings of Moritz et al., 2012). Based on the predictions of the Executive Overload Model of OCD, it is also expected that higher self-reported OIT interference will also be related to poorer working memory. Demonstrating the relationship between any of these symptom variables and working memory would increase confidence in the state account of working memory deficits.

To summarise the study's hypotheses:

Hypotheses:

Individuals primed with OITs (primed condition) will perform poorer on the 3-back task than individuals in the non-primed condition.

There will be no difference between individuals in the OIT primed condition and non-primed condition on the 1-back task.

Depression and anxiety will be negatively correlated to working memory.

Self-reported effort will be related to working memory.

Higher self-reported OIT interference will be related to poorer working memory.

3.1: Method

Design

The experiment used a one-way, independent samples design. The independent variable was OIT prime condition, with two levels (primed vs non-primed). There were four primary dependent variables (all measuring working memory: accuracy on 1-back task; reaction time on 1-back task; accuracy on 3-back task, reaction time on 3-back task). Other dependent variables were depression and anxiety (as measured on the Depression Anxiety and Stress Scale, DASS; Lovibond & Lovibond, 1995), obsessive-compulsive symptom scores (as measured by the Obsessive Compulsive Inventory – Revised, OCI-R; Foa et al., 2002), retrospective OIT frequency (as measured by part 1 of the *Obsessional Intrusive Thoughts Inventory;* Original Spanish Version: "Inventario de Pensamientos Intrusos Obsesivos", INPIOS; García-Soriano, Belloch, Morillo & Clark, 2011). In addition, a range of symptom interference was measured, including perceived OIT interference (measured on a 101-point scale).

Participants

According to a priori power analysis, with a medium effect size (f^2 [V]= .0675), an α =.05 and a power of .8, a sample of 146 participants was needed in total. One hundred and forty-four participants were recruited, via e-mail, from a staff/student pool at The University of Sheffield. Nine participants were excluded for not completing all tasks, leaving a sample of 135 participants (32 males, 102 females, 1 'other' but did not specify; mean age = 24 years; age range = 18-59 years). Individuals who reported that they had received a diagnosis of OCD were not eligible to participate in the study, as such individuals have been found to perform poorer than nonclinical individuals on a range of executive function tasks (e.g. Snyder et al., 2014). Participants were systematically assigned to either the primed condition (*n* = 65; mean age = 24 years; 19 males, 45 females, 1 other) or non-primed condition (*n* = 70; mean age = 23 years; 13 males, 57 females), such that the first participant was allocated to the primed condition, the second participant to the non-primed condition, and so on. Participants received either course credits or £5 cash reimbursement for their time.

Materials

Questionnaires

The *Obsessive Compulsive Inventory – Revised* (OCI-R; Foa et al., 2002) is an 18-item measure used to assess OCD symptoms. The OCI-R comprises a list of symptoms (e.g. "I check things more often than necessary") for which participants indicate on a scale from 0 ("not at all") to 4 ("extremely") how distressed the symptoms have made them in the past month. Items cover six sub-scales, (a) washing, (b) checking/doubting, (c) obsessing, (d) mental neutralizing, (e) ordering, and (f) hoarding. Total scores on the OCI-R are calculated by summing the items. Scores range from 0-72 with higher scores indicating higher levels of OCD symptomatology. The recommended cut-off score for the OCI-R is 21, with scores at or above this level indicating the likely presence of OCD (Foa et al., 2002). The OCI-R has demonstrated good psychometric properties in nonclinical participants; excellent internal consistency (α = .89), good test-retest reliability (1 week – r = .84), and convergent validity (significant positive correlations were found with the OCI-R and a range of OCD measures; Foa et al., 2002). Discriminant validity was mixed, with high correlations between the OCI-R and Beck Depression Inventory (BDI; r = .7); however, this is common across all OCD symptom measures (Foa et al., 2002). In this study the internal consistency for the OCI-R was α =.89.

The *Depression Anxiety and Stress Scale* (DASS-21; Lovibond & Lovibond, 1995) is a 21-item measure of depression, anxiety and stress. Participants were presented with statements (e.g. "I found myself getting upset by quite trivial things") and were required to indicate how much each statement applied to them in the past month, on a scale from 0 ("did not apply to me at all") to 3 ("applied to me very much or most of the time"). Scores for depression, anxiety, and stress are calculated by summing the items for each subscale, with higher scores indicating higher levels of each construct. Scores on the depression subscale range from 0-21 (0-4 = normal; 5-6 = mild; 7-10 = moderate; 11-13 = severe; 14-21 = very severe), scores on the anxiety subscale range from 0-21 (0-3 = normal; 4-5 = mild; 6-7 = moderate; 8-9 = severe; 10-21 = very severe), and scores on the stress subscale range from 0-21 (0-7 =

normal; 8-9 = mild; 10-12 = moderate; 13-16 = severe; 17-21 = very severe).The DASS-21 has demonstrated good psychometric properties; excellent internal consistency (α =.87 -.94 for a sample of individuals with OCD and nonclinical individuals; Antony, Bieling, Cox, Enns, & Swinson, 1998), and good convergent validity (when compared with other measures of depression and anxiety; Antony et al., 1998; Henry & Crawford, 2005). In this study, the internal consistency for each subscale was: depression (α = .90), anxiety (α = .80), & stress (α = .87).

Part one of the *Obsessional Intrusive Thoughts Inventory* (Original Spanish Version: “Inventario de Pensamientos Intrusos Obsesivos”, INPIOS; García-Soriano, Belloch, Morillo & Clark, 2011) assesses the frequency with which participants experience 48 OITs (e.g. “The documents, papers, etc. are out of order or not in their place”) using a seven-point Likert scale ranging from 0 (“never”) to 6 (“always”). Part one also includes two open-ended items (“I also have these other intrusions…”), which allow participants to report any idiosyncratic OITs. Total scale scores for part one of the INPIOS are calculated by dividing the total score by the number of items with a frequency ≥ 1 (see García-Soriano et al., 2011). Scores range from 0-6 and higher scores on the INPIOS correspond to more frequent OITs. Part one of the INPIOS has demonstrated good internal reliability (α = .94) and test-retest reliability (7-14 days, *r* = .97) (García-Soriano et al., 2011) in a non-clinical sample. The questionnaire also demonstrated adequate convergent and divergent validity with INPIOS total scores being more strongly correlated with OCD measures than with measures of depression, anxiety or worry (García-Soriano et al., 2011). In the current study the internal consistency for part 1 total score was α = .93.

Following all tasks, participants rated the frequency of OITs that they experienced during the task. Those in the primed condition were asked two questions: “Roughly how many times did you experience your most upsetting/unpleasant intrusive thought during the task?”, and “Did you experience any other intrusive thoughts of the following themes?” The OIT themes which are covered by the INPIOS were listed (contamination, aggression, sex, religion, order/symmetry, doubts, superstition) and answers were rated on a scale (1 = 1-3 times; 2 = 4-6 times; 3 = 7-10 times; 4 = 10+ times). Those in the non-primed condition were only asked one question, “Did you experience any intrusive thoughts of the following themes?” with the same theme options and scale responses as given to the primed condition.

A nine-question retrospective-performance questionnaire was used, similar to the questionnaire used by Moritz et al. (2012), to assess perceived task interference from a range of OCD-relevant phenomena. Participants indicated on a scale from 0 (‘not at all’) to 100 (‘extremely’) how: 1) much they were bothered by touching objects; 2) much they checked their responses; 3) much OITs interfered with their performance; 4) much compulsions interfered with their performance; 5) much they guessed their responses; 6) much they paid attention to the task; 7) careful and accurate they were during the task 8) they felt slowed during the task; 9) they tried when completing the task. This measure of interference is designed to capture the subjective impact of symptoms on task performance.

Neuropsychological tasks

The n-back task was used to assess visuospatial working memory. The n-back task was completed on a computer with a 17-inch monitor and running E-Prime 2.0 software (Psychology Software Tools, Inc., Pittsburgh, PA). Participants were presented with a series of images all featuring a star positioned either on the left, right, top or bottom of a diamond shape, on a 17-inch computer monitor. For each image, participants were required to indicate, by pressing the space bar on a keyboard, when the position of the star matched that of the star either a) directly before it (*1-back*, 51 trials) or b) three stars before it (*3-back*, 51 trials). One third of trials involved a match. The order of the trials was fixed for all participants.

Dependent variables for the n-back task were i) percentage of correct answers and ii) reaction time for correct answers. False alarm scores were accounted for by adding correct positive responses to correct negative responses. For example, if a participant correctly indicated a match on 13/17 trials, but incorrectly indicated a match on 3/34 trials, their total accuracy score would be 44/51 (or an accuracy of 86%).

Obsessive Intrusive Thought Prime Task

Participants in the primed condition were primed with OITs, with the aim of making them experience more frequent OITs during the n-back task. Participants first completed part one of the INPIOS (García-Soriano et al., 2011) in the laboratory, which took between 5-10 minutes to complete. Secondly, participants identified their most "unpleasant, uncomfortable or upsetting" OIT from the list in the INPIOS. Following this, they were instructed to "imagine a scene involving your most unpleasant OIT for 60 seconds". This method of priming OITs has been widely used in previous research (e.g. Purdon, 2001; Purdon & Clark, 2001; Purdon, Rowa & Anthony, 2005).

Procedure

Participants first completed the Obsessive-Compulsive Inventory – Revised (OCI-R; Foa et al., 2002), part one of the Obsessional Intrusive Thoughts Inventory (INPIOS; Garcia-Soriano et al., 2011) and the Depression Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995) online using survey platform, Qualtrics. Following this, participants attended the laboratory (3 – 10 days after questionnaire completion) and were systematically allocated to one of two conditions: the primed condition (n = 65), or the non-primed condition (n = 70). In the primed condition, participants completed the OIT priming task before completing the n-back task. In the non-primed condition, participants only completed the n-back task. Participants sat approximately 80 cm from the screen. Following the n-back task, participants were asked to report the number of OITs experienced and to complete the nine-item retrospective performance questionnaire. Informed consent was obtained from all participants and the study was granted ethical approval by the University's psychology ethics committee.

3.2: Results

Demographic Characteristics

Baseline demographic and clinical characteristics of participants in the two conditions are provided in Table 1. In order to test whether there were any significant demographic or clinical characteristic differences between conditions, a range of ANOVAs were conducted on the data (age; sex; OCD, depression and anxiety symptomatology; obsessive intrusive thoughts frequency). Those in the primed condition scored significantly higher on depression and anxiety (as measured by the DASS), and experienced significantly more OITs in general (as measured by the INPIOS) than those in the non-primed condition. No significant differences were found between the two conditions in age, gender or OCD symptomatology (as measured by the OCI-R).

Mean OCI-R score of the full sample was 16.63 (*SD* = 11.2), which compares to 28.01 (SD = 13.53) found previously in samples with OCD and 18.82 found in nonclinical samples (*SD* = 11.10) (Foa et al. 2002). One third of the sample (45/135) scored over the suggested clinical cut-off of the OCI-R; the score which is used to differentiate individuals with OCD and nonclinical individuals (Foa et al., 2002). This finding suggests that the current sample was partially representative of individuals with OCD.

Table 1 – Demographic and clinical characteristics

	Primed (*n* = *65*)	**Non-primed (*n* = *70*)**	**Analysis**
	Mean (SD)	Mean (SD)	
Age (years)	22.98 (8.12)	23.77 (8.46)	$F(1, 133) = .30$, $p = .58$, $\eta^2 = .002$
Male: Female	19: 45 [a]	13: 57	$\chi^2(1) = 3.36$, $p = .187$[b]

OCI-R Total (Max score 72; clinical cut-off < 21)	18.07 (11.77)	15.29 (10.56)	*F*(1, 133) = 2.11, *p* = .149, η^2 = .016
DASS Depression Total (Max score 21; normal 0-4; moderate 7-10; extremely severe 14+)	6.65 (5.48)	4.67 (4.21)	*F*(1, 133) = 5.56, *p* = .02, η^2 = .040
DASS Anxiety Total (Max score 21 normal 0-3; moderate 6-7; extremely severe 10+)	4.95 (3.93)	3.6 (3.6)	*F*(1, 133) = 4.35, *p* = .04, η^2 = .032
DASS Stress Total (Max score 21 normal 0-7; moderate 10-12; extremely severe 17+)	7.56 (5.03)	6.96 (4.97)	*F*(1, 133) = .479, *p* = .49, η^2 = .004

INPIOS Frequency[c] (Max score 6)	**OIT Total**	2.35 (.781)	2.09 (.711)	$F(1, 133) = 3.96$, $p = .049$, $\eta^2 = .029$

[a] = 1 participant stated gender as "other" (not specified)

[b] = excluded "other" as this participant does not identify as a male or female and therefore cannot be included in the gender comparison analysis.

[c] = not actual frequency, corresponds to OITs being experienced 0 = never – 6 = frequently, every day

Preliminary Analyses

Are there any effects of reimbursement method on n-back performance?

In the current study, some participants were compensated with cash (£5; *n* = 34) and others with course credit (*n* =101). In order to explore whether there were any effects of differential reimbursement, a series of ANOVAs were conducted, comparing n-back performance (1-back accuracy and RT; 3 back accuracy and RT) between those who received cash and those who received course credit. No significant differences were found between the two conditions on n-back performance. More specifically, no significant accuracy differences were found between those compensated with cash (*M* = 95.82%, *SD* = 8.10) and those compensated with credit (mean = 96.12%, SD = 4.92) on the 1-back task [$F(1, 133) = 0.04$, $p = 0.84$, $\eta^2 = .000$]. Similarly, no significant RT differences were found between those compensated with cash (*M*= 439.00ms, *SD* = 141.44) and those compensated with credit (mean = 461.97ms, SD = 162.76) on the 1-back task [$F(1, 133) = 0.62$, $p = 0.43$, $\eta^2 = .005$].

In addition, no significant accuracy differences were found between those compensated with cash (*M* = 79.73%, *SD* = 10.74) and those compensated with credit (*M* = 78.32%, *SD* = 8.90) on the 3-back task ($F(1, 133) = 0.46$, $p = 0.50$, $\eta^2 = .004$). Similarly, no significant RT differences were found between those compensated with cash (*M* = 607.97ms, *SD* = 234.94) and those compensated with credit (*M* = 633.27ms, *SD* = 190.32) on the 3-back task [$F(1, 133) = 0.32$, $p = 0.57$, $\eta^2 = .002$].

Manipulation Check

Were there any differences in obsessive intrusive thought frequency between the primed and non-primed conditions?

