Altered cognition in non-clinical obsessive-compulsive populations: novel investigations of bias and deficits in selective attention and long-term memory using emotional and non-emotional stimuli

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For Scarlett
Never stop asking questions, Sweetie xx
Declaration of originality

This thesis and the work to which it refers are the results of my own efforts. Any ideas, data, images or text resulting from the work of others (whether published or unpublished) are fully identified as such within the work and attributed to their originator in the text, bibliography or in footnotes. This thesis has not been submitted in whole or in part for any other academic degree or professional qualification. I agree that the University has the right to submit my work to the plagiarism detection service TurnitinUK for originality checks. Whether or not drafts have been so-assessed, the University reserves the right to require an electronic version of the final document (as submitted) for assessment as above.

December 10th 2018

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Abstract

People with obsessive-compulsive disorder (OCD) commonly report doubt and uncertainty and feel driven to perform repetitive behaviours and rituals. Neuropsychological accounts of obsessive-compulsive (OC) behaviours suggest that dysfunction in cognitive processing may underpin such symptomology. Selective attention and long-term memory have been proposed as areas of cognition in which processing may be altered in OCD. However, although the weight of evidence points to possible dysfunction in these areas, the results of previous research examining both have been mixed.

This thesis argues that inconsistencies in such research might be attributable to the use of the unsuitable methodological approaches, an inconsistent use of symptom-salient stimuli in experiments and a lack of acknowledgement of the heterogeneity of OCD or the impact of comorbidities. The studies presented here adopted methodological approaches which are novel in OCD research, with the aim of providing more nuanced accounts of OC cognition. Four studies are reported which examined how far altered OC selective attention and long-term memory, and particularly that of Checkers, may be rooted in the operation the same mechanism – bias towards distracting and symptom-salient stimuli. Studies 1, 2 and 3 used selective attention visual search paradigms with inter-trial components, based on the priming of pop-out (PoP) design. Study 4 was a comprehensive examination of verbal long-term memory, including remember/know memory, using the CID-R paradigm. All four used non-clinical OC populations, in line with arguments that clinical OCD only accounts for a minority of individuals who display OC symptomology. Study 1 (N=28) looked to establish initial evidence of possible selective attention and attentional bias differences between a homogenous OC group and Controls. Study 2 (N=43) and Study 3 (N=46) then built on these findings, examining possible differences between Checker and Non-Checker groups with the presentation of symptom-salient and emotional stimuli. Finally, Study 4 (N=59) looked to assess how far possible altered attention and bias among Checkers would also be apparent in dysfunction and bias in Checker verbal long-term memory. This study also used symptom-salient stimuli, and recruited Washer and generalised OC participants for comparison with Checkers. Key findings were as follows. In Study 1, OC participants demonstrated, firstly, a deficit in selective attention in the PoP task and, secondly, attentional bias towards distractor stimuli in particular inter-trial sequences. However, when the first of these findings was followed-up in Study 2 using Checker and Non-Checker populations and emotional pictures added to the PoP paradigm, group differences evident in Study 1 were eliminated. But in Study 3, which further examined the second finding of Study 1, evidence of attentional bias in Checkers towards emotional and symptom-salient picture stimuli when inter-trial sequences were examined. Finally, in Study 4, Checkers demonstrated bias towards checking-salient word targets when compared with Controls, and accurate hit rate performance for checking words even though they were significantly more reliant on familiarity with stimuli (‘know’ memory) than firm
recollection (‘remember’ memory). Effect sizes for group difference findings across the studies were large. The findings provide novel and nuanced evidence of the key roles of bias and emotion in the operation of OC cognition and the make-up of Checker symptomology, and further highlight the value of using non-clinical participants in OC research.
Chapter 1

Introduction and literature review
1.1. Overview of Chapter 1

This chapter presents an account of the current theoretical and clinical perspectives of OCD, along with conceptions of selective attention and long-term memory. It looks to clarify how OCD has been, and continues to be, understood in terms of its relationship with the operation of both selective attention and long-term memory processes. It examines the roles of bias and emotional regulation, and assesses the possibility of cognitive deficits, in the condition. Previous research in these fields is reviewed and critically assessed. The importance and benefits of the use of non-clinical participants in OC research is highlighted. The focus of the thesis is then discussed in the light of this assessment of previous literature, before a statement of research aims and an overview of the studies carried out are made at the end of the chapter. The chapter is divided into sections, with summaries provided at the end of key sections.

The chapter begins with a brief description of the overall aim of the thesis (Section 1.1.1). Following this, definitions and classifications of OCD are detailed, including sub-sections on subtypes of the condition (e.g., checking and washing) and how it relates to other neuropsychological disorders, and a section on how it is commonly treated (Section 1.2). There then follows a section on the advantages and theoretical justifications for the use of non-clinical OC participants in research (Section 1.3). Theoretical models of OCD, including accounts of neuropsychological dysfunction with the condition, are then considered (Section 1.4), along with evidence for attentional and memory bias (Section 1.5), emotional dysregulation (Section 1.6) and cognitive deficits (Section 1.7) with the disorder. An explanation for why, in particular, this thesis has examined cognitive processes in selective attention and long-term memory is then provided (Section 1.8).

The focus of the chapter then turns specifically to selective attention. First, an overview of selective attention and a critical assessment of previous research examining OCD and selective attention are provided (Section 1.9). In this section, gaps in the literature, which this thesis looks to address, are stated. Following this, an argument is then made for the use of visual search paradigms in OCD research (Section 1.10), and, specifically, the priming of pop-out (PoP) paradigm (Section 1.11).

The chapter then moves its focus to long-term memory. Understandings of long-term memory are detailed (Section 1.12). Then, a critical assessment of previous research which has examined long-term memory and OCD is conducted (Section 1.13). In this section, gaps in the literature, which this thesis looks to address, are stated. An argument is made for the use of the continuous identification with recognition (CID-R) paradigm in the examination of long-term memory and OCD.
In the final sub-section of Chapter 1, the aims of the thesis and gaps in the literature are re-stated, and specific details of the four studies which were we carried out, are described (Section 1.14).

1.1.1. Overall aim of the thesis

Dysfunction in cognitive processing has commonly been considered to underpin the symptomology of obsessive-compulsive disorder, or OCD (Kuelz, Hohagen, & Voderholzer, 2004; Muller & Roberts, 2005). The behaviour of people with the condition is typically characterised by doubt, repetition and ritual. It is possible that this may be, in part, reflective of deficits in selective attentional processing, but also of altered memory functioning – people with OCD regularly report difficulties with both attentional distraction and ‘poor’ recollective memory (Koch & Exner, 2015; Muller & Roberts, 2005). One mechanism that may link performance in these two areas is biasing – people with the condition have been shown to demonstrate specific attentional and memory biases towards emotional, symptom-salient stimuli.

Neurological research has consistently uncovered abnormal functioning in OCD in the frontal-subcortical circuitry of the brain (for review, see Abramovitch, Abramovitz, & Mittleman, 2013). These areas are implicated in, among other aspects of cognition, attentional and affective processes (Menzies et al., 2008). However, the evidence from neuropsychological and cognitive tests designed to examine both selective attention and memory with OCD remains mixed. In short, some studies report evidence of dysfunction with the condition, while others do not (Abramovitch et al, 2013; Muller & Roberts, 2005).

The contention of this thesis is such inconsistencies might be, at least in part, reflective of the use of experimental paradigms which differ overly in their task requirements, and which may tap into different cognitive functions or, alternatively, lack the sensitivity to effectively access the depths of obsessive-compulsive (OC) cognition. Much previous research has failed to acknowledge, or control-for, key factors which can confound the study of OCD (e.g., comorbidities, condition heterogeneity). These criticisms are in line with the conclusions of a number of reviews of OCD research (e.g., Abramovitch et al, 2013; Kuelz et al., 2004). Such reviews almost always recommend the use of symptom-salient or emotional stimuli when examining OC populations.

Additionally, a good deal of previous research has taken a categorical approach to sampling – recruiting clinically-diagnosed participants and comparing their performance with that of controls. Evidence suggests, however, that OCD is a dimensional condition, and that clinical OCD only represents a small proportion of those who may have symptoms of the condition. In the studies reported in this thesis, non-clinical participants were recruited. The aim was to provide a broader view
of the range and complexity of OC behaviour, and to provide ‘lower-level’ insights into the mechanics of OCD that might serve to inform understandings of more severe accounts of the condition.

As such, this thesis aims to demonstrate that the use of more nuanced, participant-focussed and tightly-controlled experimental designs enables a clearer examination of how selective attention and long-term memory operate in OCD. It aims to provide new evidence that altered behaviour in both these areas of cognition is founded on, and linked by, biases and emotional functioning which are specific to OC populations.

1.1.1.1. General research question of thesis
In attempting to address some of the issues in previous research via the use of alternative experimental paradigms, to what extent can selective attention and long-term memory said to be similarly altered in non-clinical OC populations, and what are the roles played by bias and emotion in any such alterations?

1.2. What is obsessive-compulsive disorder (OCD)?

1.2.1. Characterisation of OCD

1.2.1.1. Obsessions and compulsions
Obsessive-compulsive disorder (OCD) is a distressing and debilitating psychological condition, which can result in severe negative personal and social outcomes for the sufferer. The disorder is highly complex and, despite research from a variety of clinical and academic approaches, remains poorly understood. A range of clinical presentations, and numerous associated behavioural manifestations, have been characterised as components of the condition. However, in broad terms, OCD can be understood to comprise two features – obsessions and compulsions. Obsessions are intrusive, undesired and recurrent thoughts, images, impulses and preoccupations. Compulsions are repetitive physical or mental behaviours which sufferers feel that they must carry out (American Psychiatric Association, 2013). Compulsions may be performed as a consequence of, and in response to, obsessions – the aim being to nullify the anxiety associated with the obsessive concern. However, a person with OCD may also present with only one of these two features (either obsessions or compulsions) and the absence of the other (American Psychiatric Association, 2013). An example of the operation of OCD can be seen in Figure 1.1.
Among people with OCD, issues relating to contamination, harm, violence, blasphemy, sexual thoughts and symmetry are the most commonly-reported obsessions. The most common compulsions are checking, cleaning, repetition, the need to ask/confess and counting (Foa et al., 1995; Veale, 2007; American Psychiatric Association, 2013; World Health Organisation, 1992).

![Figure 1.1](image-url)

**Figure 1.1.** The typical mechanics of OCD. An internal or external trigger leads to directly-associated obsessions. This results in anxiety, which reinforces the obsessions. Commonly, but not always, a ritual is performed to reduce the associated anxiety. But this only serves to reinforce behaviour, and when obsessions manifest themselves again, repetitive rituals are performed.

Individuals with OCD commonly recognise the excessive nature of their behaviours, or that the actions they take to deal with their obsessions can be pointless (Muller & Roberts, 2005). However, despite being able to acknowledge this irrationality, they remain compelled to continually engage with their concerns. Thus, while many patients have insight into their own behaviours (though see American Psychiatric Association, 2013), they commonly do not feel they have control over their thinking or their actions (Muller & Roberts, 2005).

### 1.2.1.2. Prevalence and aetiology

OCD is considered to be the fourth most-common mental health condition, following depression, alcohol and substance misuse and social phobia (Aouizerate et al., 2004; National Institute for Health and Clinical Excellence [NICE], 2006). The lifetime prevalence of OCD in the USA is between 1.9% and 3.3% (Fullana et al., 2009; Robins et al., 1984; Ruscio, Stein, Chiu, & Kessler, 2010). Meanwhile, Weissman et al. (1994) found lifetime prevalence rates of 1.1% to 1.8% in seven countries (Germany,
Taiwan, United States of America, Korea, Canada, New Zealand and Puerto Rico). Other research suggests that, while in different countries and cultures the detail of the manifestations of individuals may vary, the broader presentations of OCD are the same (Fontenelle, Mendlovicz, Marques, & Versiani, 2004). OCD appears to be as common in men as it is in women (Rasmussen & Eisen, 1990). Its average age of onset is slightly lower for males (late teens) than females (early 20s) – though it is notable that a substantial range of ages contribute to these figures (NICE, 2006; Rasmussen & Eisen, 1990). Some evidence suggests male OCD content is more likely to centre on sexual and ordering/symmetry issues, while females more commonly present concerns related to washing/cleaning (Lensi, Cassano, Correddu, Ravagli, & Kunovac, 1996). Up to half of adults report that their condition began in childhood (Rapoport, 1990). However, OCD is often undiagnosed at this age (Chowdury, Frampton, & Heyman, 2004), the failure of which can have considerable negative personal and social consequences for the individual as they age (Laidlaw, Falloon, & Barnfather, 1999; Rasmussen & Eisen, 1990).

The aetiology of OCD is far from complete (Menzies et al., 2008), and establishing the exact causes of OCD has been problematic because of the heterogeneity of the condition (NICE, 2006; Veale & Willson, 2005). Difficult life events, socio-cultural factors, family experiences and personality traits have all been linked to its expression (NICE, 2006). However, some research has pointed to a genetic basis to OCD. A family history of the condition has been recorded in 25-30% of diagnosed children (e.g., Swedo, Rapoport, Leonard, Lenane, & Cheslow, 1989). OCD concordance rates for monozygotic twins have been found to be 67.5%, but only 31% for dizygotic pairs (Billiet, Richter, & Kennedy, 1998). At the same time, rates of OCD of 10-22.5% have been found in first-degree relatives of people with the condition. This compares to 2-3% in the general population (Nestadt et al., 2000; Menzies et al., 2008).

1.2.1.3. Stigma

Fear of negative judgements by others appears to play a key role in preventing individuals with OCD from reporting their symptoms (Simonds & Thorpe, 2003). People with OCD commonly report having had their symptoms for 10 or 15 years before seeking help (NICE, 2006). However, OCD rarely disappears or solves itself over time. Salkovskis (2005) states that ‘OCD is best thought of as being like a bully or a blackmailer, progressively demanding and taking more and more, finally forcing the sufferer to obey its every whim, often to the point of total humiliation and subjugation’ (Foreword, p.x). Deeper investigation of the mechanics of OCD is, thus, important, both to improve theoretical conceptions of the condition and to aid clinical interventions.
1.2.2. DSM-5 classification of OCD

In the fourth edition of the Diagnostic and Statistical Manual (American Psychiatric Association, 2000), OCD is classified as an anxiety disorder. However, in DSM-5 (American Psychiatric Association, 2013), the latest edition of the DSM, OCD has been removed from the anxiety section and is reclassified as part of a spectrum of obsessive-compulsive related disorders. Included in this spectrum of conditions are body dysmorphic disorder (BDD), trichotillomania and hoarding disorder, all of which are commonly characterised by obsessions and compulsions (American Psychiatric Association, 2013).

There is evidence that the conditions included in the obsessive-compulsive spectrum are comparable to OCD in terms of comorbidity, genetic and biological factors and clinical intervention outcomes (Hollander, Kim, Khanna, & Pallanti, 2007; Sica, Chiri, McKay, & Ghisi, 2010). However, the DSM-5 reclassification is not without controversy (Sica et al., 2010). For example, a study by Mataix-Cols, Pertusa and Leckman (2007) found that two in five of the mental health experts they surveyed viewed OCD as an anxiety disorder, arguing that it and anxiety conditions often presented together and could be treated with the same interventions. Others, such as Bartz and Hollander (2006), suggest that labelling OCD as an anxiety disorder may serve a clinical diagnostic purpose, but is unhelpful in gaining better understanding of the fundamental mechanics of the condition. The authors point out, for example, that neuroscientific research has suggested differing activation networks in individuals with OCD and those with anxiety disorders. Specifically, raised activity in the orbito-frontal cortex (OFC) of the brain has been consistently implicated in OCD. The amygdala, by contrast, is the area most commonly linked to anxiety (note, though, that these areas are not functionally distinct, and there are connections between the OFC and the amygdala – see Section 1.4.2). Meanwhile, family studies and comorbidity research suggest that the links between OCD and obsessive-compulsive spectrum disorders are stronger than they are with between OCD and anxiety disorders (e.g., PTSD, panic disorder and social phobia) (Bartz & Hollander, 2006). Sica and colleagues (2010) argue that neither classification of OCD is entirely satisfactory, owing to the heterogeneous nature of the condition and the continued absence of robust frameworks for its understanding.

1.2.3. Subtypes of OCD

OCD is a highly heterogeneous condition with a large range of symptom expressions (American Psychiatric Association, 2013; Abramovitch, Mittelman, Tankersley, Abramovitz, & Schweiger, 2015; Kuelz et al., 2004; NICE, 2006; Pauls, Abramovitch, Rauch, & Geller, 2014). A number of factor and cluster analysis studies have looked to establish a structure of thematic subtypes which might exist beneath the umbrella term of obsessive-compulsive disorder. For example, the Maudsley
Obsessive-Compulsive Inventory (MOCI; Hodgson & Rachman, 1977) diagnostic tool was created following a factor analysis of information from clinically-diagnosed individuals. It suggested the existence of four themed subtypes – washing, checking, doubting and slowness. A similar structure, but including five factors (washing, checking, impulses, rumination and precision), was found in the development of The Padua Inventory (PI; Sanavio 1988; van Oppen, Hoekstra, & Emmelkamp, 1995) diagnostic tool. This structure was found in both clinical and non-clinical samples. A further pair of diagnostic measures, the Obsessive-Compulsive Inventory (OCI; Foa, Kozak, Salkovskis, Coles, & Amir, 1998) and the Obsessive-Compulsive Inventory-Revised (OCI-R; Foa et al., 2002), were developed from clinical patient data to assess a larger range of obsessive-compulsive behaviours. Both accommodate six subtypes or thematic factors – washing, checking, ordering, neutralising, ordering and hoarding. Notably, this structure of six subtypes has been found in 10 further factor analysis studies with both clinical and non-clinical participant data (Abramovitch et al., 2015).

1.2.3.1. Checking and Washing

Checking and washing are the most commonly reported, and the most widely researched, subtypes of OCD. Checking is the most frequently reported OCD symptom (Ball, Baer & Otto, 1996). Approximately, 81% of patients display checking concerns (Harkin & Kessler, 2009). Meanwhile, three-quarters of people with OCD report excessive checking or washing concerns (Ball, Baer & Otto, 1996). However, there are considerable differences in the behavioural manifestations of these subtypes. The actions of checkers appear to be rooted in the prevention of adversity and harm (Rachman, 2002). Compulsions (such as repeatedly checking door locks) are often strongly characterised by doubt, indecision and considerable anxiety in the affected individual. Rachman (2002) describes checking behaviour as ‘purposeful but irrational’ (p.140) – an individual carrying out such actions does so willingly, but is motivated by an overwhelmingly urgent the need to gain relief from their concerns. By contrast, Washers are focussed on contamination avoidance and the elimination of danger (e.g., through excessive hand-washing routines) to which they believe they may have been exposed (Jones & Krochmalik, 2002). Thus, while both subtypes may be characterised by rituals and routines, the behaviour of washers may be more self-protective than that of checkers, who may feel excessive responsibility for the welfare of others.

There is some evidence that the different behaviours exhibited by checkers and washers may be reflected in differing cognitive abilities and neurological functioning (Bragdon, Gibb, & Coles, 2018). In a recent meta-analysis, Leopold and Backenstrauss (2015) reported that washers outperformed checkers in eight out of 10 neuropsychological domains which were examined. Large effect sizes were found for differences in planning and response inhibition, while smaller effect sizes were found for differences in attention and verbal and non-verbal memory. Evidence from fMRI brain-imaging research has suggested that different OCD subtypes, and in particular washing and checking, might
have different neural correlates (Gilbert et al., 2009; Mataix-Cols et al., 2004). Additionally, van den Heuvel et al. (2009) reported structural brain differences between washers and checkers. Pauls et al. (2014) note that this is a relatively new area of examination and there are only a limited number of such studies comparing subtypes that have been carried out. Additionally, people with OCD rarely fall cleanly into one subtype group, such is the complexity of the condition (Pauls et al., 2014). However, such findings provide important evidence of the possible depths of OCD heterogeneity. Clearly, however, further research is warranted.

1.2.3.2. Hoarding – no longer a subtype of OCD

Hoarders collect and retain items. This act is irrespective of the value of such items as defined by other people (Frost & Gross, 1993; van Ameringen, Patterson, & Simpson, 2014). In DSM-IV (American Psychiatric Association, 2000), hoarding was considered to be a symptom of OCD—alongside other subtypes, such as checking and washing. However, in DSM-5 (American Psychiatric Association, 2013) this is no longer the case. Hoarding is instead classified as an OCD-related condition, but distinct from OCD itself, with a distinct set of associated treatments. Evidence suggests that 80% of hoarders demonstrate no clinically diagnosable obsessive or compulsive behaviours, while only small to moderate correlations have been found between hoarding and OCD subtypes (Mataix-Cols et al., 2010). Indeed, Mataix-Cols et al. (2010) report that these correlations are similar to those between hoarding and anxiety and depression. Furthermore, there is evidence that hoarding has a distinct neural basis (An et al., 2009). This reclassification means researchers examining OCD need to be mindful of controlling for hoarding as confounding variable when designing studies and recruiting participants.

1.2.4. Conditions which are comorbid with OCD

Comorbid conditions are extremely common with OCD (Bartz & Hollander, 2006; LaSelle et al., 2004, Muller & Roberts, 2005; NICE, 2006; Ruscio et al., 2010). In LaSelle et al. (2004), only 8% of participants had no additional neuropsychiatric disorder. Furthermore, the mean number of additional conditions per participant was 2.88, with some individuals presenting up to nine comorbidities (LaSelle et al., 2004). Acknowledging this is important, as in order to make progress in understanding and treatment, it is crucial that claims made about OCD by clinicians and researchers actually reflect the condition itself, rather than the impact of such comorbidities (Abramovitch et al., 2015; Kuelz, 2004; Muller & Roberts, 2005; Sica et al., 2010). Indeed, the failure to recognise the presence of comorbidities with OCD could, in part, account for the inconsistency in findings of research into the condition (Abramovitch et al., 2015; Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005).
A range of studies have found that major depressive disorder is the most common condition additionally presented with OCD (for reviews see Bartz & Hollander, 2006; LaSelle et al., 2004). This research suggests a lifetime prevalence rate for depression of 54-66%. Furthermore, in their own study, LaSelle and colleagues (2004) found that the second most common comorbid condition was dysthymia (mild depression), which was apparent in 24% of participants. Mood disorders accounted for the most common additional conditions (81%). Notably, depression is more likely to manifest itself after a presentation of OCD, rather than the other way around, indicating that it is not a fundamental component of its make-up (Denys et al., 2004). Although OCD is now not classified as an anxiety disorder (see Section 1.2.2), anxiety-related disorders are commonly reported with OCD. Ruscio et al., (2010), for example, found anxiety conditions in 75% of participants, although in LaSelle et al. (2004) this figure was 53%. Social phobia is the most common anxiety-related comorbidity (though see Fireman et al., 2001), with prevalence rates of 23-43% (Bartz & Hollander, 2006; LaSelle et al., 2004; Ruscio et al., 2010). The percentages for other anxiety disorders (e.g., panic disorder, specific phobia) range from 1-23% across studies (Bartz & Hollander, 2006). Among OC spectrum disorders, studies have found the highest rates of comorbidity with BDD and trichotillomania (3-13% for both) (Bartz & Hollander, 2006; LaSelle et al., 2004). LaSelle and colleagues (2004) also found that substance-related and eating-related conditions were commonly comorbid with OCD in their sample (29% and 17%, respectively).

1.2.5. Frontline treatments of OCD

Single or recurrent episodes of OCD are uncommon (Abramowitz et al., 2009). Initial experiences are, in the main, gradual. But the condition of an individual with the condition will be likely to become chronic in the absence of intervention. OCD does not go away if left untreated, and its manifestations and behavioural expressions often change and adapt during its course (Abramowitz et al., 2009; NICE, 2006).

1.2.5.1. Psychological treatments

The standard psychological treatment for OCD is cognitive behavioural therapy (CBT) involving exposure and response prevention (ERP) (NICE, 2006). In therapeutic scenario, patients are repetitively exposed to the stimuli which causes them anxiety and the desire to act compulsively. They are then asked not to carry out compulsive rituals in response. The desired outcome is recognition by the patient that anxiety is not a permanent state, and that carrying out compulsive rituals is not an effective response to anxiety (Abramowitz, Taylor, & McKay, 2009). Studies which have used the Yale-Brown Obsessive-Compulsive Scale (YBOCS) (Goodman et al., 1989) have shown ERP to be effective in the treatment of OCD (e.g., Foa et al., 2006), with the reduced severity of the condition, in some cases, for two years (Abramowitz, 2006). However, because of the levels of
anxiety induced in ERP, around a quarter of patients fail to complete the treatment (Franklin, Abramowitz, Foa, Kozak, & Levitt, 2000).

1.2.5.2. Pharmacological treatments
Considerable research suggests that the use of selective serotonin-reuptake inhibitors (SSRIs, or antidepressants) can be a successful way to treat OCD (for review see Eddy, Dutra, Bradley, & Westen, 2004). SSRIs act to block serotonin (5-HT) transporters, and they aid in the reduction of raised activity in the orbito-frontal cortex of the brain, which is commonly associated to OCD (Saxena, 1998). However, they are not universally effective. SSRIs do not work for 40-60% of cases, with negligible change in the condition of patients reported with their use as a sole treatment (Eddy et al., 2004; Goodman, 1999). Furthermore, residual symptoms commonly reappear in most patients following SSRI treatment (Eddy et al., 2004). Some research has reported relapses of OCD in 24% of patients after finishing a course of sertraline (Koran, Hanna, Hollander, Nestadt, & Simpson, 2007) and 31-89% after taking clomipramine (Ravizza, Barzega, Bellino, Bogetta, & Maina, 1996; Pato, Zohar-Kadouch, Zohar, & Murphy, 1988). As such, the effectiveness of SSRIs can only be considered to be partial (Abramowitz et al., 2009).

1.2.5.3. Comparing treatments
Current research suggests ERP is more effective at treating OCD than pharmacological therapy (Abramowitz et al., 2009). For example, Foa et al. (2006) found that patient YBOCS scores decreased by just over half with ERP, but only by around a third in patients taking clomipramine. Combinations of ERP with clomipramine reduced scores by 58%, though this was not significantly different from the findings relating to ERP alone. As already stated, the aetiology and mechanics of OCD are still poorly understood. However, better understandings of the complex architecture of this condition are likely to be able to help to support treatment options and inform interventions. Indeed, specific interventions which directly address dysfunctional emotional regulation and attentional bias with the condition may be able to support frontline treatments – though these need further research (note, issues of emotional regulation are discussed in Section 1.5 and issues of attentional bias are discussed in Section 1.8).

1.2.6. Summary of Section 1.2
Obsessive-compulsive disorder (OCD) is a debilitating psychological condition, which is highly heterogeneous and complex. A range of OC subtypes comprise the condition, including checking and washing. These have different behavioural manifestations, and are likely to have differing neural correlates. It has been argued that this needs to be recognised more commonly in research. Non-
clinical OCD is common, and the use of non-clinical populations in research could enable a better understanding of the mechanics of clinical OCD. A range of other conditions are commonly comorbid with OCD, notably depression and anxiety disorders. Researchers should aim to take account of these in order that findings from research reflect, as far as possible, OCD or OC behaviours themselves, rather than the impact of associated conditions. The main treatments for OCD are CBT and ERP (psychological treatments) and the use of SSRIs, or anti-depressants (pharmacological treatments). Both can work, but no current approach to the treatment of OCD is entirely successful. However, improved understandings of cognitive processes underpinning the manifestations of OCD should be able to inform, and fine-tune, treatments for the condition.

1.3. Non-clinical OC behaviour

Research into OCD has typically focussed on the behaviours and symptomology of people who have been given a clinical diagnosis of the condition. It is notable that participants in a considerable proportion of early research into OCD were described as ‘patients’ – implying a medical ‘caseness’, which can be contrasted with a ‘non-caseness’. Studies using clinical OC samples can be highly beneficial for the examination and testing of interventions and treatment outcomes. But they are not without issues (Abramowitz et al., 2014). The presence of comorbid conditions, which are extremely common in clinical OCD (see Section 1.2.4), and the impact of previous and current interventions are major confounding problems in clinical research. As already stated, the lack of recognition of comorbidities with OCD is likely to be partly responsible for inconsistent research findings relating to the condition (Abramovitch et al., 2015; Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005). Medication-use is commonplace among people with clinical OCD (see Section 1.2.5), but the effect of pharmacological interventions may confound study outcomes – it may be unclear whether recorded effects are due to the condition or have occurred as a consequence of the taking of medication (Abramowitz et al., 2014; Gibbs, 1996).

The weight of evidence now suggests that notions of condition-presence and condition-absence cannot be applied to OCD, and that people who have been given a clinical diagnosis of the condition form only a small proportion of those who can be understood to exhibit some form of obsessive-compulsiveness (Abramowitz et al., 2014; Adam, Meinlschmidt, Gloster & Lieb, 2012; Gibbs, 1996; Grabe et al., 2000). Furthermore, what can be termed non-clinical OC behaviour is extremely common.
1.3.1. Defining non-clinical samples

Gibbs (1996) states that OC population samples are usually defined as non-clinical in three circumstances – firstly, when participants are not receiving formal healthcare or treatment for OCD; secondly, when participants self-report high OC symptomology, but do not meet full diagnostic criteria; and thirdly, when participants meet diagnostic criteria, but have not asked for treatment or intervention. The studies presented in this thesis adopt sampling criteria in line with the latter of these three definitions – participants had no clinical diagnosis of OCD, but met key criteria for the condition when measured by the OCI-R questionnaire (Foa et al., 2002). Specific details relating to sampling using the OCI-R are discussed at the end of this chapter in Section 1.14 and in the Methods sections of each study chapter.

1.3.2. Justifications for the use of non-clinical OC populations in research

Two major reviews (Abramowitz et al., 2014; Gibbs, 1996) have examined research into OCD using non-clinical populations. Both conclude that there are both considerable theoretical and practical justifications for the use of non-clinical, or analogue, samples in studies of OC behaviour. In the most recent of these reviews (Abramowitz et al., 2014), the authors advance the following arguments in favour of the use of non-clinical samples to study OCD:

1.3.2.1. Dimensionality

Obsessive-compulsive behaviours are dimensional (i.e., there are ranges of severity) and are not categorical (i.e., people either have the condition or do not). In studies which have compared OC manifestations and behaviours in clinical and non-clinical samples (e.g., Abramovitz et al., 2010; Foa et al., 2002; Garcia-Soriano, Belloch, Morillo, & Clark, 2011), symptom severity has been shown to be consistently greater among clinical participants when compared with non-clinical participants. Importantly, however, these studies showed that OC symptoms, although typically less severe, were also present among non-clinical participants. Taxometric studies have found strong evidence of dimensionality in general OCD symptomology (Olatunji, Williams, Haslam, Abramovitz, & Tolin, 2008) and in checking and washing behaviours (Haslam, Williams, Kyrios, McKay, & Taylor, 2005).

The issue of dimensionality in OCD is important on two levels. Firstly, it suggests that accounts of OCD which are based purely on the experiences and behaviours of clinically-diagnosed individuals will only provide partial insights into the condition more broadly. Secondly, it indicates that studying non-clinical participants who report OC symptomology may be a highly useful way of gaining insights into more severe expressions of the condition.
1.3.2.2. Prevalence

Studies suggest that OCD-like intrusive thoughts have been experienced by up to 90% of the population (e.g., Clark, 1992; Rachman & de Silva, 1978; Salkovskis & Harrison, 1984). Meanwhile, assessments of healthy populations have consistently shown that around a quarter of participants record scores on the OCI-R questionnaire (Foa et al., 2002) which are above the diagnostic cut-off score for OCD (e.g., Cuttler & Taylor, 2012; Jennings, Nedeljkovic, & Moulding, 2011; Kaczkurkin, 2011).

1.3.2.3. Aetiology

Twin studies carried out by Taylor (2011) and Taylor, Jang and Asmundsen (2010) examined how far clinical OCD and non-clinical OC symptomology could be attributed to genetic and/or environmental factors. Data from clinically-diagnosed (Taylor, 2011) and high-severity participants (Taylor, Jang, & Asmundsen, 2010) were compared with that from non-clinical twin samples, the participants of which had been assessed for OC symptomology. Additive genetic factors and non-shared environments were the key influences on OC behaviours in both studies, with no significant difference found in the heritability of OC symptomology and that of a diagnosis of OCD. These findings suggest that clinical and non-clinical OCD have a similar aetiology (Abramowitz et al., 2014).

1.3.2.4. Phenomenology of obsessions and compulsions

OC behavioural manifestations may be more severe and chronic with a clinical diagnosis of OCD, but the content and phenomenology of the behaviours exhibited by both clinically-diagnosed and non-clinical individuals is extremely similar (Abramowitz et al., 2014). Researchers have consistently shown that the nature and themes of obsessions reported by clinical and non-clinical participants are highly comparable (e.g., Garcia-Soriano, Belloch, Morillo, & Clark, 2012; Julien, O’Connor, & Aardema, 2009; Salkovskis & Harrison, 1984). At the same time, the compulsive phenomenology (e.g., checking, washing and ritualised repetition) evident among clinically-diagnosed individuals has also been shown to be apparent in non-clinical populations (e.g., Flament et al, 1988; Ladouceur et al, 2000). Such research findings provide further support for the conceptualisation of OCD as a dimensional condition.

1.3.2.5. Cognitive and behavioural factors

Cognitive and behavioural factors which are believed to underpin the architecture of clinical OCD – and which inform the influential cognitive-behavioural theoretical models of OCD (e.g., Salkovskis, 1985 – discussed in detail in Section 1.4) – are also demonstrable in non-clinical OC groups (Abramowitz et al., 2014). Thus, researchers have found that the behaviours of non-clinical OC participants is, like with clinically-diagnosed individuals, characterised by inflated responsibility (e.g., Ladouceur et al., 1995; Myers, Fisher, & Wells, 2008), threat exaggeration (e.g., Deacon & Olatunji,
2007; Myers, Fisher, & Wells, 2008), intolerance of uncertainty (e.g., Fitch & Cougle, 2013), attentional bias (e.g., Bar-Haim, Lamy, Pergamin; Bakersmans-Kranenburg, & van Ijzendoorn, 2007) and lack of confidence in memory (e.g., van den Hout & Kindt, 2003a).

1.3.2.6. Experimental practicality
The percentage of the OC population which is made up of individuals who are clinically-diagnosed with the condition is small (Abramovitz et al, 2014). Consequently, studies involving non-clinical participants are likely to be easier to recruit-for than those with clinically-diagnosed populations. Furthermore, non-clinical participants are less likely to taking medication for OC symptoms (Gibbs, 1996), which thus reduces the possible impact of a key confounding variable in OCD research (see Section 1.2.4).

1.3.3. Summary of Section 1.3

OC behaviours are dimensional rather than categorical. The severity of OCD symptoms is much greater in clinically-diagnosed OCD than non-clinical OCD. However the nature of the symptoms expressed is fundamentally the same in both groups (Abramowitz et al., 2014). As such, the findings from such studies using non-clinical populations can be both highly generalizable to more severely affected clinical populations and greatly relevant to deeper understandings of disorder itself (Abramowitz et al., 2014; Gibbs, 1996).

1.4. Theoretical models of OCD

A number of models of OCD have been proposed, from a variety of theoretical approaches (Jakes, 1996). These include medical/clinical (Janet, 1903, cited in Jakes, 1996), psychoanalytic (Freud, 1909; Malan, 1979), personality (e.g., Eysenck, 1979), learning (e.g., Eysenck & Rachman, 1965), cybernetic (Pitman, 1987) and evolutionary (e.g., Abed & de Pauw, 1998). None of these provide a satisfactory singular framework for understanding OCD (Jakes, 1996). More recently, cognitive-behavioural and biological/neuropsychological models of OCD have become well-established among researchers attempting to conceptualise the condition. Neither provides a complete account of the defining architecture of OCD (Abramowitz et al, 2009; Jakes, 1996), but they are not mutually exclusive. A considerable body of literature now supports both approaches.
1.4.1. Cognitive-behavioural models

A founding principle of cognitive-behavioural models of OCD (e.g., Salkovskis, 1985) is that most people will have unwanted thoughts, feelings and impulses. The majority of these people will understand that these are harmless. An individual with OCD, however, may respond to such normal intrusions in a particular manner which heightens their meaning – see Figure 1.2. Thus, if intrusions imply the threat of harm to the individual and/or other people, and, crucially, that if the individual may be deemed to have a role in responsibility for such harm, they may become obsessional (Salkovskis & Maguire, 2002). Cognitive-behavioural models thus posit a central role for the examination, or appraisal, of intrusive thoughts by an individual in the emergence of obsessive and compulsive thinking and behaviours. Among people with OCD, appraisals of intrusions which highlight threat or responsibility related to harm may become motivating – they legitimise consequent behaviour, which is commonly based on achieving safety, eliminating harm and diluting the responsibility of an individual for adverse outcomes (Salkovskis & Maguire, 2002). In order to control or prevent intrusive thoughts, and any associated harmful consequences of their presence, compulsions may develop (Abramowitz et al., 2009). Importantly, Salkovskis (1985) argues that inflated personal responsibility arising from dysfunctional core beliefs (for example, relating to blame and control) underpins the negative appraisals of people with OCD. This heightened responsibility may result in excessively controlling behaviours and preoccupations. The consequent impact on the individual with OCD may be apparent in high personal discomfort, an over-focus on intrusions and the potential for intrusions to re-appear and the use of neutralisation tactics – for example, avoidance behaviours, rituals and assurance-seeking from others (Salkovskis & Maguire, 2002). Further developments of the cognitive-behavioural model suggest that perfectionism, doubt, intolerance of uncertainty and the importance of thought-control can also inform obsessive-compulsive symptoms experienced by patients (Obsessive Compulsive Cognitions Working Group [OCCWG], 2005).