Total OIT frequency scores, from the OIT question “Did you experience any other intrusive thoughts of the following themes?” completed after n-back task (measured on the following scale: 1 = 1-3 times; 2 = 4-6 times; 3 = 7-10 times; 4 = 10+ times) were compared between the two conditions, using a one-way ANOVA. Those in the primed condition (*M* = 1.72, *SD* = 2.08) experienced significantly more OITs than those in the non-primed condition (*M* = 1.04, *SD* = 1.44; $F[1, 133] = 4.94$, $p = .028$). Participants in the primed condition reported an additional mean of 1.77 (*SD* = 2.51) OITs in the category of their primed thought, which corresponds to between 1-3 OITs. These findings confirm that the OIT prime was successful in making those in the primed-condition experience more OITs than those in the non-primed condition.

Were there any differences in perceived obsessive intrusive thought interference between the primed and non-primed conditions?

An ANOVA was conducted to compare perceived intrusive thought interference between the primed and non-primed conditions. Individuals in the primed condition reported significantly more interference in their task performance (M = 32.98, SD = 27.12) than individuals in the non-primed condition (M = 22.77, SD = 28.65; F[1,131] = -2.11, p = .037).

Relationships between depression, anxiety and n-back performance

As differences were found in depression and anxiety scores between the primed and non-primed conditions, a series of Pearson's correlations was run to explore the relationship between depression and n-back performance (1-back accuracy; 1-back RT; 3-back accuracy; 3-back RT) and anxiety and n-back performance (1-back accuracy and RT; 3-back accuracy and RT). No significant relationships were found between any of the variables. More specifically, no significant relationships were found between depression and 1-back accuracy (r[135] = - 0.01, p = .90); depression and 1-back RT (r[135] = .09, p = .31); depression and 3-back accuracy (r[135] = -.9, p = .30); or depression and 3-back RT (r[135] = .08, p = .38), suggesting that working memory was not affected by depression.

In addition, no significant relationships were found between anxiety and 1-back accuracy (r[135] = -.05, p = .59); anxiety and 1-back RT (r[135] = -.01, p = .94); anxiety and 3-back accuracy (r[135] = -.02, p = .81); or anxiety and 3-back RT (r[135] = -.09, p = .28), suggesting anxiety did not have an impact on working memory performance. Due to the lack of relationships between depression, anxiety and n-back performance, depression and anxiety were not controlled for in subsequent analyses.

Did priming obsessive intrusive thoughts affect working memory performance?

Figures 1 and 2 illustrate n-back accuracy and reaction time in both conditions and for both tasks (1-back and 3-back). In order to explore whether there were any differences in 1-back performance between the primed condition and non-primed condition, a MANOVA was conducted, with 1-back reaction time and 1-back accuracy entered as dependent variables. Using Pillai's trace, there were no significant 1-back differences between individuals in the primed condition and the non-primed condition, V = .011, F (2, 132) = .732, p = .48.

In order to explore whether there were any differences in 3-back performance between the primed condition and the non-primed condition, a MANOVA was conducted, with 3-back reaction time and 3-back accuracy entered as dependent variables. Using Pillai's trace, there were no significant 3-back differences between individuals in the primed condition and non-primed condition, V = .002, F (2, 132) = .128, p = .88.

Fig. 1. Response times (mean ± standard error) for primed and non-primed participants in both task conditions (1-back and 3-back).

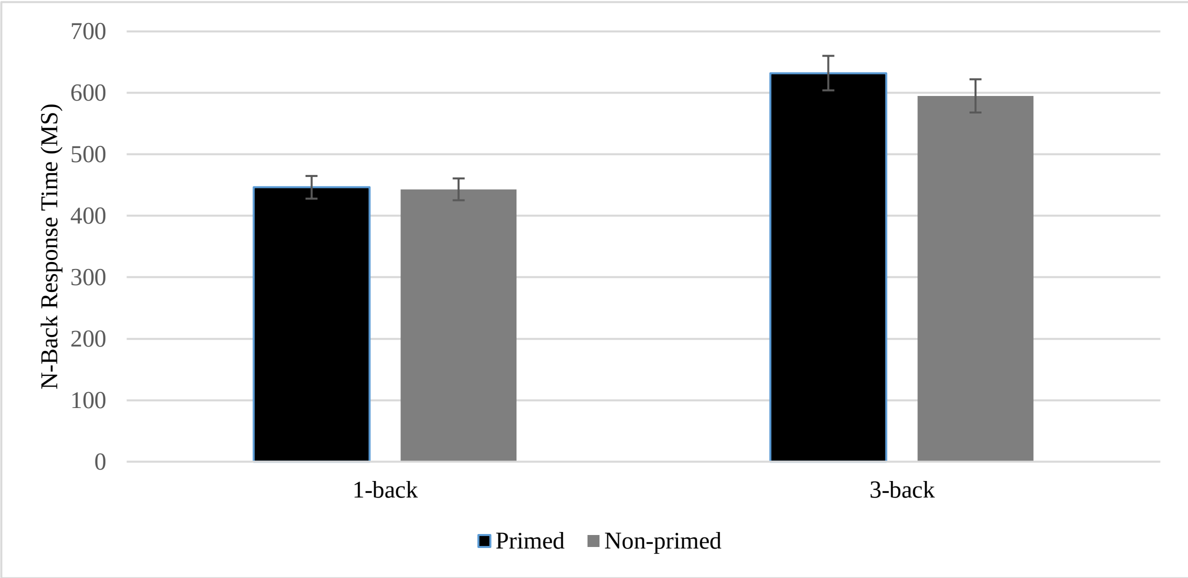
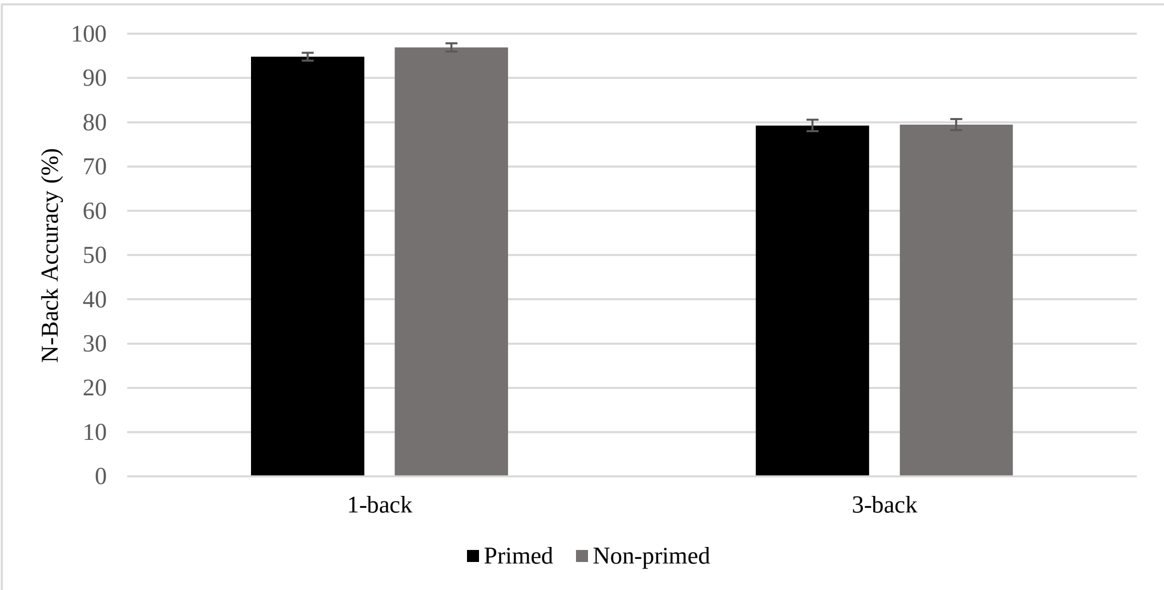


Fig. 2. Accuracy (mean ± standard error) for primed and non-primed participants in both 1-back and 3-back tasks.



Were primed OITs related to working memory performance?

A Spearman's rank correlation analysis was conducted to investigate the relationship between the number of primed OITs experienced during the working memory task and working memory performance. No relationship was found between primed OITs and 3-back reaction time (r_s[135] = -.08, p = .35). In addition, no relationship was found between primed OITs and 3-back accuracy (r_s[135] = -.09 , p = .32).

Were OCD-relevant phenomena related to working memory performance?

Pearson's correlation analysis was conducted to explore the relationship between self-reported symptom interference and working memory. A Bonferroni correction was made to correct for multiple comparisons, and P-values of <.001 (.05/36) were considered to be significant. No significant relationships were found between any of the self-reported symptom measures and working memory (r ranged from -.184 to .136; p values ranged from .033 to .987; see Appendix B for a correlation matrix).

3.3: Discussion

The main aim of the current study was to test a key prediction of The Executive Overload Model of OCD (Abramovitch et al., 2012): whether an increase in OITs would impair working memory. To address this question, two groups of participants completed a low-load (1-back) and high-load (3-back) working memory task, after one group had been primed with OITs. As predicted, no differences were found between the two groups on the 1-back task. However, contrary to predictions, no differences were found between the two groups on the 3-back task. These findings suggest that an increase in OITs does not lead to working memory impairments in a nonclinical sample.

Secondary aims of the current study were to test the impact of other state variables on working memory. More specifically, depressive and anxious symptoms were measured. Contrary to predictions, no relationships were found between depressive or anxious symptoms and performance on the 1-back or 3-back task. In addition, a range of OCD-relevant phenomena (e.g. self-reported OIT interference, excessive checking, effort, etc.) were measured. Contrary to predictions, none of these state factors were related to performance on the 1-back or 3-back task. Taken together, these findings suggest that a range of state factors associated with OCD, do not lead to working memory impairments in a nonclinical sample.

One surprising finding to come out of the present study was that, despite no working memory differences between those in the primed and non-primed condition, there was a difference between the conditions in perceived interference. Participants who were primed with OITs reported that OITs interfered with their performance more than participants who were not primed with OITs. This finding is interesting, as it would seem plausible that perceived interference and objective interference would align, such that individuals who reported more perceived interference would also demonstrate poorer working memory. However, this was not found to be the case. One possible explanation for this finding is that those participants in the primed condition needed to work harder than those in the non-primed condition in order to prevent task performance from deteriorating. However, an ANOVA conducted after the completion of the study suggested no differences between the two conditions in self-reported effort (*p* = .39). A second possible explanation is that individuals higher in obsessive-compulsive symptomatology are simply more likely to believe that OITs interfere with their performance than nonclinical individuals, even when they do not cause objective interference. That is, interference is a problem of perception, rather than demonstrable interference. A final possible explanation for the finding is that it is result of demand effects; participants who were primed with OITs may believe that the experimenter expected them to impact upon performance, and made their self-reports accordingly.

The current findings do not support one prediction of the Executive Overload Model of OCD (Abramovitch et al., 2012): that OITs will lead to impairments in working memory. However, it was beyond the scope of the current study to investigate whether OITs lead to impairments in other EFs, such as inhibition and cognitive flexibility. Working memory was chosen in the current study due to the finding that the largest EF deficit was found on the n-back (Snyder et al., 2014). However, individuals with OCD also demonstrate deficits in the areas of inhibition and cognitive flexibility (e.g. Snyder et al., 2014). It would seem surprising if OITs lead to deficits in inhibition or cognitive flexibility deficits, but not working memory deficits. However, future studies, testing the impact of OITs on other neuropsychological tests, are required to provide further valuable insights into the validity of the Executive Overload Model of OCD (Abramovitch et al., 2012).

One possible explanation for the current findings is that although an increase in OIT frequency did not lead to working memory deficits, an increase in OIT duration may have led to working memory deficits. The Executive

Overload Model of OCD (Abramovitch et al., 2012) does not make predictions about OIT duration, however, it would seem unlikely for five fleeting OITs, lasting less than a second each, to have a negative impact on working memory. On the other hand, it would seem more likely that five OITs, each lasting 10 seconds each, would have a negative impact on working memory. Obsessive intrusive thought duration was not measured in the present study, and so this hypothesis could not be tested. Future studies looking to test the impact of OITs on working memory should aim to measure OIT duration. Finding OIT duration (but not frequency) has a negative impact on working memory may suggest the Executive Overload Model of OCD should be revised to account for duration.

Overall, the findings from the present study do not support the state account of working memory deficits. That is, a range of state factors which might plausibly be thought to lead to impaired performance on a working memory task, do not in fact lead to such an impairment. Previously, depression and anxiety had been shown to impair neuropsychological performance (e.g. Basso et al., 2001; Bédard et al., 2009; Eysenck et al., 2007; Moritz et al., 2001) and self-reported effort was associated with better working memory (Moritz et al., 2012); however, the present study did not replicate those findings. In addition, there were strong theoretical reasons to believe that OITs consumed working memory resources and would lead to working memory deficits (particularly high-load visuospatial working memory tasks). This idea was captured by the Executive Overload Model of OCD (Abramovitch et al., 2002). However, the present study found evidence against the Executive Overload Model of OCD.

If working memory deficits are not caused by state factors, then the question remains as to why individuals with OCD demonstrate working memory deficits (e.g. Snyder et al., 2014). The answer to this question is beyond of the scope of the data from the present study, however, one possibility is that working memory deficits are endophenotypes of OCD. In support of this idea, working memory of individuals with OCD remains unchanged after treatment for OCD (e.g. Rao et al., 2008). In addition, non-affected relatives of individuals with OCD demonstrate working memory deficits (e.g. Rajender et al., 2011). However, if working memory deficits are endophenotypes of OCD, then it is not clear why deficits are not consistently found in individuals with OCD (Abramovitch & Cooperman, 2015) and why state factors have previously been shown to impact upon working memory performance (Bédard et al., 2009).

A further possible explanation for why individuals with OCD demonstrate working memory deficits, if not due to state factors, is that deficits are confined to a sub-group of individuals with OCD (e.g. Hwang et al., 2007; Lee & Telch, 2010). Obsessive-compulsive disorder is a heterogeneous condition, and individuals can present with a wide variety of symptoms (Markarian et al., 2010; McKay et al., 2004). If it was the case that working memory deficits are only found in a sub-group of individuals, this would explain why working memory deficits are found in some studies, but not others. That is, large numbers of individuals from the sub-group with working memory deficits may have unintentionally been included in those studies where deficits have been found. To the author’s knowledge, there is no available empirical evidence to support the idea that sub-groups of individuals with OCD demonstrate working memory deficits. However, there is evidence that sub-groups of individuals show deficits in other EF domains. For example, Hwang et al. (2007) found that individuals with late-onset OCD demonstrated deficits on a complex executive function task (Rey-Osterrieth Complex Figure Test), but those with early-onset OCD did not. Future studies would benefit from recruiting individuals with the same OCD presentation (e.g. experiencing aggressive OITs), and assessing their working memory in comparison to nonclinical individuals, or an alternative sub-group (e.g. contamination OITs). Such a study would allow the hypothesis (that subgroups of individuals with OCD demonstrate working memory deficits) to be tested.