1.4.1.1. Limitations of cognitive-behavioural models

Cognitive-behavioural appraisal models have received much support from research (e.g., Abramovitch, Nelson, Rygwall, & Khandker, 2007), and have aided the development of CBT and ERP treatment for OCD (Foster & Eisler, 2001). However, it is argued that negative appraisals and dysfunctional thinking of type highlighted by the OCCWG (2005) cannot account for all obsessive-compulsive instances, as some individuals with OCD record normal scores for measures of such variables (Taylor et al., 2006). Moreover, a substantial body of evidence suggests that biological or neuropsychological components might play significant roles in the emergence and maintenance of the disorder (e.g., Aouizerate et al., 2004, Kuelz et al., 2004), which appraisal models have not accommodated (Foster & Eisler, 2001). Cognitive-behavioural models are useful in explaining the
maintenance of OCD, but perhaps have more difficulty accounting for the initial occurrence of OCD symptoms.

**Figure 1.2.** The operation of the cognitive-behavioural appraisal model of OCD.

### 1.4.2. Biological models

#### 1.4.2.1. The fronto-striatal model

The development of increasingly advanced neuroscientific research techniques over the last 30 years has enabled ever-closer examination of the brain structure and function of people with OCD (Pauls et al., 2014). The findings of a considerable body of this research has suggested that abnormal functioning in the fronto-striatal circuitry of the brain underpins the symptomology of the condition (Abramovitch et al., 2013; Cavedini, Gorini, & Bellodi, 2006; Kuelz et al., 2004; Menzies et al, 2008; Pauls et al, 2014). In particular, a model describing malfunction in an orbitofrontal-subcortical loop linking the orbitofrontal cortex (OFC), striatum, globus pallidus, thalamus (the fronto-striatal model; Saxena & Rauch, 2000) has provided the standard neuropsychological account of the condition (Pauls et al, 2014; Menzies et al, 2008).

The existence of the orbitofrontal-subcortical loop was first hypothesised by Alexander, DeLong, & Strick (1986), following detailed analysis of the functional role played by the basal ganglia. The authors proposed that four separate loops, all parallel to an already established motor circuit (DeLong, Georgopoulos, & Crutcher, 1983), linked the basal ganglia to different areas of the frontal cortex. They labelled these loops as the following: the oculomotor, the dorsolateral prefrontal, the anterior
cingulate and the lateral orbitofrontal (Alexander et al., 1986). It was believed these loops served essentially distinct functional purposes, though, at the time, the precise role of the orbitofrontal loop was not clear (Alexander et al., 1986). However, subsequent research adapted the circuitry, adding roles for the hippocampus, amygdala and anterior cingulate (Lawrence et al., 1998; Philips, Drevets, Rauch, & Lane, 2003) – see Figure 1.3A. Because these regions were already believed to be involved in emotion production and regulation, it was suggested that this loop could be implicated in the processing of affect (Menzies et al, 2008). It is worth noting at this point, that the evidence in favour of a role for the amygdala in the psychopathology of OCD is inconsistent. What is clearer is that raised activity in the OFC has been commonly reported in OCD, while the amygdala has been more consistently linked to anxiety disorders (Bartz & Hollander, 2006).

Current theory suggests that the components of the orbitofrontal network are variously implicated in aspects of, and processes linked to, behavioural self-regulation (Sica et al., 2010). These include decision-making, feedback and motivation (OFC); action monitoring and reward-processing (anterior cingulate); implicit learning and habit learning (basal ganglia); emotion processing (OFC and amygdala); declarative and episodic memory (hippocampus); and information relay to cortical sites (thalamus) (Aouizerate et al., 2004; Graybiel & Rauch, 2000; McFarland & Haber, 2002; Melloni et al., 2012; Menzies et al., 2008; Pauls et al, 2014; Phelps, 2004). Alongside OCD, fronto-striatal deficits are functionally implicated in bulimia, anorexia and Tourette’s syndrome – conditions which are characterised by dysfunctional self-regulation (Marsh, Maia, & Peterson, 2009). It is argued that such deficits may weaken an individual’s abilities to inhibit sensations, thoughts and impulses, leading to the symptom presentations commonly seen in these conditions – e.g., obsessions and compulsions in OCD, tics in Tourette’s syndrome and weight/eating issues in anorexia and bulimia (Sica et al, 2010).

Neuroimaging research (for example, using positive emission tomography (PET) and functional magnetic resonance imaging (fMRI)) has suggested that heightened activity in the orbitofrontal loop is evident when patients with OCD are resting, that this is further increased when they manifest their symptoms, and that activity is lowered following intervention or treatment (Abramovitch et al., 2015; Aouizerate et al., 2004; Cavedini et al., 2006; Freyer et al., 2011; Pauls et al, 2012). A meta-analysis of structural MRI studies by Rotge and colleagues (2009) found consistent evidence of decreased OFC and anterior cingulate volume, along with increased thalamus size, with OCD. OFC deficits have been linked to weakened inhibition, decision-making and reward-learning, and altered affect (Bechara et al., 1994; Damasio, 1994; Eslinger & Damasio, 1985; Rolls, Hornak, Wade, & McGrath, 1994). The OFC may also be implicated in the inhibition of behaviour which has become irrelevant, having formerly been relevant (Chudasama & Robbins, 2003). It is argued that, in OCD, heightened activity levels in the OFC, with its consequences for interrupted inhibition and behavioural learning, could
functionally underpin the ritualised and repetitive behaviours commonly seen in patients (Menzies et al., 2008; Rotge et al., 2008; Sica et al., 2010).

1.4.2.2. Extending the fronto-striatal model

A limitation of the fronto-striatal model of OCD lies in the findings of neuropsychological tests which have been traditionally said to draw on fronto-striatal brain areas. In a review integrating neuro-imaging and neuropsychological literature, Menzies and colleagues (2008) found some evidence of patient deficits in decision-making and reversal learning, which are traditionally associated with the OFC, but stronger evidence of dysfunction in cognitive functions, such as inhibition, planning and set shifting, which, they argued, were likely to be reliant on brain areas other than those limited to the OFC circuitry. The authors conclude that the orbitofrontal-loop model is too basic to act as an explanatory framework for functional understandings of OC behaviour.

Menzies et al. (2008) instead propose the involvement of two circuits with OCD – the original orbitofrontal-loop and the dorsolateral pre-fronto-striatal loop, which was another of the four loops originally hypothesised by Alexander et al. (1986). The structures of this second loop include the dorsolateral pre-frontal cortex (DLPFC), the posterior parietal cortex, the head of the caudate, the globus pallidus, substantia nigra and the ventroanterior and mediodorsal thalamus (Alexander et al., 1986). While noting that neuropsychological research into OCD had produced inconsistent findings, they argued that affective tasks might still primarily involve orbitofrontal areas, but spatial, attentional and working memory tasks could be better understood as involving this dorsolateral pre-fronto-striatal loop – see Figure 1.3A and B. Notably, studies have found hypo-activity with OCD in the DLPFC loop (e.g., Reminjinse et al, 2006) – in contrast to the often-reported hyper-activity of the orbitofrontal circuitry.
Figure 1.3. The cortico-striatal circuitry and brain areas which are likely to be implicated in OCD – from Menzies et al. (2008). A – The orbitofrontal loop, as proposed by Alexander et al. (1986). Orange boxes indicate additions proposed by Lawrence et al. (1998). B - The dorsolateral pre-frontal-striatal loop. Regions which may also be involved in the circuitry are in the green boxes.
1.4.3. Summary of Section 1.4

Cognitive-behavioural and biological/neuropsychological models of OCD have become the key contemporary accounts of the condition. Research supports both models, but neither is complete. Cognitive-behavioural models are good at explaining the symptomology and maintenance of OCD, but have difficulty accounting for the biological origins of OCD and its initial occurrence in individuals. Biological models of OCD are useful for highlighting the underlying mechanics of the condition. These models are not mutually exclusive. A more integrated approach involving both accounts of OCD could be useful in future research.

1.5. Attentional and memory biasing in OCD

1.5.1. Attentional bias

Attentional bias is demonstrated when an individual selectively attends, to a greater degree, to one stimulus type over another – in particular, to threatening stimuli over non-threatening stimuli (Bradley et al., 2016; De Putter & Koster, 2017; da Victoria, Nascimento, & Fontenelle, 2012). Attentional biases towards threatening stimuli have been repeatedly reported with anxiety disorders, such as generalized anxiety disorder and social phobia (Bar-Haim et al., 2007; da Victoria et al., 2012; Koch & Exner, 2015). It may also have a key role in underpinning the development, behavioural manifestations and maintenance of OCD (Bar-Haim et al., 2007; Salkovskis & McGuire, 2002).

Bar-Haim et al. (2007) have proposed a model of attentional bias, which includes four stages of threat processing – (i). the pre-attentive assessment of stimuli; (ii). the focussing of cognitions on stimuli comprising threat; (iii) the analysis of threat context and memory of threat; and (iv). the shifting of attentional resources towards threat and away from goals. The model was developed following a meta-analysis of attentional bias studies examining a number of psychological disorders. The authors reported people with OCD demonstrated attentional bias to threat in a similar manner to those with anxiety disorders, indicating that the model is appropriate for understanding biasing towards threat in OCD (Bar-Haim et al., 2007). Meanwhile, De Putter and Koster (2017) suggest that attentional bias with OCD might be understood in terms of attentional control theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007), and an altered balance between bottom-up and top-down processing (see Corbetta & Shulman, 2002 – plus Section 1.9.5). Bottom-up processing can be triggered by internal (e.g., negative thoughts) and external threat (e.g., threat-associated objects). Top-down processing, by contrast, is goal-oriented and based on the knowledge and experience of a person. In a person with
OCD, elevated bottom-up processing may occur when they are faced with, for example, negative thoughts or threat-associated objects, with a consequent reduction in the limited resources available for top-down control. The behavioural result could be attentional bias to threat. This could possibly be demonstrated through impaired performance on tasks which place demands on attentional resources and which use threat stimuli (De Putter & Koster, 2017).

1.5.1.1. Hyper-vigilance and delayed disengagement

Although models of attentional bias have been proposed, the exact mechanisms underpinning bias towards threat with OCD remain in doubt (Bradley et al., 2016). However, it is generally considered that two theories have been developed which provide the strongest accounts of the mechanics of attentional bias in OCD. The first of these, the vigilance hypothesis (e.g., Armstrong & Olatunji, 2012), suggests that people with OCD may be hyper-sensitive to material which is salient to their concerns. Consequently, they have a comparably low threshold which needs to be reached by threatening stimuli in order for them to receive heightened levels of attentional processing. By contrast, the delayed disengagement hypothesis (e.g., Bradley et al., 2016; Georgiou et al., 2005) argues that individuals with OCD have problems extinguishing their fixations on salient, negative stimuli, or that they may be over-focussed on such stimuli in late-processing stages of selective attention. Thus, rather than being initially hyper-vigilant to threat stimuli, people with OCD may have difficulty forgetting, or moving on, from a threat stimulus which they have experienced (Bradley et al., 2016).

Defining the mechanics of attentional bias is important for the establishment of sound theoretical understandings of OCD (Cisler & Olatunji, 2010). For example, evidence supporting delayed disengagement from threat stimuli could support theories of deficits in cognitive inhibition and distractor suppression with OCD (e.g., Chamberlain et al., 2005; Enright & Beech 1990, 1993; Kaplan et al., 2006).

1.5.2. Memory bias

In addition to attentional bias, evidence suggests that memory biasing towards threat is also a component feature of OC behaviour (Klumpp, Amir, & Garfinkel, 2009; Hansmeier, Glombiewski, Rief & Exner, 2015; Muller & Roberts, 2005). In lay terms, it seems perfectly conceivable that an individual might develop exaggerated appraisals of normal mental intrusions (the cognitive-behavioural model of OCD; e.g., Salkovskis, 1985 – see Section 1.4.1) if they have problems forgetting or inhibiting such intrusions after they have become apparent (Muller & Roberts, 2005). Enhanced memory for threatening stimuli has been reported in clinically-diagnosed anxious participants (for review, see Mitte, 2008). In OCD, memory bias towards, or enhanced memory of,
threat is likely to be contingent on the direct relevance of a stimulus to the OC concerns of the individual, in addition to the levels of personal responsibility associated with the stimulus - the greater the perceived responsibility, the more likely a memory bias towards the stimulus will be apparent (Hansmeier et al., 2015; Radomsky, Rachman, & Hammond, 2001; Tolin, Hamlin, & Fox, 2002). Notably, there is also evidence that memory biasing may be a particular feature of OC checking, as checkers are more prone to doubt and sensitivity to potential threat (Rachman, 2002).

It is important to state that attentional and memory biasing mechanisms are not necessarily mutually exclusive, and both processes may feed each other. Thus, attentional bias to threat in a given context, whether reflected in delayed disengagement from or hypervigilance to troubling stimuli, may serve to trigger difficulties with the suppression of threatening memories. This, in turn, could further reinforce a person’s attentional bias to threat (Muller & Roberts, 2005). This thesis looks to examine possible bias and altered performance across both these aspects of cognition.

1.5.3. Treatments for bias and OCD

Frontline treatments for OCD (see Section 1.2.5) can be effective, but do not work in all cases. The development of additional interventions targeting the specific mechanics of the condition could help support such treatments (Mogg & Bradley, 2016). Attentional bias modification (ABM; MacLeod & Mathews, 2012) is a computer-presented intervention which aims to reduce attentional bias to threat. It was initially developed to help treat anxiety disorders, but it may also be useful for the treatment of OCD, given the general weight of evidence supporting theories of attentional bias with the condition. A review of ABM studies by Mogg and Bradley (2016) suggested the intervention was not always effective, but it could be improved by the incorporation of theories relating to top-down and bottom-up processing and inhibitory control. Interestingly, Clerkin and Teachman (2011) developed a computerised procedure called cognitive bias modification (CBM), which they used in an attempt to reduce attentional bias in a non-clinical OCD population. The authors found that, in high-level OC participants, obsessive-compulsive beliefs were reduced after they had been trained to focus their attention away from emotionally-salient stimuli. Such interventions are promising, and warrant further investigation.

1.5.4. Summary of Section 1.5

Attentional and memory biasing are likely to play an important and joint role in underpinning the development, behavioural manifestations and maintenance of OCD. The precise mechanics of attentional bias with the condition are likely to be linked to hyper-vigilance to threat stimuli or
difficulty disengaging from such stimuli. Memory bias may be a particular feature of OC checking. Frontline treatments for OCD may be supported by efforts made to reduce attentional bias.

1.6. Emotional regulation in OCD

Emotion regulation is the process by which a person controls, expresses and influences their emotions (Gross, 1998). Healthy regulation can serve to appropriately manage emotional states for the specific demands of particular circumstances. By contrast, dysfunctional regulation can impair the beneficial aspects of affective states (Stern, Nota, Heimberg, Holaway, & Coles, 2014). For example, poor emotional regulation has been linked to impaired performance in goal-orientated tasks (e.g., Gray, 2004) and weakened decision-making (e.g., Bechara, 2004). A model by Mennin and colleagues (see Mennin, Heimberg, Turk, & Fresco, 2005; Mennin et al, 2007) details four elements which comprise emotional dysregulation: (i). raised intensity of emotions; (ii). poor understanding of the meaning of emotions; (iii). negative responses when emotional states arise; and (iv). maladaptive responses to the management of emotional states.

Understandings of psychological disorder, and the development of improved treatments and interventions, may be aided by theories and research which can highlight how emotional processing can become dysfunctional (Mennin et al., 2007). The ability to regulate emotion in a flexible manner according to circumstance is important to good mental health (Kring & Werner, 2004). Cognitive-behavioural models of OCD (e.g. Salkovskis, 1985) highlight a role for emotions and mood in the mechanics of OCD. It is argued that negative appraisals may lead to the presence of negative emotional states. These may result in a person with OCD deploying avoidance-based, safety-seeking behavioural activity (Salkovskis, 1985; Yap et al., 2018). Indeed, misinterpretation of obsessional thinking has been linked to comorbid depression with OCD (Yap, Mogan, & Kyrios, 2012).

It is likely that the ability to regulate emotional states might have an impact on how OCD manifests itself and how it is maintained (Yap et al., 2018). In a recent review of research, Robinson and Freeston (2014) reported that people with OCD had impaired ability in identifying and describing emotions (alexithymia). They also had raised sensitivity to anxiety and heightened intolerance of negative emotion. Stern et al. (2014) demonstrated that poor comprehension, and a greater fear, of emotions were present in all subtypes of OCD (as defined by the OCI – Foa et al., 1998). Indeed, people with OCD have been shown to be intolerant of both novelty (Coles, Schofield, & Pietrefesa, 2006) and uncertainty (Holaway, Heimberg, & Coles, 2006). It is possible this relates to a desire to avoid emotions which they would find fearful (Stern et al., 2014). Additionally, OCD symptom
severity has been shown to be connected to emotion regulation difficulties in both non-clinical (Fergus & Bardeen, 2014) and clinical (Smith, Wetterneck, Hart, Short, & Björgvinsson, 2012) populations. Moreover, neuroscientific evidence suggests that the activation of brain areas associated with emotional regulation is enhanced in OCD (e.g., the striatum, the ACC and the OFC – see Menzies et al., 2008). Notably, the OFC has been shown to be over-active when stimuli are presented to OC participants which are specific to their concerns (Simon, Kaufmann, Müsch, Kischkel, & Kathmann, 2010).