One final possible explanation for why individuals with OCD demonstrate working memory deficits is that state factors lead to EF deficits in individuals with OCD because of some pre-existing vulnerability, such as neurobiological deficits (Snyder et al., 2014). In support of this idea is evidence demonstrating neurobiological differences in areas thought to subserve EFs (the prefrontal cortex) between individuals with OCD and nonclinical individuals (e.g. Menzies et al., 2008) and unaffected relatives of individuals with OCD and nonclinical individuals (e.g., Cavedini, Zorzi, Piccinni, Cavallini, & Bellodi, 2010; Menzies, Williams, et al., 2008; Rajender et al., 2011). Extending the previous analogy used to describe the Executive Overload Model of OCD, individuals with OCD may have less RAM available than nonclinical individuals, making them more vulnerable to interference from other computer programs (e.g. OITs). Whereas it may only take a small increase in OITs to cause deficits in individuals with OCD, it may take many more to lead to deficits in nonclinical individuals. The present study recruited a nonclinical sample and was therefore unable to investigate this idea. Future behaviour-genetic research testing for shared genetic influence on EF and OCD, or longitudinal studies following at-risk children (e.g. who have parents with OCD), may help to elucidate whether individuals with OCD demonstrate a pre-existing vulnerability to EF deficits (Snyder et al., 2014).

One limitation of the current study is the use of nonclinical participants. Nonclinical participants offer a relevant and widely used method of studying OCD-related phenomena, particularly for preliminary research which is looking to investigate new ideas and models, such as the Executive Overload Model of OCD (Abramowitz et al., 2014). However, there are several potentially relevant differences between OITs experienced by nonclinical individuals and individuals with OCD that may influence the amount interference that they cause. Notably, OITs experienced by individuals with OCD tend to be more intense, distressing, enduring and bizarre than those experienced by nonclinical individuals (Rachman & de Silva, 1978; Berry & Laskey, 2012). As a result, clinical OITs may capture an individual’s attention more readily, and mean that the thoughts are more likely to be prioritized over the working memory task, due to their salience and emotional valence. When OITs capture an individual’s attention in this way, working memory deficits are more likely to be found (Cheyne et al., 2009; Levinson et al., 2012; Smallwood et al., 2004).

A second important difference between OITs experienced by individuals with OCD, and nonclinical individuals, is that clinical OITs are more likely to be suppressed than nonclinical OITs (Berry & Laskey, 2012), a process that may depend on working memory resources (Brewin & Smart, 2005). It may be, therefore, that working memory deficits found in individuals with OCD (e.g. Snyder et al., 2014) arise specifically from attempts to control and suppress OITs. If this were the case, then such working memory deficits would not be found in the current study, as the sample was nonclinical and therefore would be less likely to suppress the OITs that they experienced. However, research in this area is limited, and further research is needed to investigate the relationship between working memory and thought suppression.

There are several other limitations of the current study that should be considered. First, following the n-back task, participants in the primed group were asked two questions regarding their experience of OITs ("Roughly how many times did you experience your most upsetting/unpleasant intrusive thought during the task?", and "Did you experience any other intrusive thoughts of the following themes?") and non-primed participants were asked one question regarding their experience of OITs ("Did you experience any intrusive thoughts of the following themes?"). The higher number of OITs experienced by the primed group could conceivably be the result of demand characteristics, whereby participants in the primed group reported more OITs because they were asked on more occasions how many they experienced. However, previous studies have demonstrated that such a priming method leads to statistically significant differences in the number of OITs experienced by primed and non-primed groups, (e.g. Purdon, 2001; Purdon & Clark, 2001; Purdon, Rowa & Anthony, 2005). It would be expected, therefore, that differences in OIT frequency would have been found, regardless of the questions asked.

Similarly, it may be that the OIT prime led to a higher number of OITs experienced on the 1-back task than the 3-back task, as that was the order in which the tasks were completed; however, this was not assessed in the present study. In other words, the 1-back task was conducted directly after the OIT prime, whereas the 3-back task was conducted following the OIT prime *and* the 1-back task, and the effect of the prime may have therefore decreased or worn off as the task progressed. Future studies might consider re-priming OITs between each set of trials (e.g. directly before the 1-back and 3-back tasks). Alternatively, future studies may prime OITs in the same way as the present study, but assess the number of OITs experienced, retrospectively, after the 1-back and 3-back task.

Finally, in the current study individuals were not screened for clinical DSM disorders, psychotropic medication, or neurological disorders. It was therefore not possible to assess the impact of these variables on task performance. Indeed, each of these variables have been linked to underperformance on EF tasks (Abramovitch & Cooperman, 2015). Future research should control for these variables.

In conclusion, data from the present study indicate that an increase in a range of OCD-relevant state factors do not impair working memory in nonclinical individuals. In particular, an increase in OITs does not impair working memory in nonclinical individuals. The findings from the present study do not provide evidence for a key prediction of the Executive Overload Model of OCD. Future research would benefit from investigating the impact of OITs on inhibition and cognitive flexibility, as such research would provide more evidence in favour, or against, the Executive Overload Model of OCD. The current findings suggest that EF deficits found in individuals with OCD may only be found in a sub-group of such individuals. Future research investigating working memory performance in different sub-groups of individuals with OCD would help to answer this question.

The findings from chapter two and chapter three do not support the trait or state account of working memory deficits in OCD, leaving a confusing picture of the relationship between working memory deficits and the symptoms of OCD. One area that has not been investigated in this thesis, so far, is the relationship between working memory and OCD-relevant thought control strategies. Executive functions, including working memory, are responsible for the control of other cognitive processes, including thoughts (Banich, 2009). Future research that investigates the relationship between working memory and the control of OITs may reveal important information about the development and maintenance of OCD. Indeed, the next chapter aims to investigate this relationship.

Chapter 4: The relationship between working memory and obsessive intrusive thought dismissibility.

The current chapter aims to investigate the question of whether working memory is implicated in the suppression of obsessive intrusive thoughts (OITs). More specifically, the chapter aims to assess whether individual differences in working memory predict the ability to dismiss OITs. The studies presented in the thesis so far provide no evidence for the state or trait account for working memory deficits in OCD. However, none of these studies have investigated the relationship between working memory and thought control strategies, despite the importance of such strategies to our understanding of OCD. This chapter, therefore, aims to investigate the relationship between working memory and thought suppression.

In this chapter, first, I will introduce thought suppression and discuss its relevance to the maintenance and development of obsessive-compulsive disorder (OCD). Next, I will discuss some of the problems with most thought suppression research and explain how measuring thought dismissibility is a more comprehensive measure of suppression success than thought frequency. Finally, I will discuss how working memory may be implicated in the suppression of thoughts, and introduce the current study.

Current cognitive theories of OCD posit that a key factor in the development and maintenance of OCD is unsuccessful thought control attempts (Rachman 1997, 1998). Most individuals experience OITs (e.g. see Radomsky et al., 2014), but individuals with OCD are more likely to appraise the thoughts in negative ways, such as by thinking the thought is an indication that something will happen which they must prevent (Salkovskis, 1985; 1999). Such negative appraisals of OITs motivate individuals to attempt to control their thoughts (often unsuccessfully), to try to reduce distress and prevent negative outcomes (Rachman 1997, 1998).

One method of thought control that has been implicated in the maintenance and development of OCD is thought suppression (Clark & Purdon, 1993; Salkovskis & Campbell, 1994). Thought suppression can be defined as the effortful process of attempting to remove a thought (Wegner, 1989) such as by saying ‘stop’ to oneself or by attempting to mentally replace the thought with another (Purdon, Rowa, & Antony, 2007). Based on this definition, it could be said that individuals are ‘successful’ at suppressing thoughts when they are able to remove the thought from consciousness, or prevent a thought from reoccurring. Although individuals with OCD are more likely to suppress OITs than nonclinical individuals (Belloch, Morillo, García-Soriano, 2007; García-Soriano & Belloch, 2013), most of these attempts are unsuccessful (Purdon, Rowa, & Antony, 2007). In addition, suppression attempts are often strenuous and time-consuming (Purdon et al., 2007), and therefore have a significant negative impact on functioning.

In a seminal study on thought suppression, Wegner (1987) found that not only are suppression attempts often unsuccessful, but they actually lead to an increase, rather than decrease in the suppressed thought. In the study, nonclinical individuals who were instructed *not to think* of a white bear experienced more thoughts of white bears than individuals who were not asked to suppress the thoughts (Wegner, 1987). The findings of this study lead to the development of the “ironic process theory” (Wegner, 1994). The central idea of the theory is that not only is thought suppression unsuccessful, but it also has a paradoxical effect: it causes the number of suppressed thoughts to *increase*.

Support for the ironic process theory of thought suppression comes from a meta-analysis that looked at the effect of thought suppression in nonclinical individuals and those with OCD (Abramowitz, Tolin, & Street, 2001). The meta-analysis found a small post-suppression effect (‘the rebound effect’; estimated $d = .30$); that is, suppressed thoughts were experienced more frequently in the period after attempting to suppress them. However, the meta-analysis did not find an overall effect of thought suppression, nor did it find that suppression lead to an increase in thoughts whilst actively suppressing (‘thought enhancement effect’). In other words, individuals are, to some extent, able to keep thoughts out of consciousness whilst actively trying to suppress them. However, once suppression efforts are relaxed, individuals experience significantly more thoughts than individuals who were not instructed to suppress in the first place.

Despite the lack of support for a thought enhancement effect in Abramowitz et al. (2001), it is clear that individuals are often unsuccessful at suppressing thoughts whilst attempting to suppress them, and also that they vary in their suppression ability. These two points are demonstrated by OIT frequency means of more than zero in suppression studies (e.g. with nonclinical participants; Purdon & Clark, 2001; with individuals diagnosed with OCD; Abramowitz, Tolin, Street, 2001). For example, Purdon and Clark (2001) instructed nonclinical individuals to suppress OITs over a six-minute period, and found that the mean number of OITs reported by the group was 6.47 (with a standard deviation of 5.54). Understanding the mechanisms behind these individual differences in suppression success would reveal important information about the persistence of OITs, and ultimately, about the maintenance and development of OCD.

Problems with previous thought suppression research

In order to understand the mechanisms underlying individual differences in thought suppression success, it is important that thought suppression is measured accurately. However, there are methodological problems with the majority of previous research on thought suppression which means that strong conclusions cannot be drawn about the findings. One problem with the majority of previous research on suppression success is that these studies have generally considered thought *frequency* (also referred to as '*thought onset',* or the number of times a thought enters consciousness; Lambert, Hu, Magee, Beadel, & Teachman, 2014) as a primary dependent variable of suppression success, rather than thought *dismissibility* (also referred to as '*thought duration*'; Lambert et al., 2014; '*thought persistence*'; Purdon, 2004; and '*thought removal*'; Ólafsson et al., 2014). Whereas thought frequency represents the *number* of OITs experienced during a suppression task, thought dismissibility represents the *length of time* that OITs are attended to during a suppression task. The problem with measuring thought frequency as a measure of suppression success is that frequency is confounded with duration, meaning only a partial picture of suppression success is provided (Purdon, 2004). In contrast, measuring thought dismissibility is able to account for both frequency and duration.

The fact that frequency is often confounded with duration in the majority of suppression studies can be demonstrated by briefly describing how suppression success is typically measured. Participants are first primed with OITs, so that they experience OITs during the experimental period and are therefore able to attempt to suppress them. Priming OITs is often achieved by asking a participant to think about an OIT for a period of time. (e.g. 30 seconds; Purdon & Clark, 2001). Following the prime, participants are asked to suppress the OIT for a period of time (e.g. "try as hard as you can to suppress the… thought", Grisham & Williams, 2009). During this suppression attempt, the number of OITs that the participant experiences are measured (e.g. by pressing a computer key; Purdon & Clark, 2001). Fewer OITs during the suppression task are thought to represent more successful thought suppression; and therefore better mental control. A participant who records only one thought occurrence during the suppression task might *appear* to be more successful at suppressing thoughts than someone who reports five thought occurrences. However, the former participant may have failed to *dismiss* the OIT for the entire duration of the task, whereas the latter participant may have successfully dismissed each of the five OITs (Purdon, Gifford, McCabe & Antony, 2011). Here, the participant who experienced five OITs may feel more in control of their thoughts (and feel like they are having more success suppressing) than the participant who experienced one OIT, but the majority of suppression tasks are unable to detect or demonstrate this crucial distinction.

It is important to note that some studies may have collected data on thought duration but chose not to report the data. That is, some studies assessed target thought frequency using a stream of consciousness verbalization (e.g. Brewin & Smart, 2005), whereby participants verbally state any thoughts that come into their head whilst attempting to suppress the target thought (e.g. "I wonder what I should have for dinner later… that was irritating earlier when the bus drove off even though the driver saw me" etc.). Participants are also asked to ring a bell whenever the target thought comes into mind. This verbalization is later coded by the experimenter for the number of times that the individual mentions the target thought and rings the bell. However, as previously mentioned, this data on thought duration is very rarely reported, and may no longer be available (e.g. if duration was not coded originally and recordings have been destroyed). In addition, this may be a problematic measure of suppression success because people may feel self-conscious about reporting thought occurrences when they have been instructed to suppress it (Purdon, 2004), particularly when the target thought covers a taboo topic, such as sex or aggression.

In contrast to studies that only measure thought frequency, studies that measure thought dismissibility do not suffer from the same problems with confounding frequency/duration. As with frequency studies, participants are also first primed with a thought/OIT. However, the suppression instructions differ to those in frequency studies: participants are typically asked to replace this thought with a neutral thought (e.g. try to replace the OIT with the thought of a *houseplant*; Purdon et al., 2011) and to indicate when they were successful in doing this (e.g. by pressing a computer key; Purdon et al., 2011). Quicker dismissal times are thought to represent greater suppression success. It is important to note that such studies are also able to measure thought frequency (e.g. the number of keyboard key presses) in addition to thought dismissibility, making the method of measurement more comprehensive than measuring frequency alone. Using this method of measuring suppression success captures both frequency and duration, and so a more complete picture of thought suppression is captured.