1.6.2.1. **Possible treatments for emotional dysregulation with OCD**

There is some suggestion that frontline treatments for OCD (see Section 1.2) may be supported by efforts made to improve emotional regulation. For example, decreased suppression of thinking and lowered severity of OCD was demonstrated in clinical patients following an intervention in which they learned how to reduce avoidance to irrelevant information (Allen & Barlow, 2009). Meanwhile, acceptance and commitment therapy (ACT) relating to emotion regulation has been shown to aid reductions in the severity of OCD (Twichig et al., 2010).

1.6.3. **Summary of Section 1.6**

It is likely that people with OCD have difficulties regulating their emotions. Poor understanding, and a greater fear, of emotions has been demonstrated in OCD and in subtypes of OCD. Mainstream treatments of OCD may be aided by interventions designed to improve emotional regulation, though these need further research.

### 1.7. Evidence of cognitive deficits and OCD

Cognitive deficits with OCD have been reported by researchers in a number of areas, including aspects of working memory, set-shifting, response inhibition, planning, selective attention and episodic memory (for reviews, see Abramovitch et al., 2013; Sica et al, 2010). However, in comparison to the more robust findings of neuro-imaging research, the results of cognitive-psychological tests which are said to target the brain regions associated with the fronto-striatal and DLPFC models of OCD (see Section 1.4.2) have been more mixed (Abramovitch et al., 2013; Kuelz et al., 2004; Menzies et al., 2008; Pauls et al., 2014). For example, poor response inhibition has been hypothesised as an endophenotype of OCD (Chamberlain et al., 2005). Yet some studies find impaired response inhibition (for example, using go/no, stop signal and Stroop tasks) with OCD in comparison with controls (e.g., Abramovitch, Dar, Schweiger, & Hermesh, 2011), and others do not
The same pattern applies to the results of tests of planning, such as the Tower of London, and set shifting, such as the Wisconsin card sorting test (Abramovitch et al., 2013). In their review, Greisburg and McKay (2003) report poor organisational strategy performance among patients, suggesting some kind of executive functioning impairment with the condition. Executive functions are processes which are considered to be of a ‘higher’ order (e.g., intention, behaviour planning and monitoring). However, both Sica et al., (2010) and Kuelz et al., (2004) argue that there is not yet enough robust evidence of broader executive dysfunction with OCD. In their review of 50 studies, Kuelz and colleagues (2004) found that there was no firm pattern of findings relating to set-shifting, planning, fluency and problem-solving in OCD. On the other hand, Menzies et al., (2008) reported consistent evidence that patients with OCD were impaired in attentional set-shifting and response inhibition, but that there was no evidence of decision-making dysfunction.

This leads to two questions. Firstly, to what extent can people with OCD be understood to have cognitive deficits? Secondly, why are findings from research examining cognition and OCD inconsistent? In an attempt to clarify the cognitive picture of OCD, Abramovitch and colleagues (2013) carried out what they argued was the first quantitative meta-analysis of research examining possible cognitive deficits in OCD. Their aim was to better establish the extent of differences, if any, between individuals with OCD and controls in a number of neuropsychological areas. The authors argued that previous attempts to pool literature (e.g., Greisburg & McKay, 2003; Kuelz et al., 2004) had been narrative reviews, and this was problematic in terms of interpretation of their findings. Following analysis of 115 studies, the authors found significantly reduced average performance by patients with OCD, in comparison to controls, in all six of the domains (attention, memory, executive function, visuospatial ability, processing speed and working memory) and all 10 of the sub-domains (e.g., verbal and non-verbal memory, sustained attention, planning, set shifting) which were assessed – see Table 1.1.
Table 1.1. Overall mean effect sizes (Cohen’s $d$) for six cognitive domains and 10 sub-domains calculated by Abramovitch et al. (2013) in a meta-analysis of cognitive research examining the performance of OCD groups and controls. Negative effect sizes indicate poorer functioning by OCD participants. (0.2 = small effect; 0.5 = medium effect; and 0.8 = large effect – Cohen, 1988).

<table>
<thead>
<tr>
<th>Main domain</th>
<th>Sub-domain</th>
<th>Mean effect size $(d)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention</td>
<td>Sustained attention</td>
<td>-0.499</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.499</td>
</tr>
<tr>
<td>Executive functions</td>
<td>Planning</td>
<td>-0.498</td>
</tr>
<tr>
<td></td>
<td>Response inhibition</td>
<td>-0.44</td>
</tr>
<tr>
<td></td>
<td>Set-shifting/cognitive flexibility</td>
<td>-0.492</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.517</td>
</tr>
<tr>
<td>Memory</td>
<td>Verbal memory</td>
<td>-0.63</td>
</tr>
<tr>
<td></td>
<td>Non-verbal memory</td>
<td>-0.332</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.761</td>
</tr>
<tr>
<td>Processing speed</td>
<td>Processing speed</td>
<td>-0.517</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.517</td>
</tr>
<tr>
<td>Visuospacial abilities</td>
<td>Visuospatial abilities</td>
<td>-0.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.35</td>
</tr>
<tr>
<td>Working memory</td>
<td>Working memory</td>
<td>-0.341</td>
</tr>
<tr>
<td></td>
<td>Spatial working memory</td>
<td>-0.343</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.369</td>
</tr>
</tbody>
</table>

At first sight, the findings of Abramovitch and colleagues (2013) appear to offer a greater degree of clarity in the search for cognitive picture of OCD. However, the authors note that only in the memory domain were medium to large effect sizes recorded. The majority of effect sizes were medium, with small effect sizes for working memory and visuospatial faculties (Abramovitch et al., 2013). Furthermore, the performance of people with OCD across domains was less than one standard deviation below that of controls. Abramovitch and colleagues (2013) suggest that key methodological problems (e.g., inconsistent experimental design and sampling issues) are likely to have contributed to the mixed picture of findings relating to OCD and cognitive processes (a conclusion also made in reviews by Kuelz et al., 2004; Muller & Roberts, 2005; Pauls et al., 2014). Thus, the weight of evidence from the meta-analysis by Abramovitch et al. (2013) suggests the presence of cognitive deficits with OCD, but it is difficult to interpret their clinical significance because of contradictions in methodology and design between the studies which have examined particular areas of functioning. These issues will be discussed in the next section.
1.7.1. Limitations of previous literature examining cognitive deficits with OCD

A good deal of evidence points to the possible presence of cognitive deficits with OCD. However, it may be difficult to assess their clinical significance, not because of the absence of clinically-meaningful distinctions between people with OCD and controls, but because of key issues of experimental design and the failure by researchers to consider crucial confounding factors. A number of reviewers (e.g., Abramovitch et al., 2013; Kuelz et al., 2004; Muller & Roberts, 2005; Pauls et al., 2014) have highlighted specific concerns with some cognitive research examining OCD. They relate to the following areas.

1.7.1.1. Low-sensitivity paradigms
Classic neuropsychological tests (e.g., the Weschler Memory Scale) are useful for the assessment of clear-cut cognitive disorders, but may be not so useful when patient populations have primary psychiatric conditions (Kuelz et al., 2004). Such tests, which have commonly been used in OCD research, are unlikely to be sensitive enough to tap into possible dysfunction in OC populations (Klumpp, Amir & Garfinkel, 2009; Kuelz et al., 2004). This would particularly be the case if researchers fail to acknowledge the heterogeneity of OCD (see Section 1.6.2.2) or choose not to use symptom-salient (see Section 1.6.2.3) in their designs.

1.7.1.2. The heterogeneity of OCD
As stated in Section 1.2.3., a number of studies have demonstrated that OCD is a multi-dimensional condition, which comprises at least four or five symptom subtypes (e.g., checking, washing). Furthermore, there is evidence that these subtypes may have different neural and genetic make-ups (for more, see Abramovitch et al., 2013; Bragdon et al, 2018; Leopold & Backenstrass, 2015; Pauls et al., 2014). However, the majority of studies of OCD have treated OC populations as a single, homogenous grouping (Abramovitch et al., 2013; Muller & Roberts, 2005). This is likely to have the effect of preventing clinically-meaningful data relating to the deeper mechanics of OCD being produced (Abramovitch et al., 2013).

1.7.1.3. The importance of emotional and symptom-salient stimuli
The complex heterogeneity of OCD means that items or information which cause OC concerns vary hugely between subtypes, and even between individuals within the same subtype. It is likely then that neutral, or general threat-related, stimuli may be less likely to trigger OC symptoms than stimuli which have been chosen or designed with the specific concerns of the participants of a particular study in mind (Moritz et al., 2008, 2009; Muller & Roberts, 2005; Tolin et al. 2001). However, a large number of studies examining OCD populations – and from which generalizable conclusions about
cognitive processes with the condition have been drawn – have only used neutral or general threat stimuli. This issue is likely to have contributed to inconsistency in research findings (Abramovitch et al., 2013; Muller & Roberts, 2005).

1.7.1.4. Comorbid conditions
As stated in Section 1.2.4., comorbid conditions are extremely common with OCD. However, it is vital that evidence reported about OCD and its relationship with cognitive processes reflects the actualities of the condition itself, and not those of comorbidities (Abramovitch et al., 2015; Muller & Roberts, 2005). This is particularly important in relation to depression (Muller & Roberts, 2005). For example, it is possible that memory biases for threat information reported with OCD might be more attributable to depression than OCD itself (see Moritz et al., 2001). The lack of recognition of the presence of comorbidities with OCD in previous research may have contributed to inconsistent patterns of findings (Abramovitch et al., 2015; Muller & Roberts, 2005).

1.7.1.5. Medication-use
Some medication may alter cognitive functioning. For example, performance in tests may be affected by the use of clomipramine (Abramovitch et al., 2015). Recruiting participants for experiments who are clinically-diagnosed with OCD, but who are not taking any medication, can be problematic. An alternative option for researchers is to carry out experiments with non-clinical OC populations, specifically recruiting volunteers who are not undergoing therapeutic intervention (Gibbs, 1996). The use of non-clinical populations in this way may help to give clearer insight into the mechanics of OCD.

1.7.1.6. Presence of hoarders
Hoarding is no longer considered a symptom of OCD (see Section 1.2.3.2). Of the studies reviewed by Abramovitch et al. (2013), 73% did not take account of hoarding symptoms among their participants. In addition, 39% of the studies that assessed hoarding among participants did not control for the symptom in their results. In mitigation of these figures, detailed understandings of hoarding as a separate condition have only come to the fore relatively recently. However, it is possible that the inclusion in hoarders in a substantial body of studies examining OCD prior to this development may have confounded findings (Abramovitch et al., 2013).

1.7.2. Summary of Section 1.7
Cognitive deficits with OCD have been regularly reported by researchers. However, methodological issues may have contributed to the lack of robustness in findings, and made it difficult to assess the
clinical relevance of these deficits. These include the use of low-sensitivity paradigms and heterogeneous OCD populations in previous research. Irregular use of symptom-salient stimuli in previous studies and inconsistent acknowledgement of comorbid conditions and medication-use among participants may have also complicated the picture of findings.

1.8. The focus of this thesis: selective attention and long-term memory in non-clinical OC populations

In the next sections, we begin to assess the particular areas of focus of this thesis – selective attention and long-term memory. We start with an overview of why these two areas are of particular interest (Section 1.8.2). There then follows by a short overview of theories of selective attention, along with an examination of theories of attentional bias with OCD, before an assessment of previous selective attention research examining OCD (Section 1.9). In this section, we discuss the gap in the literature regarding the absence of reported findings from visual search paradigms relating to selective attention with OCD. We then detail the advantages of visual search (Section 1.10) and, in particular, the priming of pop-out (PoP) paradigm (Section 1.11), for examining selective attention and OCD.

Following this, we move on to a section on long-term memory (Section 1.12). Here, theoretical conceptions of long-term memory are assessed. This is followed (Section 1.13) by an assessment of previous studies which have examined OCD and long-term memory, and a discussion of a gap in the literature relating to verbal long-term memory. We then detail the continuous identification with recognition (CID-R) paradigm, and discuss why we chose to use this paradigm in the verbal long-term memory study in this thesis.

Then, in the final section of Chapter 1 (Section 1.14), summaries of the four studies which comprise this thesis are provided.

1.8.1. Why examine selective attention and long-term memory?

OCD is characterised by recurrent thoughts and distressing preoccupations which restrict a person’s ability to focus on everyday functioning (Veale & Willson, 2005). As such, there is a logic to the suggestion of a possible relationship between the condition and aspects of attention and memory (Muller & Roberts, 2005; Amir, Cobb, & Morrison, 2008). Indeed, attentional and memory biases to
threat may trigger and feed each other, thus contributing to the maintenance and development of the condition (see Section 1.5).

As previously stated (Section 1.4), the maintenance of balanced activity in the OFC and DLPFC loops, and associated brain areas, is believed to be crucial for many cognitive, emotional and motor processes, including the successful operation of higher-level, executive functions, such as decision making and planning (Cavedini et al., 2006). However, in order for successful executive functioning to take place, certain basic lower-level operations – such as attention and memory – must be unimpaired (Cavedini et al., 2006). Consequently, it is suggested that detailed examination of individual aspects of these lower-level cognitive operations – such as selective attention, priming and long-term episodic memory – might be an important way to gain insights into the more overt manifestations of OC behaviour (Kuelz et al., 2004).

However, findings from previous studies have been mixed, and a clearer picture of the nature of OC cognition is required (see Section 1.7.1. and Section 1.9). This thesis looked to find new and more methodologically robust evidence that altered performance by OC individuals in both selective attention and memory tasks is linked by specific biasing towards emotional, symptom-salient stimuli.

1.9. Selective attention

1.9.1. What is selective attention?

William James (1890) provides a much-quoted, early definition of attention: “It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought…It implies withdrawal from some things in order to deal effectively with others” (p.403-404). James suggests that, although we are bombarded with huge amounts of sensory information at any given time, we have the capability to focus on – or select - only a small amount of this detail. As Driver (2001) puts it: “Selective attention is the generic term for those mechanisms which lead our experience to be dominated by one thing rather than another” (p.1).

In order for us the effectively function in our environments, it is theorised that the huge volume of incoming sensory information which could possibly receive attention must be subject to some kind of filtering process (for a review of research in this area, see Driver, 2001). For example, Posner (1980) suggested selective attention could be understood as a directable spotlight, lighting up and prioritising certain incoming information for processing. Information outside of the area highlighted by the
spotlight, by contrast, receives considerably reduced attention. Eriksen and Murphy (1987) conceived of selective attention as a zoom lens, arguing that that people can focus in tightly, or widen out more broadly, on particular sensory input. However, we may not always have total control over the selection of information for processing. A high volume of perceptual information – the perceptual load – in given circumstances may result in attention being tunnelled narrowly onto very specific areas, with all other areas being effectively ignored (Engel, 1971; Lavie 1995). At the same time, attention may be drawn involuntarily by an aspect of the environment, such as unexpected motion (Posner, 1980).

1.9.2. Theorised selective attention dysfunction with OCD

Given that OCD is commonly characterised by repetitive and ritualistic thoughts and behaviours, and that around 81% of people diagnosed with the condition display checking concerns (Harkin & Kessler, 2009), it has been theorised that a form of attentional dysfunction may be functionally implicated in the workings of the condition (Koch & Exner, 2015). In some laboratory tests, people diagnosed with OCD have been shown to display exaggerated distractibility when presented with irrelevant stimuli (e.g., Kaplan et al., 2006). It is suggested that this may indicate the presence of a selective attention deficit, possibly reflecting reduced goal-orientated top-down control (this is further discussed in Section 1.8.3 and Section 1.9.5.1). This impairment may serve to underpin the excessive ruminations and preoccupations which characterise this condition (Clayton et al., 1999; Enright & Beech 1990, 1993a, 1993b; Kuelz et al., 2004; Kaplan et al., 2006; Muller & Roberts, 2005; Swerdlow et al., 1999). Additionally, and as already stated in Section 1.3, a good deal of evidence suggests attentional bias towards threat stimuli - and, particularly, symptom-salient – plays a key role in development, behavioural manifestations and maintenance of OCD (Bar-Haim et al., 2007; Salkovskis & McGuire, 2003).

1.9.3. Previous research examining OCD and selective attention

In a review of attention and memory research in OCD, Muller & Roberts (2004) noted that only a small number of studies had been dedicated to examining possible altered selective attention processes with the condition. Examination of psychological literature output since then, and up to the present moment, suggests this picture has not changed much since (see Bradley, 2016). The majority of studies in this field have used either Stroop-like or dot-probe paradigms, though other research has been carried out using inhibition of return and negative priming designs. Additionally, while not strictly a test of selective attention, some studies have used the latent inhibition paradigm to assess inhibition and distraction in OCD.
1.9.3.1. Stroop-like studies

The classic Stroop (1935) paradigm requires participants to report the ink colour of individually-presented word stimuli. The word stimuli are the names of colours. The expected findings are that responses are quicker in congruent trials (when the colour and name of a stimulus correspond) than in incongruent variants (when the colour and name of a stimulus are different, thereby causing processing interference). In theoretical terms, the ink colour is said to represent the target, or the relevant stimulus. Meanwhile, the colour name is said to represent a distractor, or the irrelevant stimulus (Scerrati, Lugli, Nicoletti & Umilta, 2017).

Emotional Stroop paradigms have been a go-to choice for researchers examining OCD and attention. In typical experiments, participants must, as usual, report word stimulus colour, while ignoring the name of the word. However, in such studies, the word stimuli names comprise emotional semantic content, rather than the names of colours. Delayed response times in such trial presentations are attributed to the difficulty of avoiding processing the emotional word content due to bias (see Muller & Roberts, 2005). Lavy, van Oppen, and van den Hout (1994) reported interference effects with OCD using an emotional Stroop paradigm. Participants with OCD produced slower response times to trials involving threat words with OCD-related content in comparison to those of a control group. No such biasing was apparent for positive words or to generalised negative word stimuli. This suggests the presence of a particular bias towards OC content was evident among the OC participants. Likewise, McNally and colleagues (1994) found no interference effects with general negative and panic-related semantic content among patients. Foa, Ilai, McCarthy, Shoa, and Murdoch (1993) compared the performance of participants with specific washing compulsions, OCD participants who did not exhibit washing concerns and non-OCD controls on an emotional Stroop-like task. Stimuli comprised words relating to contamination, plus general threat words, neutral words and non-words. The authors reported that interference effects caused by contamination words were significantly stronger in the washing group than both general OCD and non-OCD participants. General OCD participants were slower at responding to general threat stimuli than washers and non-OCD participants. Again, this further suggests the possible existence of particular attentional biasing with OCD, and that this may be even more apparent within subtypes of the condition.

However, such findings have been not been consistently replicated. Thus, although McNally et al. (1994) found no interference from general threat words with OCD, a previous study by McNally, Riemann, Luro, Lukach, and Kim (1992) did find bias towards such generalised word types among their OCD patients. Kampman, Keijers, Verbraak, Naring, and Hoogduin (2002) found no differences between OCD, panic disorder and control participants in a study using OCD, panic-related and general threat stimuli. Similarly, Kyrios and Iob (1998), Moritz et al. (2004) and Moritz et al. (2008) also found no evidence of increased interference among OCD patients in comparison with
controls. Indeed, Moritz and colleagues (2008) reported that the presence of washing-related stimuli in trials actually improved performance of the emotional Stroop-like task among OCD patients.

1.9.3.2. Dot-probe studies

In a typical dot-probe task (MacLeod, Mathews & Tata, 1986), participants are shown a pair of stimuli on-screen, followed by a probe (e.g., a dot or a cross) in the position of one of the stimuli. The task of the participant is to report the location of the probe as quickly as possible. It is suggested that probe-reporting reaction times will be quicker if the probe appears in a location where the participant had been previously attending (Muller & Roberts, 2005; Bradley et al., 2016). A number of studies (e.g., MacLeod, Mathews, and Tata, 1986; Mogg, Mathews & Eysenck, 1992) have found that reaction times recorded by people with anxiety are faster than controls when the position of the probe corresponds to that of a threat-related word – suggesting an attentional bias towards threat material.

Only three studies appear to have been carried out with OC populations using dot probe paradigms. Tata, Lebowitz, Prunty, Cameron, and Pickering (1996) used a dot probe task to compare the performance of OCD and anxious participants. The OCD participants had specifically reported symptoms relating to contamination. Stimuli used in the study comprised contamination and threat words. The authors found that OCD participants demonstrated attentional bias towards the contamination words, but not the threat stimuli. Conversely, high anxiety participants displayed bias towards threat words, but not to contamination words. Likewise, Amir, Najmi, and Morisson (2009) reported attentional bias towards symptom-salient in a high-OC student sample, when compared with the performance of a low-OC student group. Notably, however, the impact of the symptom-salient appeared to diminish over the course of the experiment, with greater differences between the groups apparent in the early trials when compared to later presentations.

By contrast, however, Harkness, Harris, Jones, and Vacarro (2009) reported no attentional bias in an OCD group towards checking-related, contamination or threatening stimuli when their performance was compared with controls. From their results, the authors drew the conclusion that attentional bias may not be a component part of checking. However, it is also notable that depression was significantly higher in the OCD group than in the control group – a common confounding variable in many OCD studies (see Sections 1.2.5). Likewise, Schneier et al. (2016) reported no evidence of attentional bias in their dot probe study. However, the study used a homogenous OCD sample and emotional face stimuli, which may not have sensitive enough to trigger OC concerns.

1.9.3.3. Inhibition of Return studies

Studies of attention in healthy populations have shown that cueing an on-screen location can boost the later detection of a target at that location. However, this is usually occurs only if the gap between the
presentation of the cue and the target is under 300ms. Target detection is faster at an uncued location if the cue-target interval is between 300ms and 2,000ms (Klein, 2000). This effect is known as inhibition of return (IOR; Posner & Cohen, 1984). The effect is thought to have a functional purpose in boosting the performance of visual search by directing attentional faculties to novel aspects of the environment (Klein, 2000). It has been hypothesised (e.g., Rankins, Bradshaw, Moss & Georgiou-Karistianis, 2004) that repetitive and ritualistic behaviours, such as those demonstrated in OCD, could be reflective of reduced IOR.

OCD populations have been examined in two studies using the IOR paradigm with non-emotional stimuli (on-screen box shapes). Nelson, Early, and Haller (1993) found that participants with OCD demonstrated faster target detection at cued (rather than uncued) locations in trials with long cue-target intervals. Moreover, patients displayed reduced IOR for leftside-presented stimuli. Meanwhile, Rankins and colleagues (2004) found also reduced IOR in their OCD group in comparison with controls. Like the findings of Nelson and colleagues (1993), this reduction was lateralised – it was only apparent when participants viewed left-side-presented stimuli. However, these findings need to be treated with caution considering both the lack of research in this area and the lack of symptom-salient in both studies.

Mindful of the importance in OCD research of using stimuli which are explicitly salient to obsessive-compulsive concerns, Moritz and colleagues carried out two studies using modified emotional IOR paradigms (Amir, Elias, Klumpp & Przeworski, 2003). The authors wanted to further examine whether selective attention in OCD was characterised by vigilance (which they thought would be reflected by faster reaction times in congruent trials with short cue-target intervals) or disengagement difficulty (which would be reflected in slower reaction times in incongruent trials with longer cue-target intervals). Moritz and von Mühlener (2008) used checking-related, paranoia-related and neutral verbal words as cues. They found no group differences in attentional bias between OCD participants and controls. However, while the authors recorded depression levels among the OCD participants in the study, they did not report the equivalent scores for the control group – so it is possible that depression could have acted as a confound. Varying levels of medication were also being taken by the OCD group. Importantly, the authors themselves suggested that verbal word stimuli may not have had enough attentional pull for the OCD participants, and that different results might have been found with pictorial stimuli. Longer cue-target intervals were also possibly needed than those used in the study (either 400ms or 1,000ms) in order for adequate processing of emotional stimuli to take place. Moritz, von Mühlener, Randjbar, Fricke, and Jelinek (2009) attempted to address the latter two of these limitations with an emotional IOR study featuring checking, washing, anxiety-related and neutral pictorial stimuli as cues (for example, a picture of a dirty toilet as a washing stimulus). The OCD group comprised 42 participants (23 washers, 15 checkers, four orderers and three hoarders),
while there were 31 controls. Cue-target intervals were either 450ms or 1,200ms. No group differences were found for the IOR effect – both groups recorded faster reaction times in spatially incongruent trials with long cue-target intervals. However, independent of interval type or cueing type, all OCD participants recorded slower reaction times to all OCD stimuli. The authors concluded that these participants were generally more likely to have their attention distracted by this class of pictures than by others less salient to their individual concerns. Again, though, it should be noted that 18 participants in the OCD group had depression, while 16 were taking some form of medication. These would need to be considered as potential confounds (along with the presence of the hoarder participants).

1.9.3.4. Negative priming studies

In negative priming studies, performance decline commonly occurs when a distracting stimulus which has already been presented becomes a current-trial target – this is known as the negative priming effect. It is argued that inhibition of the stimulus in its role as a distractor remains active in the current trial, and must be overcome before a task-appropriate response can be given. Thus, slower reaction times are recorded than would be the case if there had been no presentation of the stimulus as a distractor in the previous trial (Tipper, 1985).

As already stated, people with OCD commonly report difficulties with controlling their thinking (see Section 1.2.1). Some researchers have thus suggested that negative priming paradigms might be a useful way of gaining insight into the cognitive processes underpinning such manifestations of the condition. In three early studies, Enright and Beech (1990, 1993a, 1993b) found that participants with OCD demonstrated reduced negative priming when compared with the performance of a group of patients with anxiety disorders. The studies used colour words (e.g., red or blue) and individual letters as stimuli. In a further follow-up study, Enright, Beech and Claridge (1995) reported that reduced negative priming with OCD occurred with short prime stimulus presentations (less than 100ms). Again these comparisons were made in comparison with the performance of a group comprising participants with anxiety disorders. Additionally, however, the authors also found that OCD participants with checking concerns demonstrated reduced negative priming with both short and longer (250ms and 350ms) prime stimulus presentations. They suggested that their findings indicated a deficit in attentional inhibition with OCD, with participants displaying exaggerated focus on irrelevant distractor information. It is notable that, although Enright, Beech and Claridge (1995) controlled-for medication use, while potential participants with comorbid neuropsychological conditions were excluded from taking part. In support of the findings of Enright and colleagues, McNally, Wilhelm, Buhlmann, and Shin (2001) compared the negative priming performance of participants with OCD with that of healthy controls. Short prime stimulus presentations (100ms) produced a reduction in negative priming in the OCD group compared to that of controls. However,
this difference was eliminated with long prime stimulus presentations (500ms). By contrast, however, McDonald, Antony, MacLeod, and Swinson (1999 – colour selection task) reported larger negative priming effects in their OCD group in comparison to that of controls.

Amir, Cobb, and Morrison (2008) used a modified negative priming paradigm with symptom-salient verbal stimuli to assess both inhibition and learning effects with OCD. The authors observed that negative priming effects were commonly eliminated (with positive priming often occurring in its place) when probe displays did not include distractor information (e.g., Frings & Wentura, 2006). The suggestion was that participants learn the relationship between the prime and the probe, facilitating faster reaction times. The authors found that, with the absence of distractors in probe displays, control participants demonstrated facilitated positive priming for all three word categories (OCD-threat words, OCD-positive words and neutral words) used in the study. By contrast, the OCD group only showed facilitating effects with neutral words. OCD participants were not primed by OCD-positive, and, furthermore, demonstrated negative priming when presented with OCD-negative exemplars. The authors suggest that the presence of threatening, salient stimuli disrupts the ability of people with OCD to learn the relationship between a prime and a probe. The use symptom-salient in this study helps adds a depth of meaning to these findings. However, the authors did not control for co-morbid conditions, nor did they examine possible differentiated performance among subtypes.

1.9.3.5. Latent inhibition studies
Latent inhibition is the mechanism by which the learning of conditional associations involving a particular stimulus are inhibited following the prior presentation of that stimulus as neutral or irrelevant item or distractor (Kaplan et al., 2006). The effect is most commonly associated with classical conditioning. However, because it involves the assessment of the role of irrelevant distractor information on inhibitory processes, some researchers have considered it useful in the study of possible impaired selective attention in certain disorders, such as schizophrenia (e.g., Rascle et al., 2001). Two studies using the LI paradigm both found that OCD participants, in comparison to controls, took longer to learn a target-unconditional stimulus relationship when the target was previously been presented as an irrelevant distractor (Swerdlow, Hartston, & Hartman, 1999; Kaplan et al., 2006). The authors of both studies state that their findings are in line with other research which has suggested exaggerated cognitive inflexibility with OCD. It could be additionally argued that they might also be in line with the hypothesis that people with OCD have difficulty disengaging their attention from previously presented stimuli. However, it should be noted that neither study used symptom-salient, while medication use was commonly reported by participants in the OCD groups in both studies.
1.9.4. Assessment of previous research examining OCD and selective attention

1.9.4.1. Summary of findings

The methodological concerns detailed in Section 1.6, which relate to cognitive research into OCD as whole, can be seen to equally apply to many of the studies detailed in the preceding section which have aimed to specifically examine selective attention with the condition. Keeping this mind, however, the majority of findings suggest the presence of attentional bias in people with OCD. This appears to be particularly the case when experimental designs used symptom-salient and specific OC subtype participant groups. Thus, emotional Stroop effects appear broadly to have been enhanced in OC populations, while two out of three dot probe studies demonstrated an symptom-salient attentional bias in OC participants. At the same time, studies have provided some evidence of reduced IOR in OCD, with possible left-side lateralisation – and while the results of IOR tasks with symptom-salient were more inconclusive, this is possibly partly attributable to methodological issues. Furthermore, some studies have suggested that people with OCD can demonstrate reduced negative priming effects, particularly with short stimulus presentations, which is indicative of possible difficulties in inhibiting distractor information. Finally, although not strictly a selective attention paradigm, latent inhibition studies have hinted at attentional bias and stimuli disengagement problems with OCD.

1.9.4.2. Limitations of findings

However, it remains the case that limited research been reported in this area (Muller & Roberts, 2005). That which has been carried out has been overly reliant on variants of the Stroop paradigm. Furthermore, the validity of the Stroop as a test of selective attention has been questioned by some researchers (Amir et al., 2009). For example, Fox (1993) argues that, in laboratory assessments of selective attention, targets and distractors must be in different spatial locations and outside of the direct visual gaze. Williams, Matthews, and MacLeod (1996), meanwhile, state that the Stroop effect is more reflective of cognitive avoidance than attentional bias. Similar criticisms could be levelled at negative priming research into OCD, which has largely used Stroop-like colour-naming requirements in its task designs. The modified, emotional version of this task carried out by Amir and colleagues (2008) was a valid attempt to deploy symptom-salient in the assessment of OCD. But, as detailed above, the results are perhaps more likely to have reflective altered learning capabilities with OCD, rather than altered selective attention. More broadly, there remains considerably disagreement among negative priming researchers about what processes are actually being assessed with the paradigm (Amir et al., 2008). Lamy et al. (2008), for example, argue that the results of negative priming studies are more reflective of response selection processes rather than selective attention processes (see Section 1.10.5). The evidence from the two latent inhibition studies (Swerdlow, Hartston, & Hartman, 1999; Kaplan et al., 2006), again, could be argued to be more reflective of altered learning rather than
selective attention faculties. Plus, as already noted, neither used symptom-salient stimuli. Dot-probe and inhibition of return studies, perhaps then, have provide clearer ways to tap into selective attention processes in OCD. It has been argued that evidence gained from dot probe studies about the operation of selective attention may be confounded by the ability of the eye to move and repeatedly re-fixate between presentation of prime and probe aspects of trials (Mogg, Millar & Bradley, 2000). But the bottom line is that not enough research has been carried out using these two paradigms to draw firm conclusions about selective attention processes in OCD.

1.9.5. A gap in the literature – the alternative approach adopted in this thesis

Although research findings point to selective attentional deficits with OCD, methodological concerns remain with many studies. It is notable that, little, if any, research appears to have investigated selective attention deficits in people with OCD using visual search paradigms. This is an interesting omission given the utility of such paradigms for assessing selective attention. This thesis aims to address this gap in the literature.

Visual search paradigms and theories will be discussed in Section 1.9, before we introduce the priming of pop-out (PoP) paradigm as a particular visual search task which is used in this thesis.

1.9.6. Summary of Section 1.9

People use selective attention in order to focus on one item rather than another. It has been theorised that a form of selective attention dysfunction may be functionally implicated in the workings of the condition. Attentional bias towards negative, symptom-salient has been demonstrated in people with OCD. Although previous research suggests evidence in favour of a deficit in selective attention in OC populations, only limited research has actually been carried out. Inconsistencies in findings may reflect methodological issues in experimental designs. The lack of use of visual search paradigms represents a gap in the literature, which this thesis looks to address.

1.10. Selective attention and visual search

1.10.1. What is visual search?

An essential part of living is searching for things – a person in a crowd, a location on a map, a book on a shelf. In typical visual search scenarios, people can be understood as looking for targets (e.g., a
particular person) among non-targets (e.g., a crowd in which the person might be) in order to establish if they are present or if they are not-present (Driver 2001; Moran, Zehetleitner, Liesefield, Müller & Usher, 2016; Wolfe, 1998). Numerous laboratory versions of these commonplace challenges have been developed in order to better understand the underlying mechanics of selective attention. A typical experiment might involve the on-screen presentation of stimuli in search arrays, with the task of the participant being to locate a target (e.g., a letter ‘T’) among a number of distractors (e.g., a series of letter ‘L’s). Interestingly, few, if any visual search studies have been carried out with OC populations.

Multiple visual search task experiments have produced evidence for the existence of both parallel and serial processing mechanisms in visual selective attention (Driver 2001; Moran et al., 2016; Wolfe, 1998). Thus, in a task involving the search for a red target among green distractors, the inclusion of additional green distractors which are identical to those already present does not have a deleterious effect on the time taken to find the target (the reaction time). Such a finding has been taken to indicate the operation of parallel faculties – all the stimuli are processed at the same time, with the target ‘popping out’ once this processing has reached a required level (Driver 2001; Wolfe, 1998). By contrast, though, a participant searching for a target ‘S’ in an array featuring ‘Ƨ’ distractors, for example, will have their performance impeded with the addition of extra ‘Ƨ’ distractors (Driver 2001; Wolfe, 1998). In such cases, it is suggested that serial search is required to process each stimuli item in order to confirm the presence and location of the target (Driver 2001; Wolfe, 1998).

1.10.2. Feature Integration Theory

An important theoretical explanation for the serial/parallel dichotomy in visual search is Feature Integration Theory (FIT; Treisman & Gelade, 1980). According to the authors, features of stimuli are initially processed in parallel on the basis of simple features (e.g., colour or shape). At this stage there is no need for serial analysis of each piece of information. However, serial processing is then required in a second stage to search different locations for specific targets, which can be identified via the binding of particular features (Treisman & Gelade, 1980). Thus, in an experiment which requires a participant to search for a green square target among red rectangles, the shape and colour of the target must both be subject to binding. FIT has been highly influential in the field of selective attention (Driver, 2001). However, it has not has not gone unchallenged. Wolfe (1998), for example, argues that asserting that clear distinctions exist between serial and parallel processes is a ‘potentially dangerous fiction’. Instead, it would be better to conceive of efficient and inefficient processing (Wolfe, 1998). Duncan and Humphreys (1989) suggest that FIT overstates the significance of target vs. non-target search, and understates additional relationships between stimuli in a visual scene. Indeed, although much progress has been made in understanding the mechanisms underpinning visual
search, what research continues to expose is the complexity of such information processing (Driver, 2001).

1.10.3. Development of theories of visual search

1.10.3.1. Pre-attentive operations: top-down and bottom-up processing

A number of researchers have looked to further develop understandings of visual search beyond serial/parallel debates. For example, Wolfe (1998) argues that pre-attentive processing acts to organise visual scenes into items. Simple, pre-attentive features of items (e.g. colour or shape) then serve to inform perceptual conceptions of these items. Researchers (e.g., Bravo & Nakajama, 1992; Corbetta & Shulman, 2002; Wolfe, 1998) have described two types of pre-attentive processing in visual search: (i) top-down processing and (ii) bottom-up processing. Both direct attention.

(i). Top-down processing: This describes the transference of information relating to sensory input from ‘higher’ to ‘lower’ cognitive areas (Corbetta & Shulman, 2002). Top-down processing operates via the use of a person’s knowledge and experience. Research has shown that individuals are quicker at visual search tasks if they have previously been given information relating to the targets (e.g., Bravo & Nakajama, 1992; Maljkovic & Nakayama, 1994; Eimer, Kiss, & Cheung, 2010). This enhanced performance with top-down processing is dependent the formation of ‘perceptual sets’ detailing the previously-presented information. These then function to speed up the processing of sensory input (Corbetta & Shulman, 2002).