A further advantage of measuring thought dismissibility over thought frequency is that it may reveal important information about OCD. Indeed, it is currently unclear whether OCD is a problem of thought return (i.e., frequency) or of an inability to get rid of a thought once it occurs (i.e., dismissibility; Purdon et al., 2011). Measuring thought dismissibility alongside OCD symptoms will help to answer such questions. It may be, for example, that OIT dismissibility is a further characteristic that should be considered within the continuum model of OITs (Clark & Rhyno, 2005). The continuum model of OITs suggests that OITs are experienced by everybody but differ based on a range of other variables, such as frequency and appraisals (Clark & Rhyno, 2005; Berry & Laskey, 2012). It may be, therefore, that OITs at one extreme end of the continuum are harder to dismiss than those toward the other end of the continuum.

Another methodological issue with the majority of previous thought suppression studies is that they cannot determine whether low frequency of OITs reflects poor suppression success or difficulties with selecting an appropriate suppression strategy (Ólafsson et al., 2014). Participants are typically instructed to try to suppress the thought (e.g. “it is very important that you try as hard as you can to suppress the… thought”, Grisham & Wlliams, 2009), leaving the participant to decide upon the most effective suppression strategy. However, possible options for thought suppression could include saying “stop” to oneself, replacing the thought with another thought, trying to relax, keeping busy, distracting oneself physically, or avoiding something that may trigger the thought, amongst others (Purdon et al., 2007). Each of these suppression strategies vary in how effective they are (although none are particularly effective; Purdon et al., 2007). In contrast, dismissibility tasks typically provide participants with a strategy to use (e.g. “if the *basket* thought comes to mind… immediately try to replace the thought of a *basket* with the thought of a *houseplant*”; Purdon et al., 2011). Providing participants with a suppression strategy means that difficulties with selecting appropriate strategies can be ruled out as an explanation of the findings. It can therefore be inferred that poor dismissibility scores reflect unsuccessful suppression (or poor mental control).

In summary, the problems with previous thought suppression studies could be overcome in future studies by adopting a thought dismissibility measure of suppression, rather than a thought frequency measure, for four reasons. First, thought frequency measures confound frequency with duration, whereas thought dismissiblity measures do not. Second, dismissibility measures offer a more comprehensive measure of suppression success, as they capture both frequency and dismissibiltiy. Third, thought dismissibility measures offer a clear suppression strategy for participants to use, ruling out the possibility that findings are due to difficulties choosing a suppression strategy. Fourth, thought dismissibility measures may reveal previously unknown information about OCD.

Thought dismissibility studies

Despite the clear advantages of measuring OIT dismissibility over OIT frequency alone, few studies have taken this approach (Edwards & Dickerson, 1987; Magee & Teachman, 2012; Purdon et al., 2011; Ólafsson et al., 2014;

Lambert et al., 2014). Broadly speaking, dismissibility has been measured in two ways: subjectively and objectively. Subjective dismissibility has been measured through the use of self-report questionnaires, and refers to *perceived difficulty* in dismissing OITs (Rachman & de Silva, 1978; Salkvoskis & Harrison, 1984; Ólafsson et al. 2014). Objective dismissibility has been measured through experimental studies, and refers to *actual ability* in dismissing OITs. Of those studies that have been conducted into OIT dismissibility, although there are many methodological similarities, there are also some key differences. That is, the studies vary in priming method and in the way dismissibility data is captured (physical/manual vs computerised). In order to inform future studies on OIT dismissibility, it is therefore important to not only consider the key findings, but also the strengths and weakness of each methodology.

In the first study to measure objective OIT dismissibility, 43 nonclinical participants were assessed on their ability to dismiss an OIT by replacing it with a neutral thought (unspecified) (Edwards & Dickerson, 1987). Participants were first asked to think of an upsetting OIT (for an unspecified period of time, chosen from the Intrusive Thoughts Questionnaire; Edwards, 1985) and to press a reaction time buzzer when they had formed the thought. Following this, a tone sounded and participants were required to replace their OIT with a neutral thought (and vice versa) and to press a reaction time buzzer when they had successfully replaced the thought. Time taken to replace one thought with another served as a measure of objective dismissibility. The key finding was that participants took longer to dismiss OITs than neutral thoughts. This was the first study to find an association between OCD symptoms and thought dismissibility.

The finding that OITs take longer to dismiss than neutral thoughts was later replicated with a computerised version of the dismissibility task (Ólafsson et al. 2014; experiment 1). To begin, sixty-one female participants were presented with a blank screen and sound cue. On the cue, participants were asked to form an image of either i) a personal OIT (selected from the Interpretation of Intrusions Inventory, III; Obsessive Compulsive Cognitions Working Group, 2005), ii) a standard OIT ("you hit a six-year-old girl with your car"), or iii) a neutral thought ("you are bicycling when you see a middle-aged man in a green scarf"). Participants were then instructed to hold the thought in mind for 15 seconds, before replacing the thought with a neutral thought ("sitting on a bench, waiting for a bus to arrive"), and indicating when they had done so. This process of thinking of a thought, holding it for 15 seconds, then replacing it, was repeated six times for each target thought (18 times in total). The time taken to replace the thought was used as the participant's objective dismissal score. Personal OITs (but not standard OITs) took longer to dismiss than neutral thoughts. In addition, both personal OITs and standard OITs were reported as being more difficult to dismiss than neutral thoughts (subjective dismissibility). However, this study did not find that symptoms of OCD were related to objective dismissibility times, suggesting that OCD symptoms cannot explain individual differences in OIT dismissibility.

The second part of the same experiment (Ólafsson et al. 2014; experiment 2), looked to investigate the relationship between OCD symptoms and objective dismissibility further. Forty university students (32 female) were recruited and divided into a “high OCD” and “low OCD” group, based on their OCD symptom scores (Obsessive Compulsive Inventory-Revised; Foa et al., 2002). All participants completed a shorter version of the dismissiblility task that was used in experiment 1. In line with the study’s first experiment, there was no difference between the high OCD group and the low OCD group in objective OIT dismissibility (mean latency to dismiss OITs). However, the high OCD group reported poorer subjective dismissibility than the low OCD group. The findings from experiment 1 and 2 suggest that OCD symptomatology is related to perceived, rather than actual, difficulty with OIT dismissal.

While the evidence presented so far suggests that OCD symptomatology may not be related to poorer objective thought dismissal, only one study has looked directly at this phenomenon in individuals with OCD (Purdon et al., 2011). In this study, 25 participants with a diagnosis of OCD were first primed with their most upsetting OIT, and 25 participants with a diagnosis of panic disorder were primed with their most upsetting panic-related thought. The prime involved thinking about the thought in vivid detail for 30 seconds. Following the OIT prime, all participants were given a computerized thought replacement task, where they were first given a neutral thought and then asked to replace the neutral thought (e.g. shoebox) with their most upsetting OIT or panic related thought, and vice versa. Participants sat at a computer for two eight-minute intervals and were asked to indicate using a key on a keyboard each time they had experienced the target thought and then each time they had successfully replaced the thought. This measure of dismissibility captured four different variables: thought frequency, objective thought dismissibility, time taken for the OIT to return, and the total amount of time spent thinking about the OIT. Individuals with OCD experienced more frequent OITs and experienced them for a longer total period of time than individuals with panic disorder (with panic-related thoughts). However, there were no differences between the groups in time taken to dismiss thoughts, suggesting thought dismissibility alone is not a problem that is specific to OCD.

In addition to these experimental studies of objective thought dismissibility, several studies have measured subjective dismissibility alone (Parkinson & Rachman, 1981; Rachman & de Silva, 1978; Salkovskis & Harrison, 1984). The general finding from these questionnaire studies is that individuals with OCD report more difficulty dismissing OITs than nonclinical individuals. These findings are in line with some of those previously discussed (Ólafsson et al. 2014; experiment 1 and 2). However, self-report questionnaires suffer from "memory effects", enhanced or impaired recollection of memories due to the time delay between the experience and the self-report, meaning participants may not be accurately reporting their experiences. It is important, therefore, that these findings are not interpreted as representing poorer OIT dismissibility in individuals with OCD. Rather, the findings represent poorer perceived difficulty with dismissing OITs in individuals with OCD.

There are several important methodological limitations in the thought dismissibility literature that should be considered. Most dismissibility studies, barring one (Edwards & Dickerson, 1987) utilised computerized versions of the suppression task, which are superior to non-computerized versions, due to ease of administration, superior time measurement accuracy, and reduced demand effects (as the experimenter does not need to be in the same room as the participant). There is also variation in the method used to prime OITs, with some studies only asking participants to briefly think of an OIT (Edwards & Dickerson, 1987) and some asking participants to think of pre-selected OIT for 40 seconds (Magee & Teachmann, 2012). The problem with asking participants to “think” about OITs for a period of time is that some participants may fail to actually do it; either due to poor motivation or an unwillingness to think about an upsetting thought. A superior method of priming OITs would be to ask participants to write about their OITs for a period of time, thus forcing them to engage with the task. Very few studies have used this method of priming (e.g. Najmi, Riemenn, & Wegner, 2009; Bomyea & Amir, 2011) and no studies have used this method of priming when measuring OIT dismissibility. It would therefore be methodologically superior to use computerized tasks and a writing OIT prime.

To summarise, although the research on thought dismissibility is scarce and varies methodologically, current findings suggest that symptoms of OCD are related to poorer subjective thought dismissibility, but not poorer objective thought dismissibility. It is not surprising that perceived difficulty with dismissing OITs is related to OCD symptomatology, as it has been found previously that individuals with OCD are more likely to appraise OITs as being uncontrollable (Cartwright-Hatton & Wells, 1997; Clark, Purdon, & Wang, 2003). It is more surprising that there is no relationship between objective dismissibility and OCD symptoms. Overall, it seems that symptoms of OCD cannot explain differences in thought dismissibility, however, further research is needed to clarify the relationship.

Working memory and suppression

In addition to OCD symptomatology, a further possible explanation for individual differences in suppression success is variations in working memory. Indeed, several studies have implicated working memory in the successful suppression of thoughts, both neutral and OITs (Brewin & Beaton, 2002; Brewin & Smart, 2005; Bomyea & Amir, 2011; Rosen & Engle, 1998). In the first study to investigate the relationship between working memory and thought suppression, Rosen and Engle (1998; experiment 2) recruited 120 nonclinical participants. Participants completed a working memory task (a variation of the operation span task; OSPAN, Turner & Engle, 1989) and a word learning task. The word learning task involved learning three lists, each containing 12 pairs of words. The initial word in each list was the same, but the paired word changed from list 1 to list 2 and then back to the original in list 3 (e.g., bird-bath, bird-dawn, bird-bath). The idea behind this set of lists was to create interference, so that the paired words in list 1 would interfere with learning list 2. The key finding from the study was that individuals with better working memory were slower to re-learn the list 3 pairs, suggesting they had more successfully suppressed the words in order to learn the words on list 2. This finding suggests that the working memory system is responsible for controlled attention to a range of stimuli, which includes the exclusion of irrelevant or unwanted material.

Another study that suggested individual differences in working memory may explain differences in suppression success was carried out by Brewin and Beaton (2002). Sixty nonclinical participants were asked to complete a working memory task (operation span task; OSPAN, Turner & Engle, 1989) and a thought suppression task. The OSPAN task is a prototypical working memory task whereby participants are asked to remember and recall a sequence of letters, each of which is separated by an arithmetic problem. The thought suppression task followed a standard “white bear” paradigm (Wegner et al., 1987); whereby participants were instructed not to think of a white bear and to express, via bell rings, when the thought of a white bear entered consciousness. The study found that working memory was negatively associated with number of thoughts experienced during an active suppression attempt. That is, participants with better working memory were more successful at suppressing thoughts than participants with poorer working memory. This finding implicated the working memory system in the successful suppression of thoughts.

There are several limitations to Brewin & Beaton (2002) that may limit its generalizability (Erskine, Georgiou, Joshi, Deans, & Colegate, 2017). More specifically, the mean number of intrusions experienced over a five-minute active suppression period was 15.53 (*SD* = 11.27), which is much higher than the usual frequency reported across studies (Erskine et al., 2017). It is possible that this high frequency of thoughts represents an immediate enhancement effect, which is rarely found within the literature (Erskine et al., 2017). In addition, the average IQ of the sample in the study was 119, much higher than the average European IQ range of 95-100 (Gelade, 2008). This could be problematic as IQ is positively associated with working memory capacity (Ackerman, Beier, & Boyle, 2005) and may therefore explain the high number of thoughts reported during the suppression task (Erskine et al., 2017). However, this seems unlikely as the study found that working memory was related to fewer, not more, thoughts during suppression. Despite these limitations, the findings from the study suggest a relationship between working memory and the successful suppression of thoughts (Erskine et al., 2017).

The findings of Brewin and Beaton (2002) were later replicated by Brewin and Smart (2005), but with OITs instead of thoughts of a white bear. All participants completed a suppression task and a working memory task (OSPAN). Before completing the suppression task, participants were primed with their most upsetting OIT (chosen from the Revised Obsessional Intrusions Inventory; Purdon & Clark, 1994) and were asked to suppress this thought for the next five-minute period. Again, OSPAN scores were found to correlate negatively with suppression success, such that participants with better working memory also experienced fewer OITs during the suppression task. Again, these findings implicated the working memory system in the successful suppression of thoughts.

The findings from these two correlational studies that suggest working memory plays a role in thought suppression were later supported by a working memory intervention study (Bomyea & Amir, 2011). Fifty nonclinical student participants were recruited, and half of the participants were given a working memory training intervention. Next, participants completed a working memory task (OSPAN; Turner & Engle, 1989). Participants were then primed with negative personal memories relating to OITs, by writing down a negative personal experience that had led to the experience of an OIT, for three minutes. Following this, participants were asked to suppress thoughts of their upsetting memory. Those participants in the intervention condition performed better on the working memory task. Crucially, they also reported fewer upsetting memories in the suppression condition than participants who did not receive working memory training. This experimental finding highlighted the role of working memory in the suppression of upsetting thoughts.

In sum, although research is sparse, these findings suggest that working memory may be implicated in the successful suppression of OITs. That is, individual differences in thought-suppression abilities may be explained by differences in working memory. However, these studies have all measured thought frequency (rather than dismissibility) as a key measure of suppression success, which is problematic for reasons previously discussed. It would be informative to investigate whether working memory is related to an individual's ability to dismiss OITs. Whereas in the case of OIT frequency, working memory may serve to *maintain* attention to a distractor thought, in the case of OIT dismissibility, working memory may serve to *shift* attention away from the suppressed thought and to a distractor thought. Indeed, it may be that working memory is implicated more closely in dismissing OITs once they occur, rather than preventing them from reoccurring. To date, no studies have investigated the relationship between working memory and OIT dismissibility.