(ii). Bottom-up processing: This describes the transference of information relating to sensory input from ‘lower’ to ‘higher’ cognitive areas (Corbetta & Shulman, 2002). Bottom-up processing operates from sensory input, conveying information based solely on this input to perceptual and motor areas. Importantly, this occurs in the absence of knowledge-based input from ‘higher’ areas (Corbetta & Shulman, 2002). In visual search studies, participants have been shown to be slower at locating targets when tasks are weighted towards bottom-up processing (e.g., when they have no prior information about target features) in comparison to those in which top-down processing is possible (e.g., when prior information is provided about target features) (Bravo & Nakajama, 1992; Maljkovic & Nakayama, 1994; Eimer et al., 2010).

There is evidence that the two systems of processing having differing neural correlates – top-down faculties being located in the intraparietal cortex and superior frontal cortex, and bottom-up operations being located in the temporoparietal cortex and inferior frontal cortex (Corbetta & Shulman, 2002). Research suggests that, in healthy populations, the processing of sensory input occurs via a balance of both top-down and bottom-up operations (for a review, see Corbetta & Shulman, 2002). However,
given that some theories of attentional bias (see Section 1.8.3) suggest that impaired top-down control could be a feature of OCD, it is possible that this balance could be altered in OC populations. Corbetta and Shulman (2002) state the selection of sensory stimuli for attention might occur through the use of ‘salience maps’ which comprising the content of bottom-up and top-down information for stimuli. In a person with OCD, enhanced bottom-up processing may occur when they are confronted with threat-associated stimuli, with a consequent reduction in top-down control. The result could be attentional bias to threat. It is possible this might be demonstrated through impaired performance on tasks which place demands on attentional bottom-up resources and which use threat stimuli (De Putter & Koster, 2017).

1.10.3.2. Perceptual load theory
According to perceptual load theory (Lavie, 1995; Lavie & Tsal, 1994), the successful operation of selective attention and visual search processes is directly connected to the demands on placed on processing resources in a task (Murphy, Groeger, & Greene, 2016). The theory states that target selection performance is influenced by both cognitive load (e.g., demands on working memory) and perceptual load (e.g., demands placed on attentional processes by sensory input). Individuals have a limited capacity with which to process perceptual information. Thus, in visual search tasks with high perceptual loads (e.g., increased complexity of bottom-up information) it is likely that participants demonstrate comparably inefficient search performance (Murphy et al., 2016). This is interesting for the study of selective attention processes with OCD because people with the condition potentially have reduced top-down control. This could result in poor task performance by OC populations with increased perceptual load.

1.10.4. Summary of Section 1.10

Visual search is the cognitive process of selecting targets among non-targets. Visual search paradigms have enabled better understandings of the mechanics of selective attention in healthy populations, but they do not seem to have been used in the study of OCD. This is interesting, because an altered balance between top-down and bottom-up processing and a dysfunctional focus on distracting and, in particular, threatening stimuli have been theorised as forming part of the mechanics of OCD. This further suggests the viability of visual search as a tool for examining selective attention with the condition.
1.11. The priming of pop-out (PoP) visual search paradigm

The PoP paradigm is an established visual search measure of selective attention (Eimer et al., 2010). The paradigm forms the basis of the selective attention studies which are reported in this thesis. A classic trial sequence in a PoP paradigm can be seen in Figure 1.4.

![Figure 1.4](image)

**Figure 1.4.** A variant of Maljkovic and Nakayama’s (1994) basic PoP paradigm, which established the PoP effect. The figure shows trial sequences in which target colour is repeated and in which it is swapped. The task of the participant is to report whether the odd-colour target was cut on either its top or its bottom.

In a key piece of research, Maljkovic and Nakayama (1994) examined the reaction time performance of healthy participants visually searching for odd-one-out singleton targets in arrays which also featured two homogenous distractors. They found that search performance was aided if the discriminable feature of the target (its colour) had also been the feature of the target in the immediately preceding trial. This inter-trial priming effect is called priming of pop-out (PoP). Thus, when the target colour presented was randomised on a trial by trial basis, participants recorded faster reaction times when the colour was repeated over successive trials than when it was swapped (e.g., if
trial \( N-1 = \) red target and trial \( N = \) red target, reaction times were facilitated; if \( N-1 = \) red target and \( N = \) green target, reaction times were not facilitated). A number of studies with healthy populations which followed (e.g., Eimer et al., 2010; Lamy, Antebi, Aviani & Carmel, 2008; Maljkovic & Nakayama, 1996; Wolfe, Butcher, Lee & Hyle, 2003; Yasher, Makovski & Lamy, 2013) confirmed the original findings of Maljkovic and Nakayama (1994). These studies have established that implicit memory activity plays an important role in priming behaviour over successive visual search trial sequences. The PoP paradigm has been used in the studies in this thesis because it has a number of advantages for the study of selective attention – but, interestingly, it has not been used previously with an OC population. These advantages will be detailed in the following sub-sections.

1.11.1. Disassociation of selective attention and response selection processes

One of the difficulties with drawing conclusions about selective attention processes in OCD from the findings of studies using some reaction time behavioural paradigms (like those detailed in Section 1.8) is that it may not be clear what such findings actually represent in terms of cognition. That is, it is questionable whether it can be definitively concluded that slowed responses among patients with OCD (as recorded in some negative priming and IOR studies, for example) can be attributed to deficits in selective attention, or whether they reflect slower response selection – which could be possibly indicative of altered motor function. A key advantage of the PoP paradigm is that, in a typical experiment, the attention-defining, discriminable feature of the target is disambiguated from its response-selection feature (Lamy et al, 2008; Maljkovic & Nakayama, 1994). Thus, in Maljkovic and Nakayama’s (1994) study, the attention-defining of the target was its colour (red or green). However, participants responded to variations in the shape of the target. All stimuli (targets and distractors) were diamond shapes which were cut on either their left or right side. The task of the participant was to spot the odd-colour target, but then report (using a button box press) whether it was cut at the left or right.

1.11.2. Separation of target activation and distractor inhibition processes

It has been proposed (see Lamy et al., 2008; Eimer et al., 2010) that PoP effects are underpinned by two separate selective attention mechanisms – target activation and distractor inhibition. Thus, when visual search is aided by the repetition of a previous target feature, performance may be enhanced because the activation of target features triggered by the previous trial carries over to current trial, resulting in facilitation. This is known as target activation (Lamy et al., 2008). However, task performance may also be aided by the repetition of a distractor feature from a previous trial. In this scenario, inhibition of distractor features triggered in the previous trial remains in place in the current
trial, making it an easier to job to reject them as possible targets. This is distractor inhibition (Lamy et al., 2008).

Figure 1.5. The six-level inter-trial PoP task, as used by Eimer et al. (2010). This task, with this acronym naming-system for inter-trial types, is used in Study 2 (see Chapter 2). FR = full repetition; PRnewD = partial repetition with new distractors; PRnewT = partial repetition with new target; PSnewD = partial swap with new distractors; PSnewT = partial swap with new target; FS = full swap.

An assessment of the relative contributions of these two mechanisms to PoP was examined in detail by Eimer et al. (2010). In the study, the authors expanded Maljkovic and Nakayama’s (1994) original paradigm into a six-level inter-trial task, involving three stimuli colours. They recorded reaction times and assessed activity of the electrophysiological N2pc event-related potential (ERP) component. As can be seen in Figure 1.5, this resulted in the creation of a full repetition and two partial repetition inter-trial types, along with a full swap and two partial swap inter-trial sequences. The contention of Eimer and colleagues was that the influence of target activation processes would be reflected by performance in two of the partial sequences (PRnewD; PSnewT), while the influence of distractor inhibition would be evidenced by performance in the two other partial sequences (PRnewT, PSnewD) – see Figure 1.6.
Figure 1.6. Examples of (A) target activation sequences and (B) distractor inhibition sequences within the six-level inter-trial PoP task, as used by Eimer et al. (2010). These sequences are used Study 2 in this thesis (see Chapter 2). PRnewD = partial repetition with new distractors; PSnewT = partial swap with new target; PRnewT = partial repetition with new target; PSnewD = partial swap with new distractors.

Eimer and colleagues found no differences in either reaction time performance or N2pc latency onset when the two partial repetition inter-trial types were compared, and when the two partial swap inter-trial types were compared. The PoP effect, they stated, was underpinned by a combination of both target activation and distractor inhibition mechanisms. The electrophysiological and behavioural findings of Eimer et al. (2010) supported similar results from earlier studies which reported that target
activation and distractor inhibition were equally functional components in the operation of PoP (e.g., Bichot & Schall, 2002; Lamy et al., 2008).

Studies such as these have yet to be carried out with OC populations. However, difficulties with disengagement from, and vigilance towards, distracting stimuli have been consistently theorised as forming part of the mechanics of OC behaviour. As such, the utility of the PoP paradigm as a method of assessing the operation of target activation and distractor inhibition processes is likely to make it a highly useful tool with which to assess the possible alteration of such functions, and further examine attentional bias, in OC populations.

1.11.3. Potential for use with emotional stimuli

PoP effects have been examined largely with simple feature stimuli, varying in aspects of colour, size and orientation. Questions remain over how, or to what extent, inter-trial priming effects can be said to operate in more complex, ecologically-valid circumstances – and what implications this might have for understandings of aspects of real-world behaviour. As has previously stated, the use of symptom-salient in studies examining OCD has been highly recommended by reviewers of previous research (e.g., Abramovitch et al., 2013; Muller & Roberts, 2005). Along with its other advantages, the PoP paradigm has been shown to be adaptable for use with more ecologically-valid emotional stimuli (Kristjánsson, Óladóttir & Most, 2013; Lamy, Amunts & Bar-Haim, 2008).

Lamy et al. (2008) attempted to examine the functioning of PoP using target and distractor feature stimuli comprising emotional faces. Research has found that participants are quicker to attend to emotional face stimuli than neutral face stimuli (e.g., Eastwood, Smilek & Merikle, 2001). Evidence also suggests that threatening emotional faces (e.g., with angry or fearful expressions) may act to improve attentional performance (e.g., Hansen & Hansen, 1988). Lamy et al. (2008) looked to examine if inter-trial sequences of face stimuli featuring targets with the same emotion would result in improved PoP facilitation. Their findings were that reaction time performance was facilitated by the repetition of emotional face targets (both happy and sad face stimuli) but not for neutral face targets. Notably, such performance benefits were absent when the experimental task was repeated with face stimuli presented upside-down. The authors concluded that the types of emotion, rather than the visual content of the stimuli, the key contributing factor to the enhanced PoP performance that was observed. However, it should be noted that the emotions of faces may be more automatically processed than other stimuli, which might result in enhanced priming effects between trials (Hansen & Hansen, 1998).
Another study, by Kristjánsson et al. (2013), examined the possible impact of neutral and negative emotional pictures (e.g., images of violence and distress) on performance in a standard PoP task. In this study, participants were shown a neutral or a negative emotional picture on screen prior to each search array. The authors reported that the PoP effect was recorded (speeded reaction times with target feature repetition), despite the presence of the additional, emotional stimuli between trials. However, negative emotional stimuli did act to slow reaction times in immediately subsequent search arrays in comparison with neutral pictures.

1.11.4. Further evidence for PoP as a measure of selective attention

Maljkovic & Nakayama (1994) argue that, by disambiguating attention-driving and response-selection aspects of targets, performance in a PoP task is reflective of the active operation of early selective attentional processes and not late response-based processes. This conclusion has been supported in other research (e.g., Becker, 2008; Eimer et al., 2010; Yasher & Lamy, 2010). However, it should be noted that there is not universal agreement about this interpretation of the PoP effect. Some researchers (e.g., Huang, Holcombe & Pashler, 2004; Cohen & Magen, 1999) have proposed post-perceptual response-based accounts of the PoP effect, in which potential targets undergo some kind of checking procedure before a response is made. More recently, Lamy, Yasher, and Ruderman (2010) posited a dual-stage interpretation of the PoP effect, suggesting a role for early attentional and late motor-based components in the production of the effect. However, the dominant theory remains that inter-trial effects reflect the operation of early stage selective attentional processes (Eimer et al., 2010; Lamy et al., 2008). This is further supported by fMRI brain-imaging research (Kristjánsson, Vuilleumier, Schwartz, Macaluso & Driver, 2007) which found that areas associated with attentional control (e.g., anterior cingulate and frontal eye fields) and ventral areas associated with feature processing were implicated in inter-trial effects. Meanwhile, event-related potential research (Eimer et al., 2010) focussing on the operation of the N2pc ERP component (a neurological marker of early attentional allocation) reported consistent early attention effects in a variant of Maljkovic and Nakayama’s (1994) PoP task.

1.11.5. Summary of utility of PoP for examination of OC populations

PoP inter-trial effects have been examined extensively in healthy populations. Yet, despite the robustness of the PoP effect, researchers do not seem to have used the paradigm to examine selective attention in patient groups. To our knowledge, no research exists that has studied visual search or PoP effects with clinical or non-clinical OC populations. This seems an unusual oversight given the validity of paradigm for the clear examination of such processes (Eimer et al., 2010) and existence of a longstanding theoretical premise that a deficit in selective attention may, at in part, underpin the
repetitive and ritualised behaviour manifestations commonly associated with OCD (Enright & Beech 1990, 1993; Kaplan et al., 2006; Muller & Roberts, 2005; Swerdlov et al., 1999). Furthermore, it fulfils the requirements of Fox (1993) that laboratory assessments of selective attention must use designs in which targets and distractors must be in different spatial locations and outside of the direct visual gaze.

The adaptations of the PoP paradigm (e.g., Eimer et al., 2010, Lamy et al., 2008) enable clear examination of target activation and distractor inhibition processes in selective attention. Moreover, Lamy and colleagues (2008) argue that the negative priming paradigm (which, as we have seen, has been used to assess inhibition in OCD) records effects occurring at response selection rather than attentional target selection. They suggest that this is because the connectivity between aspects of stimuli associated with repetition and response is often more prominent in negative priming tasks, while they are disambiguated in a typical PoP study. This line of thinking is further supported by neuroscientific research which found that negative priming effects were correlated with activity in brain regions connected to episodic retrieval (Egner & Hirsch, 2005). PoP, on the other hand, has been linked with brain areas known to be implicated in attentional processing (Eimer et al., 2010; Kristjánsson et al., 2007).

Reviewers (e.g., Abramovitch et al., 2013) have called for the use of more sensitive, participant-orientated paradigms in OCD research in order to tease out more reliable data relating to the condition. Certainly, previous neuropsychological and cognitive OCD research to-date has, provided only hints and suggestions relating to the underlying mechanisms of the condition. This thesis argues that visual search and, in particular, PoP paradigms might provide interesting new approaches to the study of this condition, given their clear advantages for the assessment of selective attention.

1.11.6. Summary of Section 1.11

The PoP paradigm is an established visual search measure of selective attention. It has not previously been used to study selective attention processes in OCD. This is an interesting omission from the literature, as the advantages of the PoP paradigm are that it enables both the disassociation of selective attention and response selection processes, and the separation of target activation and distractor inhibition processes. Importantly, it can be adapted for use with emotional stimuli. The PoP paradigm forms the basis of the attention studies which are included in this thesis.
1.12. Long-term memory

Memory forms what we know about ourselves and the world around us. Psychologists have traditionally broken the operation of memory down into three areas – encoding (processing of sensory input); storage (retaining of representations); and retrieval (the use of stored information) (Rutherford, 2005). The majority of researchers have differentiated a short-term, or working, memory (which holds detail for seconds unless rehearsed) and a long-term memory (which can store information for years).

1.12.1. Multiple systems models

Multiple systems models of long-term memory expanded the original multi-store conceptions of memory devised by Atkinson and Schriffin (1968). The most influential have been those of Tulving, Schacter and associates, who argue that long-term memory needs to be understood as comprising four systems – episodic memory, semantic memory, perceptual representation and procedural memory (see Schacter & Tulving, 1994; Schacter, Wagner & Buckner, 2000). Figure 1.7 provides a schematic illustration of Schacter and Tulving’s multiple systems model, which includes both working and long-term memory components (Schacter & Tulving, 1994). Broadly speaking, episodic and semantic systems are understood to form part of what has been termed explicit memory. Explicit memories are considered to be those based on conscious recollection of an event or experience. Tulving (1972) first suggested that some types of long-term memories could be understood as episodic, while others could be categorised as semantic. Episodic memory is said to comprise personal experiences (or episodes), and includes the location where such experiences take place and specific time of their occurrence. Semantic memory, on the other hand, is effectively a repository of general knowledge about the world and its rules, meanings and symbols. Meanwhile, perceptual representation and procedural memory are said to represent an alternative component known as implicit memory (Eysenck, 2006). Implicit memories are said to reflect the automatic processing of events or experiences in the absence of conscious awareness (Schacter, 1987). The perceptual representation system is said to be involved in the processing of incoming perceptual information relating to the form of stimuli (Schacter et al., 2000). This could include, for example, the structure of written words. This system is said to underpin two important processes. Priming, firstly, is the well-established research finding that repeating the presentation, to a person, of a stimulus that they have previously encountered in a task will facilitate performance on the processing of that stimulus. Secondly, perceptual priming, in which the correct identification of a target stimulus is enhanced following a presentation of only a partial version of that stimulus, if it has previously been presented to the person performing the task in its complete form (Eysenck, 2006). Meanwhile, procedural memory is involved in the learning of cognitive and motor abilities (Schacter et al., 2000) - for example, when a person learns to play a guitar or drive a car.
1.12.2. Criticisms and re-evaluations of the multiple-systems model

Schacter and Tulving’s model of memory has been highly influential. However, it remains unclear how far the hypothesised multiple systems can be understood to be distinct from each other (Eysenck, 2006; Rutherford, 2005). There has been a tendency among multiple systems advocates to hypothesise the existence of increasing numbers of separate systems to accommodate different aspects of memory functioning, as opposed to focusing on strengthening the theoretical basis of the multiple systems model with evidence (Rutherford, 2005). An important re-evaluation of the multiple-systems model suggested the existence of two systems of long-term memory – declarative and procedural (Cohen & Squire, 1980; Squire, 1992 – see Figure 1.8). Declarative knowledge pertains to ‘knowing that’ – for example, the knowledge that strawberries are red. Procedural knowledge concerns ‘knowing how’ – for example, the knowledge that a person needs to draw on to play a guitar (Rutherford, 2005). Squire argues that episodic and semantic memory functions to produce declarative information. Procedural
knowledge, meanwhile, is comprised of skills, priming, classical conditioning and non-associative learning.