The effect of mood on suppression

In addition to OCD symptomatology and working memory, a further possible individual difference that may explain suppression success is mood. Indeed, some of the previously discussed suppression studies found a relationship between mood and suppression. For example, Brewin and Smart (2005) found a relationship between depression and the number of OITs experienced during a suppression task. Wentzlaff and Wegner (2000) argued that anxiety and depression are associated with poorer suppression success, because suppression often involves searching for a distractor thought, and distractor thoughts may trigger the recurrence of OITs because of similar negative content. In line with this idea, individuals experiencing dysphoria have more difficulty suppressing negative thoughts than positive thoughts (Conway, Howell, & Giannopoulos, 1991) and individuals who are not experiencing dysphoria have more difficult suppressing positive thoughts than negative thoughts (Howell & Conway, 1992). However, much of the thought suppression literature has failed to account for the effects of depression and anxiety. Other studies have measured mood but have failed to find a relationship. For example, Ólafsson et al. 2014 did not find a relationship between depression and objective OIT dismissibility. Despite this contradictory finding, there is some evidence to suggest a relationship between mood and suppression success, and future studies should therefore consider the role of mood in suppression studies.

The present study

The main aim of the present study is to investigate whether individual differences in working memory predict an individual’s ability to dismiss OITs. It was expected that individuals with better working memory will also be quicker at dismissing OITs once they occur. A further aim of the current study is to investigate whether individual differences in working memory predict the ability to prevent OITs from reoccurring/occurring in the first place. Based on previous findings (Brewin & Beaton, 2002; Brewin & Smart, 2005), it was predicted that individuals with better working memory will also experience fewer OITs during a suppression task. A final aim of the current study is to investigate the relationship between OIT dismissibility (subjective and objective) and OCD symptoms. It was predicted that subjective dismissibility, but not objective dismissibility, will be related to OCD symptoms. Each of these aims will be investigated in a nonclinical sample. As discussed in previous chapters, the use of nonclinical participants offers a valid method of studying these phenomena due to the dimensional experience of obsessive-compulsive symptoms (Abramowitz et al., 2014). These aims will be investigated by asking participants to complete a working memory task (OSPAN) and a dismissibility task on a computer. In addition, participants will complete several questionnaires measuring mood and OITs.

The current study will measure working memory using the OSPAN task (Turner & Engle, 1989) for two reasons. First, previous studies that have investigated working memory and suppression have utilised the task (e.g. Brewin & Beaton, 2002; Brewin & Smart, 2005), meaning more confident conclusions can be drawn from between-study comparisons. Second, the OSPAN has been associated with emotion regulation, such that individuals who scored higher on the OSPAN suppressed expressions of negative emotion (from watching a gruesome film) better than individuals who scored lower on the OSPAN (Schmeichel, Volokhov, & Demaree, 2008). It seems plausible, therefore, that the OSPAN may also be related to the suppression of OITs (Grisham & Williams, 2013). Objective OIT dismissibility will be measured using a computerized version of a thought dismissibility task (a shortened version of the task used by Purdon et al., 2011) and a two-minute OIT writing prime. That is, participants will first write about an upsetting OIT for two minutes. Following this, participants will sit at a computer and will be instructed to think of whatever they like, but to suppress (using a thought replacement strategy) the selected OIT each time it enters consciousness. Participants will be asked to indicate, using assigned keyboard keys, i) when the thought has come into consciousness and ii) when the thought has successfully been replaced with a neutral thought. Distress related to the OIT will be controlled for, as distressing OITs are more difficult to dismiss than neutral thoughts (Edwards & Dickerson, 1987; Ólafsson et al., 2014). Depression and anxiety will also be controlled for, as there is evidence to suggest that that these states have a negative impact on suppression success (Wentzlaff & Wegner, 2000).

To summarise the study's hypotheses:

Hypotheses:

Better working memory will predict quicker objective OIT dismissibility (when controlling for depression and OIT distress).

Better working memory will predict less frequent OITs (after controlling for depression and OIT distress).

Obsessive intrusive thought dismissibility will not be related to OCD symptomatology.

Subjective OIT dismissibility will be related to OCD symptomatology.

4.1: Method

Design

The study used a within-subjects design. The primary predictor variable was working memory performance (as measured by the *Operation Span task,* OSPAN; Unsworth et al., 2005). The primary outcome variables were objective

OIT dismissibility (mean latency to dismiss OITs) and subjective OIT dismissibility (perceived difficulty in dismissing OITs) (on a 101-point scale). Distress associated with the primed OIT, and depression scores (as measured on *Depression Anxiety and Stress Scale*, DASS-21; Lovibond & Lovibond, 1995) were entered as control variables. Other variables were depression, anxiety and stress scores (as measured on the Depression Anxiety and Stress Scale, DASS; Lovibond & Lovibond, 1995), obsessive-compulsive symptom scores (as measured by the Obsessive Compulsive Inventory – Revised, OCI-R; Foa et al., 2002), retrospective OIT frequency (as measured by part 1 of the *Obsessional Intrusive Thoughts Inventory;* Original Spanish Version: “Inventario de Pensamientos Intrusos Obsesivos”, INPIOS; García-Soriano, Belloch, Morillo & Clark, 2011), the number of times the OIT occurred during prime (thought frequency); the total time spent thinking about OITs (total time); the mean latency with which the OIT returned (mean latency to return).

Participants

According to a priori power analysis, with a medium effect size ($f^2 = .15$), an α =.05 and a power of .8, a sample of 85 participants was needed in total. Ninety participants were recruited, via e-mail, from a staff/student pool at The University of Sheffield. Nine participants were excluded from the study for not completing all relevant tasks, and four participants were excluded for scoring below 80% accuracy on the maths problems in the Operation Span Task (OSPAN task; Unsworth et al., 2005). A total sample size of 77 participants (15 males, 62 females; mean age = 20 years; age range = 18-40 years) remained. Individuals who reported that they had received a diagnosis of OCD were not eligible to participate in the study, as they have been found to perform poorer than nonclinical individuals on some executive function tasks (e.g. Snyder et al., 2014). Participants received either course credits or £5 cash reimbursement for their time.

Materials

Questionnaires

The *Obsessive Compulsive Inventory – Revised* is an 18-item measure used to assess OCD symptoms. The OCI-R comprises a list of symptoms (e.g. "I check things more often than necessary") for which participants indicate on a scale from 0 ("not at all") to 4 ("extremely") how distressed the symptoms have made them in the past month. Items cover six sub-scales, (a) washing, (b) checking/doubting, (c) obsessing, (d) mental neutralizing, (e) ordering, (f) hoarding. Total scores on the OCI-R are calculated by summing the items. Scores range from 0-72 with higher scores indicating higher levels of OCD symptomatology. The recommended cut-off score for the OCI-R is 21, with scores at or above this level indicating the likely presence of OCD (Foa et al., 2002). The OCI-R has demonstrated good psychometric properties in nonclinical participants; excellent internal consistency (α = .89), good test-retest reliability (1 week – r = .84), and convergent validity (significant positive correlations were found with the OCI-R and a range of OCD measures; Foa et al., 2002). Discriminant validity was mixed, with high correlations between the OCI-R and Beck Depression Inventory (BDI; r = .7); however, this is common across all OCD symptom measures (Foa et al., 2002). In this study, the Cronbach's alpha was .90.

Part one of the *Obsessional Intrusive Thoughts Inventory* (Original Spanish Version: "Inventario de Pensamientos Intrusos Obsesivos", INPIOS;

García-Soriano, Belloch, Morillo & Clark, 2011) assesses the frequency with which participants experience 48 OITs (e.g. "The documents, papers, etc. are out of order or not in their place") using a seven-point Likert scale ranging from 0 ("never") to 6 ("always"). Part one also includes two open-ended items ("I also have these other intrusions…"), which allow participants to report any idiosyncratic OITs. Total scale scores for part one of the INPIOS are calculated by dividing the total score by the number of items with a frequency ≥ 1 (see García-Soriano et al., 2011). Scores range from 0-6 and higher scores on the INPIOS correspond to more frequent OITs. Part one of the INPIOS has demonstrated good internal reliability (α = .94) and test-retest reliability (7-14 days, *r* = .97) (García-Soriano et al., 2011) in a non-clinical sample. The questionnaire also demonstrated adequate convergent and divergent validity with INPIOS total scores being more strongly correlated with OCD measures than with measures of depression, anxiety or worry (García-Soriano et al., 2011). In the current study the internal consistency for part 1 total score was α = .95.

The *Depression Anxiety and Stress Scale* (DASS-21; Lovibond & Lovibond, 1995) is a 21-item measure of depression, anxiety and stress. Participants were presented with statements (e.g. "I found myself getting upset by quite trivial things") and were required to indicate how much each statement applied to them in the past month, on a scale from 0 ("did not apply to me at all") to 3 ("applied to me very much or most of the time"). Scores for depression, anxiety, and stress are calculated by summing the items for each subscale, with higher scores indicating higher levels of each construct. Scores on the depression subscale range from 0-21 (0-4 = normal; 5-6 = mild; 7-10 =

moderate; 11-13 = severe; 14-21 = very severe), scores on the anxiety subscale range from 0-21 (0-3 = normal; 4-5 = mild; 6-7 = moderate; 8-9 = severe; 10-21 = very severe), and scores on the stress subscale range from 0-21 (0-7 = normal; 8-9 = mild; 10-12 = moderate; 13-16 = severe; 17-21 = very severe). The DASS-21 has demonstrated good psychometric properties; excellent internal consistency (α =.87 -.94 for a sample of individuals with OCD and nonclinical individuals; Antony, Bieling, Cox, Enns, & Swinson, 1998), and good convergent and divergent validity (when compared with other measures of depression and anxiety; Antony et al., 1998; Henry & Crawford, 2005). In this study, the internal consistency for each subscale was: depression (α = .91), anxiety (α = .80), & stress (α = .85).

Working memory measurement

A computerized version of the *Operation Span task* (OSPAN; Unsworth et al., 2005) was used to assess working memory capacity. The OSPAN was completed on a computer with a 17-inch monitor and running E-Prime 2.0 software (Psychology Software Tools, Inc., Pittsburgh, PA). For each trial, participants were presented with a sequence of three to seven letters that they were asked to remember. At the end of each trial, participants were presented with a matrix of 12 letters and were asked to indicate which letters they had been presented with, in the correct order, using a mouse. In between each letter, participants were presented with a maths problem (e.g. 4 + 5), which they were asked to answer by selecting whether a presented number is "true" or "false" (e.g. 9; for the sum "4 + 5" this answer would be "true"). The primary purpose of these maths problems was to prevent participants from rehearsing the letters in their short-term memory, so that the test would more closely assess executive attention and working memory, rather than short-term retention and rehearsal (Conway et al., 2005).

Participants practiced both the letter recall, and math problems, before the main trials began. Participants were then presented with 15 trials, which included three of each letter set-size (ranging from three to seven letters). The order of set sizes was random for each participant. The OSPAN produced three key dependent variables: the total number of letters recalled in the correct position (OSPAN partial score); the total number of letters recalled as a full set (OSPAN absolute score); and maths accuracy. The OSPAN partial score was used as the main dependent variable for working memory capacity.

Obsessive Intrusive Thought Lab Measurements

A shorter version of the thought dismissibility task used by Purdon et al. (2011) was used to assess objective OIT dismissibility. This task was completed on a computer with a 17-inch monitor and running E-Prime 2.0 software (Psychology Software Tools, Inc., Pittsburgh, PA). For the task, participants were required to indicate when they were successful in replacing an OIT with a neutral thought. Participants were first allowed to practice the task, where they were first asked to generate an image of a *basket* in their heads. Participants were asked to monitor their stream of consciousness for two minutes, and indicate, by pressing a red key on a keyboard, when the thought of a *basket* came into their heads. Participants were told that they could think about anything they liked during this time. Participants were then instructed to try and immediately replace the thought of a *basket* with the thought of a *houseplant,* and indicate this by clicking a blue key.

Following the practice task, participants were primed with their most upsetting OIT from the INPIOS (García-Soriano et al., 2011). For the prime, participants were asked to write about a scene involving their most upsetting OIT for two minutes.

Immediately following the priming task, participants began the main trial of the thought dismissibility task. Participants were asked to monitor their stream of consciousness for five minutes and indicate, by pressing a red key, when their most upsetting OIT came into their head. As with the practice trial, participants were told that they could think about anything they liked, but if the OIT came into their head, they should try and immediately replace it with the thought of a *houseplant*. Participants were instructed to indicate when they had successfully replaced the thought, by pressing a blue key. This task produces four dependent variables, which were recorded by the computer: the number of times the OIT occurred (thought frequency); the mean latency to replace the OIT (thought dismissibility); the mean latency with which the OIT returned (mean latency to return), and the total amount of time spent thinking about the OIT (total time).

Following the thought dismissibility task, participants were assessed on subjective OIT dismissibility ("On average… how difficult was it to dismiss your intrusive thoughts") and OIT distress ("On average… how distressed did the intrusive thoughts make you feel?"), assessed using a 101-point scale (0-100).

Procedure

All participants attended the laboratory and completed: a short demographic questionnaire; the Obsessive-Compulsive Inventory – Revised (OCI-R; Foa et al., 2002); the Obsessional Intrusive Thoughts Inventory (INPIOS; Garcia-Soriano et al., 2011); and the Depression Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995) on a computer, using the survey platform, Qualtrics. Participants then completed the OIT dismissibility task, and subsequent dismissibility and distress questions. Following this, participants completed the OSPAN task (Unsworth et al., 2005). Participants sat approximately 80 cm from the screen. Informed consent was obtained from all participants and the study was granted ethical approval by the University's psychology ethics committee.

4.2: Results

Descriptive statistics

Participants scored a mean of 17.29 (*SD* = 10.99) on the OCI-R (OCI-R clinical cut off ≥ 21). The mean total number of OITs endorsed on the INPIOS across the sample was 27 (*SD* = 11). The average total score on the INPIOS was 2.18 (*SD* = .69) (total frequency of thoughts divided by total number of thoughts endorsed; see INPIOS description above for more details). For the DASS depression subscale participants scored a mean of 5.44 (*SD* = 4.60) (out of a maximum score of 21; normal 0-4; moderate 7-10; extremely severe 14+), for the DASS anxiety subscale participants scored a mean of 4.94 (*SD* = 4.02) (out of a maximum score of 21 normal 0-3; moderate 6-7; extremely severe 10+), and for the DASS stress subscale participants scored a mean of 6.97 (*SD* = 4.48) (out of a maximum score of 21 normal 0-7; moderate 10-12; extremely severe 17+).