**Figure 1.8.** Schematic illustration of Squire’s (1992) model of declarative and procedural memory.

### 1.12.3. A focus on retrieval – remember/know memory

Problems associated with the multiple-systems model of memory (e.g., the number of systems hypothesised) have led a number of researchers to shift the focus of their examinations to the operation of memory retrieval (Rutherford, 2005). Of particular interest have been the distinctions that people can make between what are known as remember judgements and know judgements (Tulving, 1985). The premise of this approach is that long-term memories can be divided into two types. Firstly, there are those which can be firmly recollected, known as ‘remember’ memories. Then there are those which have only a looser sense of familiarity about them, but which cannot be consciously recollected – called ‘know’ memories. Remember and know judgements are, thus, subjective. They reflect how a person interprets the meaning of ‘remembering’ and ‘knowing’ alongside their recollection abilities (Rutherford, 2005). Differing percentages of remember and know judgments can be found in participant groups who have demonstrated similar recognition abilities (Gardiner & Richardson-Klavehn, 2001). The distinction between these two types of retrieval is not without criticism. Donaldson (1996), for example, argues that remember and know judgements are reflective of strength of particular memories (with remember memories being stronger than know memories), rather than differentiable cognitive processes. However, research support for a dual-process account of recognition memory is substantive (see Yonelinas, 2002). Furthermore, a number of
neuropsychological event-related potential studies have provided evidence that remember and know memories can be functionally dissociated (e.g., Curran, 2000, 2004; Friedman & Johnson, 2000; Opitz 2010). Remember/know paradigms thus enable the examination of possible differences in the way memories are processed even when accuracy is unimpaired (Tulving, 1985).

### 1.12.4. Summary of Section 1.12

A number of researchers have imagined long-term memory as multiple-system network. The exact nature of this system, and its sub-components, remains a controversial topic of debate. Consequently, some theorists have switched their focus to retrieval processes in memory. These include assessing the distinctions which can be made between remember judgements and know judgements.

### 1.13. Long-term memory and OCD

As with examination of the research into selective attention and OCD, it is worth reminding ourselves of the heterogeneous complexity of OCD. That is, when it comes to understanding or explaining the condition, the operation of individual cognitive processes can only highlight aspects of a much broader picture. While bearing this in mind, however, one commonly reported finding from research is that people with OCD often associate the need to carry out repetitive behaviours (e.g., checking or washing rituals) with apparent ‘poor memory’ (Cougle, Salkovskis, & Thorpe, 2008). Studies have reported that individual with the condition are often uncertain over whether they have performed an activity, or whether they have only imagined doing so – and thus they experience the urge to repeat their actions (Alocolado & Radomsky, 2011; Harkin & Kessler, 2009; Muller & Roberts, 2005, Rachman, 2002; Rachman & Schafran, 1998; Woods, Vevea, Chambless, & Bayen, 2002). As a consequence, a good deal of research in this field has looked to assess the operation of long-term memory, driven by theories of possible mnestic deficits with OCD (e.g., Talis, 1997; Sher, Mann, & Frost, 1984), the presence of which might explain why rituals continue to be carried out by individuals repeatedly after their first performance. Such studies have tended to be divided into two strands of investigation – memory for non-verbal stimuli, such as figures, images, photographs, and memory for verbal stimuli, such as words, sentences, narrative text (Muller & Roberts, 2005; Woods et al., 2002).

The focus of this thesis is long-term verbal memory. However, in the following section we begin with an outline of key studies which have examined non-verbal memory, before moving on to an assessment of research which has examined verbal memory. Many of these studies have looked for
evidence of global memory dysfunction. We then suggest different ways in which verbal memory research with OCD could be approached, before detailing the study that was carried out for this thesis.

1.13.1. Non-verbal memory

The most consistent evidence for a deficit in memory with OCD has come through assessment of non-verbal memory in patients (Abramovitch et al., 2013; Muller & Roberts, 2005; Veale, Sahakian, Owen, & Marks, 1996; Woods et al., 2002). In their review, Abramovitch et al. (2013) reported large effect sizes for differences in non-verbal memory between OC and controls. This was the only cognitive domain out of all those that they assessed (six main domains and 10 sub-domains) which produced large effect sizes for group differences. For example, Sher, Frost, Kushner, Crews, and Alexander (1989) found that participants with checking concerns performed more poorly overall than controls on the Weschler Memory Scale (WMS), but most particularly on its sub-section assessing visual memory. Poor performance has also been apparent when patients are compared with controls on the Rey-Osterrieth Complex Figure (ROCF) test. This is a pen and paper test in which participants are asked to copy a specific detailed figure, and then reproduce the figure from memory. Reduced performance by participants with OCD, in comparison with that of controls, been reported in a number of studies (e.g., Penades, Catalan, Andres, Salamero, & Gasto, 2005; Shin et al., 2004). It has been proposed that dysfunctional organisational abilities associated with executive functioning might be implicated in the pattern of weakened performance on the ROCF by participants with OCD (Abramovitch et al., 2013). Because non-verbal stimuli is commonly more abstract than verbal information, it may require enhanced organisational processing (Greisburg & McKay, 2003; Kuelz et al, 2004). A logical possibility here, then, is that the group differences recorded in these studies might actually reflect differences in executive functioning, rather than differences in non-verbal memory (Abramovitch et al., 2013).

1.13.2. Verbal memory

By comparison with findings relating to non-verbal memory, research assessing verbal memory with OCD has produced, as with OCD studies examining most other cognitive domains, more inconsistent results (Abramovitch et al, 2013; Harkin & Kessler, 2009; Kuelz et al., 2004; Muller & Roberts, 2005; Sica et al., 2010; Woods et al., 2002). Thus, Sher, Mann, and Frost (1984) reported that checkers with severe symptomology performed more poorly than non-checkers on the logical memory subtest of the WMS, in which participants are asked to report details from narratives which have been read to them. Additionally, they also performed more poorly than checking participants with lower symptom severity. Similar results were found by Deckersbach et al. (2000) in an assessment of participants with OCD using the California Verbal Learning Test (CVLT). Participants with OCD performed poorly at
immediate and delayed recall of 16 shopping-related items. Likewise, Zitterl et al. (2001) and Cha et al. (2008) also found that participants with OCD performed more poorly in tests of verbal memory than controls. By contrast, however, no differences in verbal memory between participants with OCD and controls have been reported in a number of studies – including Sher et al. (1989), MacDonald, Antony, MacLeod, & Richter (1997) and Moritz, Kloss, von Eckstaedt, & Jelenik (2009). Indeed, Moritz and colleagues (2009) argue that the support for a general memory deficit with OCD was diminishing, and the focus of research would be better trained on particular aspects of the condition, such as enhanced responsibility.

1.13.3. Possible explanations for inconsistent verbal memory findings

It may be the case that the failure to find robust empirical support for a memory dysfunction theory, particularly in relation to verbal memory, lies in the choice of paradigms used for testing, and aspects of the experimental design. It has been argued, for example, that broad, well-established neuropsychological tests (e.g., the WMS) which have been used in some studies of OCD are only appropriate for the examination of clear-cut cognitive disorders, because this is what they have been specifically designed to assess (Kuelz et al., 2004). Furthermore, such tests have been constructed with the aim of discriminating between the performance of patients with such clear-cut cognitive disorders and that of healthy controls. They are not so useful when patient populations have primary psychiatric conditions (Kuelz et al., 2004). Consequently, such tests may not be sensitive enough to flag-up possible memory dysfunction in OC populations (Klumpp, Amir, & Garfinkel, 2009; Kuelz et al., 2004).

Additionally, and as already stated, it is generally agreed that a number of OC subtypes (e.g., checking and washing) exist below the broader umbrella of an OCD diagnosis. These subtypes may be characterised by differing cognitive abilities and neural correlates (Bragdon et al., 2018; Mataix-Cols et al., 2004). As with the study of selective attention and OCD, the complex heterogeneity of the condition suggests that neutral or generalised threat-related stimuli may be, in and of themselves, less likely to trigger OC symptoms than stimuli specifically tailored to the precise concerns of the participants of a particular study (Abramovitch et al., 2013; Moritz et al., 2009; Muller & Roberts, 2005; Tolin et al. 2001). As such, it may be that the inconsistent results of previous verbal memory studies have been produced because the stimuli used may not have been relevant to the specific concerns of OC participants, who may in turn have been treated as a homogenous grouping (Abramovitch et al., 2013; Hermans et al., 2008). Furthermore, and again like with research into selective attention and the condition, some of the findings of some of these studies are likely to have been compromised the failure to consider comorbid conditions (Muller & Roberts 2005; Kuelz et al., 2004; Woods et al., 2002).
1.13.4. Suggested approaches for the examination of verbal memory

The focus of the memory component of this thesis is long-term verbal memory. It argues that a number of different approaches to the examination of verbal memory in OCD could be incorporated within experimental tasks to help clarify findings. These will be discussed in the following section.

1.13.4.1. Assessment of OC subtypes

There most common OC subtypes are checking and washing. As already stated (see Section 1.2.3.1), there are evident behavioural differences between the two. There is some suggestion that there may also be differences in verbal memory functioning between checkers and washers. For example, in a meta-analysis, Leopold & Backenstrauss (2015) found that checkers were more impaired than washers in both verbal (and non-verbal) memory. It is possible that altered memory functioning may be more a feature of checking behaviour than of washing behaviour, possibly connected to the high levels of doubt which are commonly reported among checkers (Woods et al., 2002). Indeed, Cha et al. (2008) did not find any differences between washers and controls in verbal memory. But the literature is not entirely clear-cut in its findings regarding checking and washing memory. For example, Ceschi, Van der Linden, Dunker, Perroud, & Bredart (2003) found that washers had a better memory of verbal contamination material than controls. A review by Woods et al. (2002) concluded that checkers perform more poorly than non-OC controls at verbal memory tasks. However, checkers have also been shown to display enhanced memory for verbal stimuli if it is directly-relevant to their concerns (Hansmeier et al., 2015). Improvements to experimental design (see the following sections) could help understandings of how memory functions among checkers and washers, and in comparison to non-OC individuals.

1.13.4.2. Assessment of the effects of OC behaviours on memory and confidence

The somewhat unfruitful pursuit of evidence for a global memory deficit has led to alternative approaches to understanding memory with OC behaviour. One such line of research has been to examine the effects that repetitive behaviours have on memory (Klumpp et al., 2009; Hansmeier, Glombiewski, Rief & Exner, 2015; Harkin & Kessler, 2009; Harkin & Kessler, 2011b; Hermans, et al, 2008). The most robust finding from studies taking this perspective is that OC participants consistently show a reduced trust or confidence in their memory (Alcolado & Radomsky, 2016; Cougle et al., 2008; Rachman, 2002). In a typical behavioural manifestation of memory mistrust, an obsessive-compulsive person may check a door lock and leave the location. A representation in memory of the action has been formed, but the person lacks (what they regard as) the required confidence to accept the veracity of that memory. Consequently, a checking routine can often begin (Hermans et al., 2008). Reduced confidence in memory has been demonstrated in numerous studies.
(for reviews, see Hermans et al., 2008; Radomsky, Dugas, Alcolado, & Lavoie, 2014). However, it would be useful to know more about how verbal memory and confidence operate within the same task.

1.13.4.3. Further use of remember/know paradigms
A number of researchers have attempted to tap the possible deeper nuances of OC memory through the use of paradigms based on remember/know principles (Tulving, 1985) – see Section 1.11.3. As already stated, the premise of this theory is that memories can be divided into two types – those which can be firmly recollected (remember memories) and those which have only a looser sense of familiarity about them (know memories). Remember/know paradigms enable the examination of subtle differences in memory processing even when accuracy of memory is normal (Tulving, 1985). In a series of remember/know-type studies, van den Hout & Kindt (2003a, 2003b, 2004) asked non-clinical participants to perform checks on virtual cooker stove switches. It was found that repeated checking of the cooker switches in between pre-test and test phases of their task served to decrease confidence in memory and made the recollections of the participants less detailed and vivid. This was in comparison to the performance of participants who performed the same task without repeated checking of the cooker between the pre-test and test (they were asked to carry out checks on light bulbs instead). The authors argued that the act of continued checking increased familiarity with (rather than firm recollection of) stimuli – excessive repetition had resulted in an alteration in the source of memory, even though their original intention would have been to try to rule out any doubt (van den Hout & Kindt, 2003a). These findings have been replicated using a real cooker (Radomsky, Gilchrist & Dussault, 2006) and in clinical OCD (Boschen & Vuksanovic, 2007) and checking populations (Hermans et al., 2008; Radomsky et al., 2014). Such studies have good ecological validity. The further use of remember/know designs with symptom-salient written stimuli tailored to the concerns of specific OC subtypes could help deepen understandings of OC verbal memory.

1.13.4.4. Assessment of possible enhanced memory for symptom-salient stimuli
It may be the case that, in certain circumstances, OC memory might be enhanced rather than weakened following the presentation of emotional material. In a review of the effect of emotion on memory, Levine and Edelstein (2009) argue that experiencing emotion can boost memory for information salient to current goals, but this in turn can lead to a narrowing of memory for other material. In laboratory tests, memory can be aided by emotional stimuli, with the same effects not being seen for neutral stimuli (see Hamann, 2001; Levine & Edelstein, 2009). Studies of anxious clinical populations have demonstrated enhanced memory for threat-related information (see Mitte, 2008), and, as already stated, attentional bias towards threatening information has regularly been found in OC groups – see Section 1.8.3. In light of these considerations, it is notable that checkers have been shown to have better recall than controls for ecologically-valid activities (e.g., lighting then
blowing out a candle) which generated anxiety (Constans, Foa, Franklin, & Mathews, 1995). Radomsky et al., (2001) reported that checkers had improved memory for threatening information, particularly in scenarios with raised levels of responsibility. This study had followed previous research by Radomsky and Rachman (1999) which reported enhanced memory for threatening information among washers. More recently, Hansmeier et al. (2015) found that high-level checkers demonstrated enhanced immediate recall abilities for verbal material (short passages with OC narratives) which was directly relevant to checking concerns. Meanwhile, using directed forgetting paradigms, other studies have shown that the forgetting of personally-relevant material may be problematic for OC participants (e.g., Tolin et al., 2002).

In an interesting variation on research to date, Klumpp et al., (2009) used a remember/ know paradigm to examine false memories for verbal material in non-clinical OC washers. The stimuli used were written OC-threat scenarios, alongside generalised positive and negative scenarios. The research had followed other false memory studies with non-OCD populations which had demonstrated that numbers of memory errors could increase in scenarios in which the stimuli presented to is of direct relevance to the participants (Baird, 2003; Castel, McCabe, Roediger, & Heitman, 1998). Klumpp and colleagues (2009) found that OC participants had more false memories of OC-threat stimuli than controls (though not anxious controls). In line with much of the remember/ know research already detailed, these memories were more likely to be familiarity-based than firmly remembered (in comparison to both anxious and non-anxious controls). These are interesting findings. However, it remains unclear under what conditions OC verbal memory may be impaired or enhanced, and further research is required.

1.13.4.5. Examination of implicit memory
Despite being recommended as an area for future research in the review by Woods (2002), few studies have examined implicit memory in OC populations – and there is no real agreement among those which have (Kim et al., 2006). Deckersbach et al. (2002) reported that implicit learning was impaired in OCD patients when it was interfered with by concurrent explicit learning demands. However, Foa et al. (1997) found no evidence of implicit memory deficits with OCD in an old/new task involving the rating of noise levels accompanying stimuli presentations. Likewise, in an event-related potential study using verbal word stimuli, Kim et al. (2006) also reported preserved implicit memory in OCD patients. It is notable that none of these studies examined subtype groupings within OC populations, and none used stimuli which could be considered directly relevant to specific OC concerns.

1.13.4.6. Use of signal detection measures in experimental designs
A verbal remember/ know experiment might involve a study phase in which a group of words are shown to a participant, and a test phase in which these words are shown again along with a new group
of words. The task of the participant is to report whether or not a word shown in the test phase has previously been presented (an old/new judgement). This approach allows for the use of signal detection measures in analysis of data. A study/test experiment of the type described allows for the comparison of four possible memory outcomes – hits (old items described as old), misses (old items described as new), false alarms (new items described as old) and correct rejections (new items described as new). This enables researchers to assess levels of sensitivity and bias towards different types of stimuli in the same populations using of signal detection theory (SDT) methodology (see Rose, 2006). SDT aims to quantify the ability of a person to distinguish a relevant item (a signal) from irrelevant information (noise), taking in account that individuals might display differing decision-making bias (Rose, 2006; Stanislaw & Todorov, 1999). As can be seen in Figure 1.9, the probabilities of the four possible responses (hits, misses, false alarms and correct rejections) can be understood as separate areas below the signal (target present) and noise (target absent) distribution curves. In an experiment requiring old or new judgements about stimuli, old targets would equate to signals and new items would equate to noise. The distance between the means of the two distributions is called $d'$, and reflects sensitivity to target items. Thus, a larger distance between curves indicates a greater target-sensitivity. The central line ($C$) indicates the criterion decision-making level. This is used to assess bias, or the tendency to report that a target is old (signal) or new (noise). The further the line is positioned to the right, the greater the strength of evidence which is needed by a participant to report that a target is old. More positive scores indicate more conservative the decision-making. Negative scores (central line moved towards the left) indicate more risky, or liberal, decision-making. Despite broad acceptance of its methodological value (Stanislaw & Todorov, 1999), limited research appears to have used SDT to examine memory in OC populations. However, the assessment of rates for hits (old words reported as old) and false alarms (new words reported as old), and follow-up calculation of discriminatory sensitivity ($d$-prime or $d'$) and bias ($C$), could provide clearer insights into the operation of verbal memory in OC populations.
Figure 1.9. Example signal detection theory probability distributions for target-absent (noise) and target-present (signal) judgements. In an old/new experiment, old targets would equate to signals and new targets would equate to noise. (Hs = hits, Ms = misses, FAs = false alarms, CRs = correct rejections)

1.13.5. A gap in the literature – the alternative approach adopted in this thesis

The functioning of verbal long-term memory in OC populations remains unclear. Although reviews (e.g., Kuelz et al. 2004; Muller & Roberts, 2005; Woods 2002) have recommended that experimenters need to be more mindful of the sensitivity of their paradigms when testing OC participants, there remains limited research examining verbal memory in OCD using designs which can access more subtle aspects of OC cognition, such as those based on remember/know theory. There appears to have been limited use of signal detection methodology, despite its advantages for measuring bias and accuracy. Additionally, there has been little research examining OC subtype populations (e.g., checkers and washers) which uses verbal stimuli which has been selected because of its saliency to the particular concerns of those subtypes. Notable exceptions are the studies by Hansmeier et al. (2015) and Klumpp et al. (2009), both of which found altered verbal memory in OC populations. In the case of Hansmeier et al. (2015), checkers demonstrated enhanced, rather than impaired, memory for verbal material that was sensitive to their concerns. This issue of whether, or under what
circumstances, OC verbal memory can be found to be enhanced or impaired warrants further investigation. There is a gap in the literature for an in-depth study of multiple aspects of long-term verbal memory in OC populations which may help clarify understandings in this area. This thesis aims to address this issue through a study using an extended CID-R paradigm, investigating multiple aspects of long-term verbal memory in OC populations. This paradigm is discussed in the following section.