For the thought dismissibility task, participants experienced a mean of 7.6 OITs (*SD* = 8.01). It took participants a mean time of 6.8 seconds (*SD* = 9.3) to dismiss the OITs, it took a mean of 43.3 seconds (*SD* = 42.89) for the OITs to return after dismissal, and participants spent a mean total time of 37.57 seconds (*SD* = 42.88) thinking about the OITs.

Preliminary analysis:

Are there any effects of reimbursement method on OSPAN performance?

In the current study, some participants were compensated with cash (£5; *n* = 33) and others with course credit (*n* = 44). In order to check that there were no unintended effects of differential reimbursement, two ANOVAs were conducted, comparing OSPAN performance (absolute score and partial score) between those who received cash and those who received course credit. Reimbursement method was entered as the independent variable (with two levels; cash or credit) and OSPAN absolute score and OSPAN partial score were entered as dependent variables. No significant differences were found between the two groups on OSPAN performance. More specifically, no significant differences in OSPAN absolute score were found between those compensated with cash (*M* = 42.06, *SD* = 15.24) and those compensated with credit (*M* = 38.34; *SD* = 16.71; $F[1, 75] = 1.00$, $p = 0.31$). Similarly, no significant differences in OSPAN partial score were found between those compensated with cash (*M* = 59.12, SD = 12.10) and those compensated with credit (*M* = 56.02, SD = 11.84; $F[1, 75] = 1.27$, $p = 0.26$).

Main analyses:

Does working memory capacity predict objective obsessive intrusive thought dismissibility?

A linear hierarchical regression analysis was conducted to determine whether working memory capacity predicted objective OIT dismissibility (assessed by the mean latency to replace OITs), whilst controlling for depression, anxiety and distress associated with the primed OIT. The model containing only depression, anxiety, and OIT distress explained 11.3% of the variance (see table 1). The model containing all variables also explained 11.3% of the variance in objective OIT dismissibility (see table 1). Working memory capacity was not a significant predictor of objective OIT dismissibility (see table 1).

Table 1. Multiple regression model, predicting OIT dismissibility (mean latency to replace obsessive intrusive thoughts) from working memory (OSPAN), depression, anxiety (DASS) and distress associated with primed OIT.

		Unstandardized Coefficients		Standardized Coefficients
		B	*SE b*	β
Step 1				
	Constant	459.17	2342.97	
	Depression (DASS)	248.61	300.20	.13
	Anxiety (DASS)	-208.25	355.94	-.09
	OIT distress	101.57	37.56	.32**
Step 2				
	Constant	1725.06	5315.61	
	Depression (DASS)	245.38	302.43	.13
	Anxiety (DASS)	-204.78	302.43	-.09
	OIT distress	101.72	37.80	.32**
	Working Memory (OSPAN)	-22.24	83.67	-.030

DASS = Depression, anxiety and stress scale; OSPAN = Operation span task

* = p <.05; ** = p < .01

R^2 = .11 for Step 1 (p = .03): ΔR^2 = .11 for Step 2 (p = .07)

Does working memory capacity predict obsessive intrusive thought frequency?

A linear hierarchical regression analysis was conducted to determine whether working memory capacity predicted OIT frequency, whilst controlling for depression, anxiety, and distress associated with the primed OIT. None of the independent variables predicted OIT frequency: working memory (B=.05, $SE\ b$ = .08, β = .07, p = .57), depression (B = -.21, $SE\ b$ = .29, β = -.12, p = .48), anxiety (B = .30, $SE\ b$ =.34, β = .15, p = .39), or OIT distress (B = .00, $SE\ b$ =.04, β = .02, p = .91).

Are symptoms of obsessive-compulsive disorder related to objective obsessive-intrusive thought dismissibility, subjective dismissibility, frequency or total time experiencing obsessive-intrusive thoughts?

Pearson's correlation analysis and spearman's rank correlation analysis were conducted to explore the relationship between OCD symptomatology, objective OIT dismissibility, subjective OIT dismissibility, OIT frequency and total time experiencing OITs. A Bonferroni correction was made to correct for multiple comparisons, and P-values of <.0125 (.05/4) were considered to be significant. Pearson's correlation analysis revealed a significant association between OCD symptomatology and perceived difficulty in dismissing OITs (r[77] = .40, p < .01) and between OCD symptomatology and total amount of time thinking about OITs (r[77] = .28, p = .01). There were no significant relationships between OCD symptomatology and mean time taken to dismiss OITs (r[77] = .17, p = .14)

A Spearman's rank correlation analysis demonstrated no significant relationship between OCD symptomatology and OIT frequency (r_s(77) = .20, p = .08)

Is there a relationship between obsessive compulsive symptoms and perceived difficulty with dismissibility, after controlling for obsessive intrusive thought distress?

A partial correlation revealed a significant relationship between OCD symptomatology (OCI-R) and perceived difficulty with dismissibility (subjective dismissibility), after controlling for OIT distress ($r[73] = .29$, $p = .01$).

4.3: Discussion

The main aim of the current study was to investigate whether individual differences in working memory predicted an individual's ability to dismiss OITs. To investigate this question, participants completed a working memory task followed by an OIT dismissal task. The tasks were carefully chosen to most accurately measure their constructs and to increase the generalizability of the findings. Contrary to what was predicted, working memory did not predict an individual's ability to dismiss OITs. This finding suggests that the working memory system is not implicated in one particular type of OIT suppression: the removal of thoughts once they have already occurred. A further aim of the present study was to investigate whether individual differences in working memory predicted the ability to prevent OITs from reoccurring/occurring in the first place. Again, contrary to what was predicted, working memory did not predict the number of OITs experienced during a suppression task. A final aim of the present study was to investigate the relationship between OIT dismissibility (both objective and subjective) and OCD symptoms. In line with predictions, OCD symptoms related to subjective, but not objective, OIT dismissibility. That is, individuals who reported more symptoms of OCD also experienced more difficulty when dismissing OITs, but this was not reflected by slower dismissibility times.

Taken together, the findings from the current study suggest that working memory is not implicated in the suppression of OITs. This finding is surprising when considering the role of the working memory system. According to Baddeley and Hitch’s model (1974), the working memory system is responsible for selectively maintaining and manipulating goal relevant information. In addition, the working memory system is responsible for the exclusion of irrelevant or unwanted material (Rosen & Engle, 1998). It was therefore expected that this system would be responsible for the exclusion of OITs, thoughts which, by definition, are unwanted. The results of the present study, however, suggest that this is not the case.

Interestingly, although working memory was not related to objective OIT dismissibility, the level of OIT distress was related to objective OIT dismissibility. That is, participants who reported that their OITs were more distressing, also found them more difficult to dismiss. This finding is in line with previous research that has found OITs are more difficult to dismiss than neutral thoughts (Edwards & Dickerson, 1987; Ólafsson et al., 2014). One plausible explanation for this finding is that upsetting thoughts are difficult to dismiss because of the emotional distress and physiological arousal associated with the thoughts (Edwards & Dickerson, 1987). In other words, OITs capture an individual’s attention in a way that neutral thoughts do not, and are therefore harder to dismiss. This finding not only increases confidence in the idea that distressing thoughts are harder to dismiss than neutral thoughts, but also increases confidence that the prime used in the current study was able to elicit distressing OITs in participants.

Mood, on the other hand, had no impact on suppression success. Neither depression nor anxiety were related to an individual’s ability to dismiss OITs or prevent them from reoccurring/occurring in the first place. Prior to the study being conducted, strong predictions could not be made about this relationship between mood and suppression success, as much of the OIT suppression literature has not investigated the relationship. Of the research that had investigated the relationship between mood and suppression success, some had found a relationship (e.g. Brewin & Smart, 2005) and some had not (Ólafsson et al., 2014). The difference in suppression task and instructions used in these two studies could explain this discrepancy in findings. It has been suggested that that anxiety and depression are associated with poorer suppression success because suppression often involves searching for distractor thoughts, and distractor thoughts may trigger the recurrence of OITs due to similar negative content (Wentzlaff & Wegner, 2000). The dismissibility task by Ólafsson et al. (2014) provides participants with a neutral distractor thought, meaning the participant is unable to identify their own (potentially negative) distractor thought. Brewin and Smart (2005), on the other hand, simply instructed participants to suppress the thought. The instructions given by Brewin & Smart (2005) therefore allowed participants to choose their own distractor thoughts (if this is the suppression method that they chose to implement). Allowing participants to choose their own distractor thoughts increases the probability that participants with more negative moods will select negative distractor thoughts, meaning they will be poorer at suppression. In other words, allowing participants to choose their own method of suppressing thoughts increases the potential impact of mood on suppression success.

The lack of a relationship between working memory and OIT frequency is somewhat surprising as this relationship had previously been demonstrated by Brewin and Smart (2005). Despite recruiting a similar sample type, sample size, and using the same method of assessing working memory, the current study did not replicate Brewin and Smart's (2005) findings. However, there were differences in the task used, and there is a small possibility that this is the reason for the discrepancy in findings. The task used in the current study instructed participants to employ a specific suppression strategy (thought replacement) whereas Brewin and Smart (2005) instructed participants to suppress the OIT using whatever strategy they wished. It may be that suppression techniques used in Brewin and Smart (2005) recruited the working memory system, whereas the current thought dismissibility task did not. However, this seems unlikely, as there are strong theoretical reasons to believe that working memory would be implicated in thought replacement. It could be expected that the central executive would direct attention away from the OIT, and towards the replacement thought, which it then focusses on. It is less clear how working memory could be implemented in other suppression techniques that may have been used in Brewin and Smart's (2005) study, such as trying to relax, or avoiding something that may trigger the thought (Purdon et al., 2007). Future studies could assess the relationship between working memory and a range of different suppression techniques, to help demonstrate whether a difference in suppression techniques could explain the discrepancy between the findings from the current study and those from Brewin and Smart (2005).

The finding that OCD symptoms related to perceived difficulty dismissing OITs, but not poorer dismissibility times, suggests OCD is a problem of OIT appraisals rather than actual difficulty dismissing thoughts. This relationship between perceived difficulty dismissing OITs and OCD symptoms remained after controlling for OIT distress. Indeed, this finding was in line with findings from previous questionnaire and experimental studies. Questionnaire studies have demonstrated individuals with OCD are more likely to report difficulty dismissing OITs (Parkinson & Rachman, 1981; Rachman & de Silva, 1978; Salkovskis & Harrison, 1984) and that individuals with OCD are more likely to appraise OITs as being uncontrollable (Cartwright-Hatton & Wells, 1997; Clark, Purdon, & Wang, 2003). Experimental studies have found no differences in OIT dismissal times between individuals who score high vs low on OCD symptoms, but have found that high-OCD symptom groups report more perceived difficulty with dismissing OITs (Ólafsson et al. 2014; experiment 1 and 2). Although this finding may simply indicate a difference in dismissibility perception between individuals, an alternative explanation is that individuals who are higher in OCD symptomatology must expend more effort in order to dismiss OITs as quickly as individuals who are lower in OCD symptomatology. Asking participants to dismiss thoughts for five minutes may have created a ceiling effect, whereby most individuals are able to dismiss thoughts quickly over a five-minute period. If this is the case, differences in dismissibility may become apparent by increasing the demands of the dismissibility task (e.g. by increasing the length of time of the task). It may be that once the ceiling difficulty level of the task has been increased, differences in OIT dismissibility become apparent.

The lack of a relationship between OCD symptoms and OIT dismissibility suggests that dismissibility is not a characteristic that should be considered by the continuum model of OITs. That is, thought dismissibility does not decrease as symptoms of OCD increase. It seemed plausible that such a relationship would be found, as subjective OIT dismissibility is a variable that is already accounted for by the continuum model and it could reasonably be expected that objective and subjective dismissibility would be related. However, the findings from the present study suggest that although subjective OIT dismissibility varies from being very easy to dismiss, to very difficult to dismiss, throughout the population, objective OIT dismissibility does not.

Interestingly, there was a relationship between OCD symptoms and total time spent thinking about OITs; which can be thought of as a combination of OIT frequency and duration (or dismissibility). Neither frequency nor dismissibility alone were related to OCD symptoms. Based on this finding, and in response to Purdon et al.'s (2011) question of whether OCD is a problem of thought return or getting rid of the thought once it occurs, the answer would appear to be: both in combination.

There are several limitations of the current study that should be considered. First, although a previously used thought dismissiblity task was used in the current study to measure dismissibility (Purdon et al., 2011), it may not be accurately measuring dismissibility. Participants are required to signal when their OIT has occurred and also when it was dismissed. But in order to signal the latter, participants must still be experiencing the OIT in some form (Purdon et al., 2011). Dismissibility is a relatively understudied concept, and so it is understandable that there are some issues with measurement. Although there are methods of overcoming this particular issue, they themselves suffer from their own issues. For example, using experience-sampling methodology, participants could be asked at random intervals when they last experienced an OIT and how quickly they were able to dismiss it. This method would avoid the issue of still thinking about the OIT in some form, whilst stating that it has been dismissed. However, this method then suffers from issues with memory decay, whereby participants forget how quickly they dismissed thoughts (particularly if the thoughts were fleeting). Future studies may therefore benefit from taking a mixed methods approach.

A second limitation of the current study is the length of the dismissibility task. The task was based on that used by Purdon et al. (2011), however, a shorter version of the task was adopted in the present study to reduce participant demands. Reducing the length of the task could have plausibly created a ceiling effect (as previously discussed), which meant that differences between individuals high and low in working memory could not be detected. Future studies assessing dismissibility would benefit from using a longer version of the task.

Overall, this study suggested that working memory is not implicated in the suppression of OITs. In addition, OCD seems to be a problem of perceived difficulty with removing OITs once they occur, rather than any demonstrable difficulty with removing them. Future research would benefit from adopting a mixed methods approach to measuring dismissibility, to clarify whether the current findings are due to the lab-based, short, nature of the task.

Chapter 5: General Discussion

The current thesis aimed to investigate the relationship between obsessive-compulsive symptoms and executive functions (EFs), and to provide information that could be used to update cognitive theories of OCD. Particular focus was placed on working memory as an EF, as previous research suggests it is the most relevant to OCD (i.e. the largest EF deficit found in individuals with OCD was on a working memory task; Snyder, Kaiser, Warren & Stiller, 2014; and associations have been found between working memory and thought suppression; e.g. Brewin and Smart, 2005). Three separate studies were conducted that involved either assessing the relationship between OCD symptomatology and EFs (chapter two and chapter four), or assessing the impact of OCD symptomatology on EFs (chapter three).

Chapter two assessed whether there were any EF differences between individuals with subclinical levels of obsessive-compulsive symptomatology (subclinical OCD) and nonclinical individuals. Few studies had investigated this question and the results of those that have are inconsistent. For this experimental study, a group of individuals with subclinical OCD and a group of nonclinical individuals completed a battery of computerised EF tasks assessing working memory, inhibition, and cognitive flexibility. Based on limitations of previous research, care was taken to choose stringent measures of the construct they were assessing, and to exclude individuals with potential undiagnosed OCD. Contrary to predictions, EF differences were not found between the two groups. In other words, individuals with subclinical OCD did not demonstrate EF deficits. This finding was seemingly contrary to previous research that has demonstrated EF deficits in individuals with OCD (e.g.

Snyder et al., 2014), as subclinical OCD is a term used to describe a less severe form of the disorder. It is plausible that previous EF deficits in individuals with OCD may have been caused by state factors (e.g. symptom interference), rather than representing an underlying deficit. Based on this idea, it is also plausible that individuals with subclinical OCD did not demonstrate EF deficits in the current chapter because their symptoms were not severe enough to interfere with task performance. However, the sample in this study precluded direct comparison with an OCD group.

The findings from chapter two also helps inform current cognitive theories of OCD. These theories posit that OITs become more severe (e.g. more frequent, distressing, intense) when they are negatively appraised (e.g. "I am a bad person for having this thought") and responded to in ineffective ways (e.g. suppression) (Clark & Purdon, 1993; Rachman, 1997, 1998, 2003; Salkovskis, 1985, 1989, 1999). However, there is evidence to suggest that negative appraisals and ineffective control strategies do not lead to an increased frequency of OITs (Woody, Whittal, & McClean, 2011), leaving the question open as to why some individuals experience more OITs than others. One possible explanation was that differences in EFs could explain differences in OIT frequency, and chapter two aimed to test this hypothesis. However, this hypothesis was not supported, as individuals with subclinical OCD did not demonstrate poorer EFs than nonclinical individuals, and OIT frequency was not associated with EFs. It is plausible that the study presented in chapter two was underpowered and so future studies should aim to recruit larger samples of individuals, including individuals with OCD, and administer a wider battery of

EF tasks. Such a study would increase our understanding of the relationship between OIT frequency and EFs.

Chapter three aimed to investigate whether state factors impair working memory. In particular, the study aimed to test a key prediction of the Executive Overload Model of OCD (Abramovitch, Dar, Hermesh, & Schweiger, 2012): that OITs impair working memory. A secondary aim of the study was to assess the relationship between a range of other OCD-relevant phenomena (e.g. depression, anxiety, compulsive checking, contamination fears etc.) and working memory. Two groups of nonclinical participants were recruited and completed a working memory task. One group of participants were first primed with OITs ("primed" condition), the other group were not ("non-primed condition"). Following the task, participants completed a questionnaire that assessed perceived interference from a range of OCD-relevant variables. In addition, participants completed measures of depression and anxiety. Contrary to predictions, no working memory differences were found between participants in the primed condition and non-primed condition, suggesting that OITs do not impair working memory in nonclinical individuals. This finding does not support the predictions of the Executive Overload Model of OCD. In addition, the study did not find an association between any other self-report state factors and working memory performance. Taken together, these findings offer preliminary evidence that state factors may not account for working memory deficits in individuals with OCD.

Chapter four aimed to resolve an unanswered question of cognitive theories of OCD: why are there individual differences in OIT suppression ability? It was hypothesised that working memory differences could explain differences in suppression success (particularly dismissibility). Nonclinical individuals carried out a working memory task and an OIT dismissibility task. Contrary to predictions, there was no relationship between working memory and OIT dismissiblity. Further to this, no relationship was found between working memory and the number of OITs experienced in the lab. Together, these finding suggests that working memory is not implicated in the suppression of OITs. The question remains, therefore, as to why there are individual differences in suppression success. One possibility is that inhibition is related to an individual's ability to suppress OITs, rather than working memory. Future studies should aim to replicate the study found in chapter four, but replace the working memory task for an inhibition task.

In summary, the findings from this thesis suggest: 1) individuals with subclinical OCD do not demonstrate EF deficits, 2) an increase in OITs does not lead to working memory deficits, 3) individual differences in working memory do not explain differences in suppression success. These three studies present findings that can be used to inform current cognitive theories of OCD. More specifically, EFs do not explain differences in OIT frequency, and working memory does not explain differences in suppression success.

No support for trait or state account of executive function deficits in obsessive-compulsive disorder

Taken together, the findings from this thesis do not support either the trait *or* state account of EF deficits in OCD. The trait account suggests that EF deficits are an endophenotype of OCD and should therefore i) be associated with causes of the OCD ii) be state independent (i.e. occurs in the individual even if they do not display the disorder) iii) be heritable iv) co-segregate with illness within families v) be present in unaffected relatives at a higher rate than the general population (Gottesman & Gould, 2003; Gould & Gottesman, 2006). If EF deficits were an endophenotype of OCD, then it would be expected that individuals with subclinical OCD would also show such deficits, as these individuals are at higher risk of developing OCD (Black, Gaffney, Schlosser, & Gabel, 2003; Fullana et al., 2009). However, chapter two did not demonstrate such deficits in individuals with subclinical OCD.

In contrast to the trait account, the state account suggests that individuals with OCD do not have deficient EFs *per se*, but that state factors interfere in task performance and therefore create the appearance of EF deficits. The Executive Overload Model of OCD (Abramovitch et al., 2012) was developed to account for the impact of state factors on EFs. The Executive Overload Model of OCD predicts that an increase in OITs leads to impairments in EF tasks. However, in chapter three, experimentally induced OITs did not impair performance on a working memory task in nonclinical individuals. Other state accounts predict that symptoms such as excessive checking or contamination fears should also interfere in EF tasks (Moritz, Hottenrott, Jelinek, Brooks, & Scheurich, 2012). However, in chapter three, no self-reported state factors were related to performance on a working memory task. In other words, the findings from chapter three did not support the state account of EF deficits in OCD. In addition, depressive and anxious symptoms did not correlate with task performance in any of the empirical chapters, suggesting these state factors are unlikely to account for EF deficits either.

The lack of support for both trait and state accounts of EF deficits in OCD is surprising, as both accounts have previously received empirical support and both appear to be plausible accounts of EF deficits. However, since the completion of the empirical chapters of this thesis, a study has been published that also supports neither the trait nor state accounts of EF deficits. De Putter, Cromheeke, Anholt, Mueller, & Koster (2017) recruited forty nonclinical participants who scored high in contamination symptoms of OCD, and forty-four nonclinical participants who scored low in contamination symptoms of OCD. All participants first completed an inhibition task (Stop-Signal Task). Following this, all participants were randomly assigned to either be induced with contamination-specific symptoms, or a neutral mood induction. The participants then completed the inhibition task for a second time. Contrary to predictions, individuals in the high contamination symptom group performed better than the participants in the low contamination symptom group on the baseline measure of inhibition. This finding is contrary to the trait account of EF deficits, which predicts deficits in individuals high in OCD symptomatology. In addition, after being induced with contamination symptoms, there were no changes in inhibition in any of the participants. This finding is contrary to the state account of EF deficits, which predicts that an increase in OCD symptoms would impair EF performance. In summary, the findings from De Putter et al. (2017) align with those of the current thesis and do not support either the state account or the trait account of EF deficits.

One plausible explanation for the lack of support for the state or trait accounts of EF deficits in OCD, in the current thesis and in De Putter et al. (2017), is that the samples did not have a diagnosis of OCD. It is plausible that individuals with subclinical OCD and nonclinical individuals do not experience severe enough symptoms of OCD, even after symptom induction procedures, to cause EF interference. This highlights a potential difference between individuals with subclinical OCD/nonclinical individuals, and those with a diagnosis of OCD: symptoms of OCD have a negative impact on EFs only in individuals with OCD. If this is the case, studies assessing the state account of EF deficits should attempt to induce state factors (e.g. anxiety, OITs) in individuals who have been diagnosed with OCD. In addition, trait factors may not be found in individuals with subclinical OCD because this sample of individuals may be protected from the development of OCD, due to intact EFs (or some other factor). This is more likely to be the case when the participants are adults, as OCD often develops in childhood or adolescence (Millet et al., 2004). In other words, if individuals have not developed OCD by adulthood, they may be unlikely to develop it at all, and this may be due to some protective factor. In support of this idea is research demonstrating an increased risk of developing post-traumatic stress disorder in individuals with poorer EF (Aupperle, Melrose, Stein, & Paulus, 2012), suggesting that EF deficits may convey a vulnerability for other psychological disorders. However, this explanation does not account for the inconsistent findings in relation to EFs and OCD presented elsewhere (e.g. Snyder et al., 2014).

The current thesis did not investigate the relationship between EFs and OCD in individuals diagnosed with OCD. However, understanding the heterogeneous findings in relation to EFs and OCD (e.g. Snyder et al., 2014) can help us to understand more about the mechanisms of OCD, including why individuals with subclinical OCD do not demonstrate EF deficits. One possible explanation for the heterogeneous findings in relation to EFs and OCD is that EF deficits are only found in particular subgroups of individuals with OCD (e.g. Hwang et al., 2007; Lee & Telch, 2010). Individuals with OCD can present with a wide range of symptom types (e.g. contamination OITs vs aggressive OITs) and may be diagnosed at different times (e.g. early vs late onset). It may be that only individuals with a specific subtype of OCD demonstrate EF deficits. Indeed, there is evidence that individuals who mainly experience autogenous OITs (highly aversive, ego-dystonic [perceived to contradict an individual's self-image], spontaneous) have poorer inhibition than individuals who mainly experience reactive OITs (realistic, ego-syntonic, less spontaneous) (Lee, Yost, & Telch, 2009). If this was the case, inadvertently assessing EFs in large numbers of people who mainly experience autogenous OITs, would lead to the conclusion that individuals with OCD have EF deficits. On the other hand, studies that inadvertently included fewer individuals who mainly experience autogenous OITs, would conclude that individuals with OCD do not demonstrate EF deficits. Testing EF deficits of particular sub-types of OCD was beyond the scope of the present thesis. However, the findings from De Putter et al. (2017) suggest that individuals with contamination symptoms do not demonstrate inhibition deficits. Future studies would benefit from investigating EFs in other sub-types of OCD, in both clinical and subclinical samples.

Objective vs subjective performance and interference

One interesting finding to come out of the current thesis is the dissociation between subjective (i.e. self-report) events and objective (i.e. EF tasks, time taken to dismiss OITs) events. Chapter three demonstrated that individuals primed with OITs reported more task interference from OITs than individuals who were not primed. However, this subjective rating did not translate to the working memory task, such that there was no difference in task performance between individuals who were primed with OITs and those who were not primed. Similarly, in chapter four, individuals higher in obsessive-compulsive symptomatology reported that OITs were more difficult to dismiss than individuals lower in obsessive-compulsive symptomatology. However, there was no relationship between OCD symptoms and duration of time taken to dismiss OITs. The findings in chapter three could plausibly have been the result of demand characteristics, as only one group were primed with OITs; however, this could not be the case in chapter four. One possible explanation for the findings of chapter four is that individuals higher in OCD symptomatology need to expend more effort in order to dismiss OITs. The dismissibility task used for chapter four may have not been demanding enough to cause dismissal problems for individuals higher in OCD symptoms. Alternatively, these findings suggest that for those individuals in chapter four who scored highly on measures of OCD, they had a problem of perception rather than actual deficit. Indeed, cognitive models of OCD highlight the importance of the subjective appraisal of OITs in the development of OCD, rather than the experience of OITs themselves. It may have been, for example, that individuals higher in symptoms of OCD are less confident about their performance than individuals lower in symptoms of OCD, leading them to report that they were not competent at the task.

Future directions

There is a range of methodological issues with the studies in the current thesis that should be considered for future studies. When looking for EF differences between individuals with subclinical OCD and nonclinical individuals, efforts should be taken to increase statistical power, such as by increasing the sample size. The EF deficits in individuals with OCD are generally moderate in size (e.g. Snyder et al., 2014), and it may be that there are EF deficits in subclinical OCD that are small in size. Based on this, large samples are needed to detect EF differences between individuals with subclinical OCD and nonclinical individuals. Indeed, low statistical power is not only an issue found in chapter two of this thesis, but an issue found more widely throughout the OCD/subclinical OCD and EF literature.

When assessing the success of an OIT prime, future studies should take care to ask participants, in different groups, the same number of questions. In chapter three, primed participants were asked two questions about the number of OITs experienced, whereas non-primed participants were asked one question. As a result, it cannot be concluded with confidence that the primed group reported experiencing more OITs because of the prime, or as a result of demand effects.

Future studies that aim to measure OIT dismissibility (e.g. the relationship between inhibition and OIT dismissibility) should adopt a longer version of the task than that which was used in chapter four, e.g. to two eight minute periods instead of one five minute period. Increasing the demands of the task in this way may increase the ceiling demands of the task, potentially highlighting differences between individuals who score high on measures of OCD symptomatology and individuals who score low. If differences are not found, then the idea that this is because the task is not sufficiently demanding can be ruled out.

More broadly, the findings from this thesis suggest a range of possible directions for future research. First, research into individuals with subclinical obsessive-compulsive symptoms remains an interesting area of research due to its implications for the prevention of OCD. However, future research in this area would benefit from greater clarity and consistency in relation to definition and methodology. Indeed, chapter two demonstrated some of the difficulties with operationalising subclinical OCD; care was taken to exclude individuals with OCD, but this may have inadvertently created a sample who were more representative of the general population than individuals with subclinical OCD. It is important to note that subclinical OCD is not a formal diagnosis. Rather, it is a term used in research that may serve to help identify individuals who are at risk, or protected from, developing OCD. Future studies may benefit from recruiting individuals who score highly on an OCD symptom measure, and then excluding individuals with OCD via diagnostic interview. Alternatively, research may benefit from taking a more nuanced approach to subclinical obsessive-compulsive symptoms. For example, it may be that particular variables (e.g. OIT distress) are more useful and predictive of developing OCD than broad categorisations of symptoms. Longitudinal studies measuring a range of OCD-relevant variables over multiple time points would provide information on risk and protective factors for OCD.

Longitudinal studies would also be useful in helping to resolve some of the current debates around trait vs state accounts of EF deficits in OCD, and in telling us more about the development of OCD (including potential risk factors). Following children who are at risk of developing OCD (e.g. as they have a parent with OCD) and monitoring EFs and symptoms over time may help to clarify whether EFs lead to OCD symptoms, whether OCD symptoms lead to EF deficits, or whether some third factor leads to both EF deficits and OCD symptoms. However, this research is likely to be resource intensive. A less resource intensive method of helping to resolve the trait vs state debate of EF deficits in OCD would be to further test the Executive Overload Model of OCD (Abramovitch et al., 2012). Studies investigating the impact of OITs on cognitive flexibility, and studies that prime OITs in individuals with OCD, could reveal important information about the validity of the Executive Overload Model of OCD, and the state account of EF deficits in OCD as a whole. However, such a study may tell us less about the developmental factors of OCD than longitudinal studies. In combination, findings from the proposed longitudinal study alongside findings from the proposed experimental study will be useful for informing future preventative interventions.

Finally, future studies that investigate EFs in particular sub-types of OCD would help to confirm whether the current field of inconsistent findings is due to the fact that only a subgroup of individuals demonstrates EF deficits. Indeed, Lee, Yost, and Telch (2009) found that individuals with OCD who mainly experienced autogenous OITs demonstrated poorer inhibition than individuals who mainly experienced reactive OITs. In addition, subgroups within other clinical diagnoses have also demonstrated differential relationships with executive functions (e.g. in post-traumatic stress disorder; Polak, Witteveen, Reitsma, Olff, 2012). Future research should investigate whether individuals who experience mainly autogenous OITs demonstrate deficits in working memory and cognitive flexibility compared to individuals who experience mainly reactive OITs.

Conclusion

In conclusion, this thesis investigated the relationship between obsessive-compulsive symptomatology and EFs. Individuals with subclinical OCD did not demonstrate EF deficits. Obsessive intrusive thoughts did not lead to deficits in working memory. Working memory was not associated with the suppression of OITs. The findings from this thesis are contrary to the trait or state account of EF deficits in OCD. Future research should adopt longitudinal designs, investigate the Executive Overload Model of OCD further and investigate EFs in sub-types of OCD.

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Appendices

Appendix A – Scatter plots to show the relationship between executive functions and symptoms of obsessive-compulsive disorder.

Fig. 1. Relationship between OCI-R total score and SwIFT reaction time switch cost (MS).

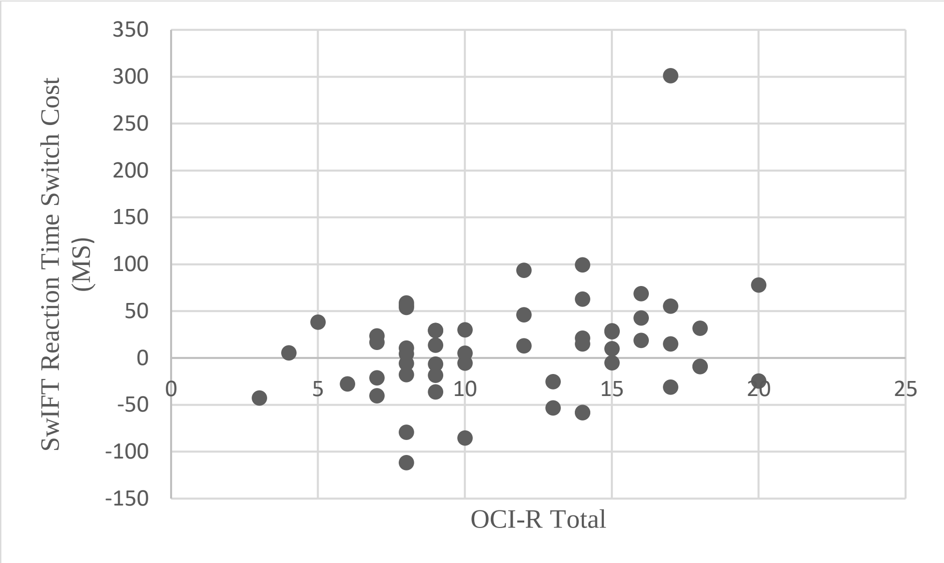


Fig. 2. Relationship between OCI-R total score and SwIFT accuracy switch cost (%).

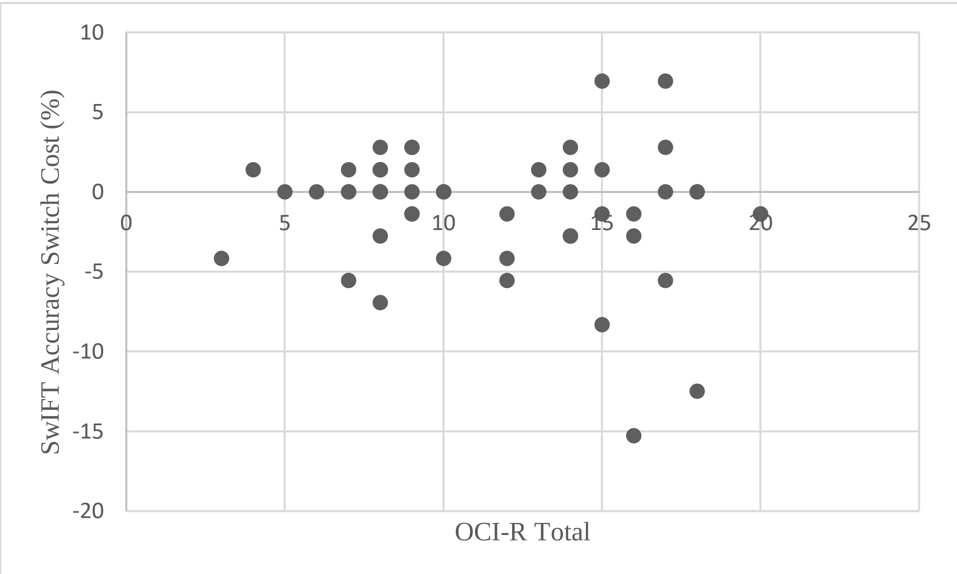


Fig. 3. Relationship between OCI-R total score and Flanker Reaction Time Interference Cost (MS).

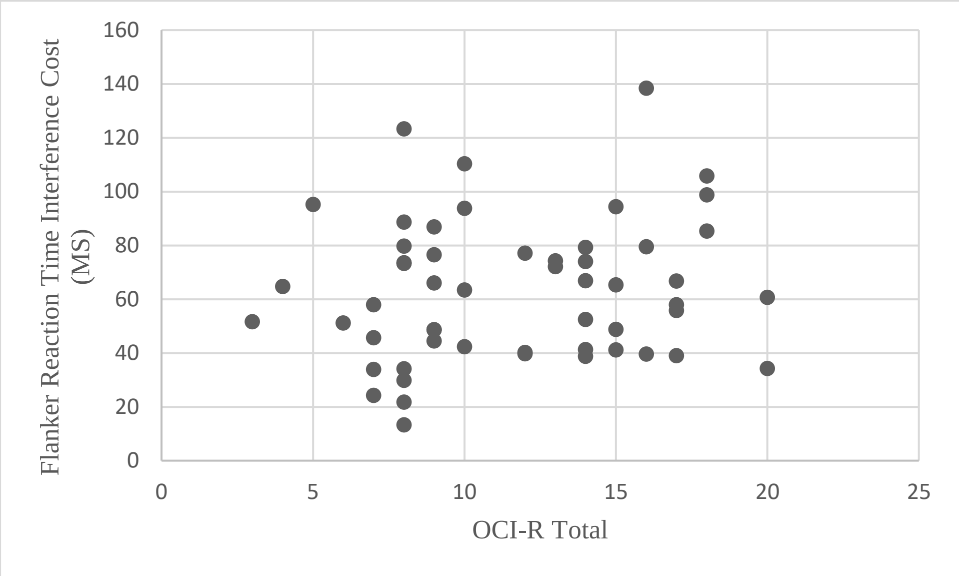


Fig. 4. Relationship between OCI-R total score and Flanker Accuracy Interference Cost (%).

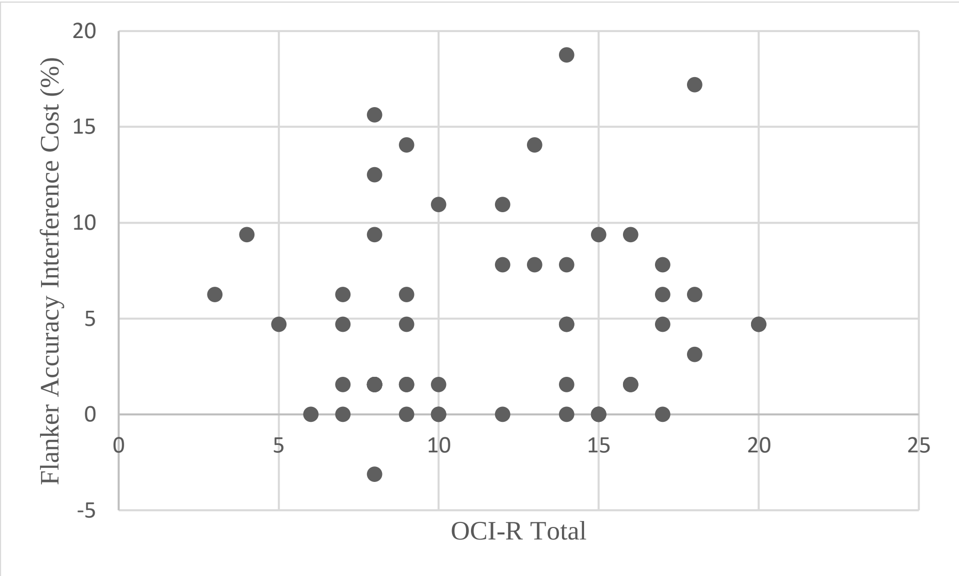
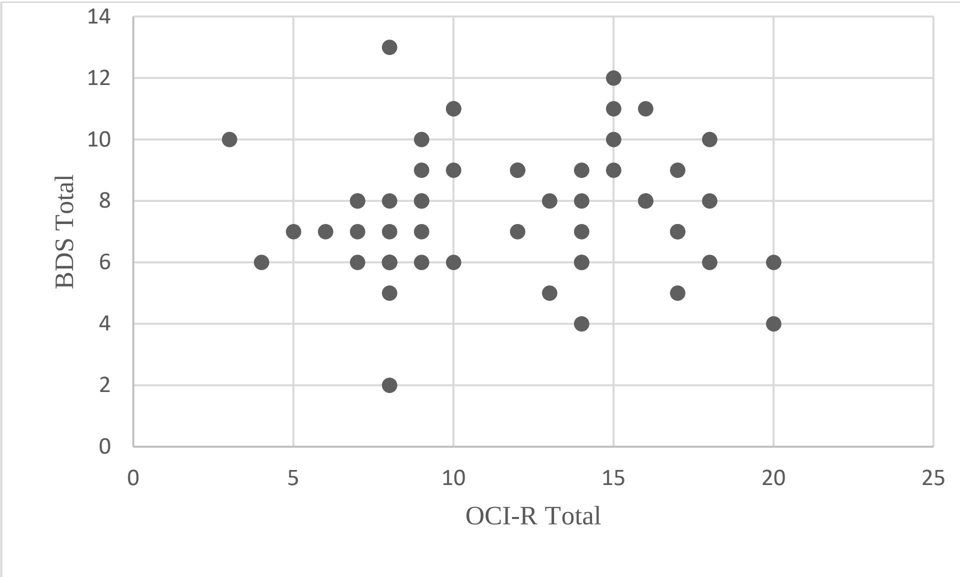


Fig. 5. Relationship between OCI-R total score and Backward Digit Span Total Score.



Appendix B – Correlation matrix to show the relationships between self-reported OCD-relevant symptom interference and working memory

			1	2	3	4	5	6	7	8	9	10	11	12	13
1.	1-back RT	Pearson correlation													
		Sig. (2-tailed)													
2.	1-back acc	Pearson correlation	-.055												
		Sig. (2-tailed)	.523												
3.	3-back RT	Pearson correlation	.434	.081											
		Sig. (2-tailed)	.000	.353											
4.	3-back acc	Pearson correlation	-.195	.339	-.178										
		Sig. (2-tailed)	.024	.000	.039										

			1	2	3	4	5	6	7	8	9	10	11	12	13
5.	Touching objects	Pearson correlation	-.025	-.048	-.173	.031									
		Sig. (2-tailed)	.776	.577	.045	.721									
6.	Checked responses	Pearson correlation	-.021	-.001	-.019	.020	.208								
		Sig. (2-tailed)	.806	.987	.823	.814	.016								
7.	OIT interfere	Pearson correlation	.085	-.048	.008	-.110	.107	.361							
		Sig. (2-tailed)	.328	.580	.927	.208	.220	.000							
8.	Compulsions interfere	Pearson correlation	-.065	.050	-.184	.041	.279	.306	.334						
		Sig. (2-tailed)	.453	.569	.033	.635	.001	.000	.000						

			1	2	3	4	5	6	7	8	9	10	11	12	13
9.	Guessed responses	Pearson correlation	.009	.016	.024	-.099	.092	.302	.226	.196					
		Sig. (2-tailed)	.920	.857	.785	.253	.291	.000	.009	.023					
10.	Paid attention	Pearson correlation	-.126	.037	-.058	.040	-.062	-.104	-.268	-.041	-.412				
		Sig. (2-tailed)	.146	.670	.501	.649	.474	.231	.002	.636	.000				
11.	Careful and accurate	Pearson correlation	-.045	.006	-.041	.048	-.011	-.181	-.052	.024	-.549	.597			
		Sig. (2-tailed)	.605	.942	.634	.582	.901	.036	.554	.786	.000	.000			
12.	Felt slowed	Pearson correlation	.136	-.126	.011	-.076	.181	.215	.339	.312	.246	-.192	-.068		
		Sig. (2-tailed)	.117	.148	.900	.380	.036	.013	.000	.000	.004	.026	.438		

			1	2	3	4	5	6	7	8	9	10	11	12	13
13.	Tried when completing task	Pearson correlation	-.116	.095	-.024	.004	-.003	.112	-.003	-.045	-.234	.587	.459	-.144	
		Sig. (2-tailed)	.179	.271	.782	.961	.975	.198	.974	.609	.006	.000	.000	.097	

RT - Reaction Time; Acc - Accuracy