1.13.6. What is the Continuous Identification with Recognition (CID-R) paradigm?

CID-R paradigms have previously been used to assess priming and explicit memory in healthy populations (e.g., Berry, Shanks & Henson, 2008; Stark & McClelland, 2000). A typical CID-R trial is illustrated in Figure 1.10. A basic CID-R experiment involves two phases – a study phase and a test phase. In the first phase (study), participants are shown a series of single words which are presented individually on a computer screen. The words are initially masked, but then gradually revealed. Participants are asked to report the name of the word as soon as they recognise it. Later, in a second phase (test), they perform the same task, but a new series of words are included alongside the original stimuli. The participants are then additionally asked to report whether they think a given word is old or new.

Importantly, the standard CID-R paradigm can be adapted to record remember/know judgements and measures of confidence in memory. A further advantage for the study of OC behaviour is that it also allows for the assessment of priming, alongside explicit memory, within the same design. As has already been stated, explicit memories are considered to be those based on conscious recollection of an event or experience. Priming reflects the automatic processing of events or experiences in the absence of conscious awareness (Schacter, 1987). Thus, in a CID-R study, explicit memory is indexed by conscious old versus new judgements, while implicit memory is indexed by automatic repetition priming effects in test phase reaction times (Berry et al., 2008; Stark & McClelland, 2000). Moreover, the CID-R paradigm allows for the examination of sensitivity and bias using signal detection methodology.
Figure 1.10. A typical CID-R trial. With time, the word stimulus (‘Fish’) becomes increasingly clear. Once the participant identifies the word, they state it verbally (in this example, the individual letters of the word). They are then asked to report whether they think that the word is has previously been presented in the study phase (old), or whether they think that it is new. If the word has not been recognised once it appears for 250ms, no response is recorded. The task then begins again.

1.13.7. Summary of Section 1.13

People with OCD often report having ‘poor memory’. There is good support for a deficit in non-verbal or visual episodic memory with OCD. Findings relating to verbal memory are less clear. However, research in this field may have been affected by similar methodological issues to those which seem to have been apparent in the examination of selective attention and OCD (e.g., the use of low-sensitivity paradigms). There is some evidence that, for symptom-salient stimuli, verbal memory may be enhanced rather than impaired. This needs further investigation. This is the aim of the long-term memory section of this thesis. The CID-R paradigm has been used to assess priming and explicit
memory in healthy populations. It has not been used previously with OC populations. The paradigm can be adapted to record remember/know judgements and measures of confidence in memory, and it enables researchers to assess levels of sensitivity and bias towards different types of stimuli using signal detection theory (SDT) methodology. This makes it particularly advantageous for the detailing examination of long-term memory in OC populations. The paradigm is used in Study 4 in this thesis.

1.14. The present thesis

1.14.1. Summary of contentions and aims

This thesis adopts novel experimental approaches for the examination of possible dysfunction in OC cognition. The studies reported assess the operation of selective attention and long-term memory with the condition. The aim is to demonstrate that two key mechanisms – cognitive bias and emotional response to stimuli – underpin performance in both selective attention and long-term memory. The thesis looks to show that such findings can be recorded in non-clinical populations, thus further highlighting the complex, dimensional nature of OCD, which has important implications for understandings of the condition going forward.

Following analysis of the literature, it is evident that inconsistencies in previous research examining both selective attention and long-term verbal memory in OC populations might be, at least in part, reflective of the use of experimental paradigms which may lack the sensitivity to effectively tap into the depths of OC cognition. The failure to acknowledge, or control-for, key factors (e.g., comorbidities, the heterogeneity of the condition) is likely to have confounded the study of OCD. Additionally, while reviewers commonly recommend the use of symptom-salient stimuli when examining OC populations, such stimuli have been used in some studies, but not others.

This thesis contends that the use of tightly-designed experimental designs and nuanced paradigms – such as PoP and CID-R – is likely to enable a clearer examination of how selective attention and long-term memory operate in OC populations. The weight of evidence suggests that altered functioning in both areas contributes to the reported symptomatology of the condition. However, the novel approaches adopted in the studies presented in this thesis may serve to better demonstrate this than those used which have been used in previous research.
1.14.1.1. Gaps in the literature

Only a small number of studies have examined possible altered selective attention and bias in OC behaviour. Of these, the majority have used either Stroop-like or dot-probe paradigms. However, little, if any, research appears to have investigated selective attention deficits in clinical or non-clinical OCD, or in OC subtypes, using visual search paradigms – or, furthermore, using symptom-salient stimuli with such paradigms. Meanwhile, there has been only limited research examining verbal memory and bias in OCD using experimental designs which focus on more subtle aspects of OC cognition – for example, remember/know paradigms. Despite its utility for measuring bias and accuracy, there appears to have been limited use of signal detection methodology in this field of research. Furthermore, little research has examined OC subtype populations using symptom-salient verbal stimuli. This thesis addresses these gaps in the literature.

1.14.1.2. Sampling for the studies

In all the reported studies, non-clinical participants were assessed for OC tendencies using the OCI-R questionnaire (Foa et al., 2002). The OCI-R is an 18-item, self-report measure which features a five-point Likert scale. Participants are asked to report how much they relate to each item statement (0 = ‘not at all’ and 4 = ‘extremely’). The total OCI-R score can range from 0-72. A total OCI-R score of 21 or above is said to be indicative of excessive obsessive-compulsive tendencies (Foa et al., 2002).

The OCI-R is also designed to assess levels of obsessive-compulsiveness in six subtypes of the condition – checking, washing, ordering, neutralising, obsessing and hoarding. The maximum score for each subtype is 12. Cut-off scores indicating the presence of OC tendencies are considered to be the following: checking = ≥5; washing = ≥4; ordering = ≥7; neutralising = ≥4; obsessing = ≥5; and hoarding = ≥7 (Foa et al., 2002; Hajcak et al., 2004). The OCI-R has good internal consistency and construct validity (Foa et al., 2002). As already stated, the six-subtype structure of the OCI-R has been found in 10 further factor analysis studies with both clinical and non-clinical participant data (Abramovitch et al., 2015).

All participants were recruited from the University of Surrey student population. Studies 2 and 3 (see Section 1.14.2) were run concurrently and used the same specific participant pool. Full details of the recruitment process for Studies 2 and 3 are included in the Methods section of Study 2 (Section 3.2.1).

1.14.2. Thesis studies

Four studies were carried out examining possible dysfunctional cognition in non-clinical OC populations. Three studies (Studies 1, 2 and 3) assessed bias and deficits in selective attention, and one study (Study 4) looked at bias and deficits in long-term verbal memory. The selective attention
studies used variants of the PoP paradigm, and involved both simple-colour and symptom-salient emotional stimuli. The long-term memory study used an extended CID-R paradigm to produce a detailed assessment of multiple cognitive aspects of OC long-term verbal memory. Details of the studies are as follows:

**Study 1**
The first study had two main aims. Firstly, following Maljkovic and Nakayama (1994), it looked to assess whether the basic PoP effect (facilitated reaction time performance with target-feature repetition) would be altered in an OC group of participants. Secondly, following Eimer et al. (2010), it looked to examine whether the balance of target activation and distractor inhibition processes which are considered to underpin the PoP effect were altered in the OC group when compared to Controls. A total of 28 participants took part in the study. Fourteen were in a non-clinical OC group and there were 14 Controls. At this stage, our research was exploratory and looking to whether differential selective attention effects between groups could be established. For this reason, the OC group was general, and not restricted to a particular subtype. However, hoarders were excluded from participation, while medication-use and comorbid disorder were also controlled for.

**Study 2**
This study was a follow-up to Study 1. It looked to examine the impact of symptom-salient emotional stimuli on the performance of an OC group in a PoP task. The study aimed to investigate possible selective attention deficits with OC behaviour in more nuanced detail by examining a non-clinical OC Checker population, and using visual picture stimuli tailored to checking concerns. The study used three categories of pictures – checking, negative and neutral. Participants were asked to carry out a two-colour PoP task. However, before the presentation of each search array, a single picture from one of the three categories was shown on screen. A total of 21 non-clinical OC Checkers took part in the study, along with 22 Non-Checkers. None of the participants used medication or reported comorbid conditions.

**Study 3**
This study was also a follow-up to Study 1. It looked to assess attentional bias in visual search in an OC population. Like in Study 2, the performance of non-clinical Checker and Non-Checker participants was examined. The study used visual picture stimuli tailored to checking concerns, along with negative and neutral pictures. Participants were asked to perform a visual search task derived from the PoP paradigm. Picture images were used as the defining-features of targets and distracters, instead of colours. The study had two conditions – one in which target pictures remained neutral, but distractors could change between category type; and a second in which distractor pictures remained neutral, but targets could change between category type. Twenty-three Checkers took part in the
study, along with 23 Non-Checkers. None of the participants used medication or reported comorbid conditions.

As stated, Study 2 and Study 3 were run concurrently and used the same participant pool. All participants took part in Study 3 prior to completing Study 2. However, the studies are presented in the order that they because Study 2 was a further assessment of the first key finding of Study 1 (overall slowing among OC participants in a selective attention task), while Study 3 re-examines the second key finding of Study 1 (slowing among OC participants in specific selective attention task sequences).

**Study 4**
The final study of the thesis assessed whether deficits and biasing attributed to differentiated performance in attentional studies were also apparent in a long-term verbal memory task. A CID-R paradigm similar to that of Berry et al. (2008) and Stark and McClelland (2000) was used, but extended the design to incorporate measures allowing analysis of both remember/know memory and memory confidence, alongside those assessing priming and explicit memory. Taking a more expanded approach to sampling than the first three studies, the performance of non-clinical Checkers was compared with that of Washers and a generalised OC group, along with Controls. The study used a bespoke, written-word stimuli dataset which included categories of words tailored to OC checking and washing concerns, alongside generalised negative and neutral word stimuli. A total of 61 non-clinical participants took part in the study – 14 Checkers, 11 Washers, 16 general OC participants (OCGs) and 20 Controls.
Chapter 2

Study 1:

Investigating PoP in a non-clinical OC population
2.1. Introduction

The suggestion that selective attention dysfunction and/or biasing might be at the root of some of the commonly-seen OC behaviours has good face validity. People with OCD typically report that their everyday lives are restricted by repetitive, distractive and time-consuming thoughts and preoccupations. There seems a logic, then, to deficit-based theories of OCD, which hypothesise that the condition is underpinned by an inability to normally process sensory input into that which is important and that which is unimportant (e.g., Clayton et al., 1999; Enright & Beech 1990, 1993a, 1993b; Kaplan et al., 2006; Swerdlow et al., 1999).

As stated in Chapter 1, neurological research (see Abramovitch et al, 2013; Kuelz et al., 2004) has consistently uncovered abnormal functioning with OCD in the frontal-subcortical circuitry of the brain, areas which are implicated in the operation of attentional and affective processes (see Menzies et al., 2008). The evidence from neuropsychological tests designed to examine selective attention with OCD is, by contrast, somewhat mixed (Abramovitch et al, 2013; Muller & Roberts, 2005). Some studies (e.g., Enright & Beech, 1990, 1993a, 1993b) have reported evidence of attentional deficits with the condition. However, others have not (e.g., Kyrios & Iob, 1998; Moritz et al., 2008). One possibility is that inconsistencies in research findings relating to selective attention and OCD could be, at least partially, reflective of the use of experimental paradigms which are overly-differing in their task demands, and which may vary in their sensitivity to measure dysfunction in the condition. In addition, some research has failed to acknowledge or control-for key factors which can confound the study of OCD (e.g., comorbid conditions). Interestingly, there appears to have been no studies reported which have used visual search paradigms to examine selective attention in either clinical or non-clinical OC populations.

This thesis makes the argument that the PoP visual search paradigm could enable a more fine-tuned examination of selective attention in OCD than has previously been provided by research. The PoP effect (facilitated visual search performance with the repetition of feature-defining aspects of a target from the previous trial) is a robust measure of selective attention in healthy populations (Lamy et al, 2008). Despite this, it has barely been used with patient groups, and, as far as can be ascertained, it has not been used at all to examine OC populations. This is curious given the advantages of the PoP paradigm – namely that it enables disambiguation of attentional and response features of task performance; while it can also be adapted to examine how far performance may be influenced by distractor inhibition and target activation processes (see Section 1.11). This gives it potential as a highly useful tool with which to assess the possible cognitive bias in OC participants.
Study 1 looked to establish an initial account of what PoP might reveal about selective attentional processes in OCD. The design of the study was based on that of Eimer et al., (2010), which itself was an adaptation of the original PoP paradigm established by Maljkovic and Nakayama (1994) – these are detailed in Section 1.11. Three stimuli colours were used (red, green and blue), with participants being asked to complete blocks of trials in two conditions – a Pure condition (repetition-based) and a Mixed condition (swap-based); pure and mixed being the labels used by Eimer and colleagues to describe different blocks of inter-trial sequences. In the Pure condition, target and distractor colours were the same in each block (e.g., red targets and green distractors in each trial). However, colour combinations changed with each block. Thus, in different blocks, trials could include green targets and red distractors, or blue targets and red distractors, throughout. The participants were told in advance of each block what colour target and distractors to expect, thus providing a strong top-down aspect to this component of the study. In the Mixed condition, the targets and distractor colour combinations were randomised, and could be drawn from any of three colours. No information about target or distractor colour was presented to participants in advance of the blocks, except to state that colour presentation would be random and vary from trial to trial. This implied that performance in the Mixed condition blocks would be more reliant on bottom-up processes. This top-down vs. bottom-up component of Study 1 has theoretical relevance, given that some theories of attentional bias (see Section 1.5.1 and 1.9.5) suggest that the balance between top-down control and bottom-up processing may be altered in OCD. It is argued that this could be demonstrated through comparatively poor performance on tasks which place increased demands on bottom-up attentional resources (De Putter & Koster, 2017).

Following Eimer et al. (2010), the Mixed condition also allowed for an assessment of the balance of target activation and distractor inhibition processes which are assumed to underpin the PoP effect (for more, see Section 1.11.2). The use of three colours enabled the creation of six inter-trial sequences – a full repetition and two partial repetition inter-trial types, along with a full swap and two partial swap inter-trial sequences (see Figure 2.2). In line with Eimer et al., (2010), it was assumed that the influence of target activation processes would be reflected by performance in two of the partial sequences (PRnewD; PSnewT), while the influence of distractor inhibition would be evidenced by performance in the two other partial sequences (PRnewT, PSnewD) – see Figure 2.3.

Study 1 had two main aims. Firstly, following Maljkovic and Nakayama (1994), it looked to establish whether the basic PoP effect (speeded reaction time performance with target-feature repetition) would be altered when an OC group of participants took part in a typical PoP task. Reaction time performance of the OC group, and that of Controls, would be compared in the two conditions (Pure vs. Mixed), as well in the full repetition and full swap levels in the Mixed condition. Secondly, following Eimer et al. (2010), it looked to assess whether the balance of target activation and
distractor inhibition processing, which has been shown to underpin the PoP effect, was altered in the OC group when compared to Controls.

The participants in Study 1 were drawn from a non-clinical student population. There are considerable advantages to the use of non-diagnosed participants in the study of OC behaviour (Abramovitz et al., 2014 – see Section 1.3). Study 1 was exploratory and looking to whether differential selective attention effects between groups could be established using the PoP paradigm. For this reason, the OC group was general, and not restricted to a particular subtype. However, hoarders were excluded from participation. Potential participants with a history of neurological or neuropsychological disorder were also excluded from participation.

2.1. Hypotheses

Because of the findings of previous research had inconsistent, and because Study 1 was somewhat exploratory, caution was exercised when making hypotheses. Based on previous research, it was predicted that Control participants would record faster reaction times in repetition-based inter-trial sequences than in swap-based sequences (the PoP effect) – Hypothesis 1. However, it was not known if the PoP effect would be altered in the OC group. If selective attention deficits were present in the OC group, it was expected that OC participants would record significantly different reaction times to those of the Controls – Hypothesis 2a. This might particularly be the case in the six-level Mixed condition because of its increased demands on attentional resources – Hypothesis 2b. However, if selective attention deficits were not apparent in the OC group, there should be no differences in reaction times between the groups – Hypothesis 2c. No specific predictions were made regarding possible group differences in operation of target activation and distractor inhibition processes.

2.2. Methods

2.2.1. Participants

2.2.1.1. Recruitment process

Participants were recruited via an advert on the SONA Systems research participant recruitment website, hosted by the University of Surrey, and via poster and email adverts directed at University of Surrey students. Volunteers who completed the study were paid £7.50 for taking part, although psychology students could receive course credit in the form of two lab tokens as an alternative form of
compensation. This study received a favourable ethical opinion from the University of Surrey Ethics Committee (see Appendix 1).

2.2.1.2. Inclusion and exclusion criteria

Prior to the lab-based study, potential participants were screened for OC tendencies using the Obsessive-Compulsive Inventory - Revised (OCI-R; Foa et al., 2002). The OCI-R is an 18-item, self-report measure used to assess levels of obsessive-compulsiveness. Using a five-point Likert scale, participants are asked to report how much they relate to each item statement (0 = ‘not at all’ and 4 = ‘extremely’). The total OCI-R score can range from 0-72. A total OCI-R score of 21 or above is said to be indicative of excessive obsessive-compulsive tendencies (Foa et al., 2002). In the present study, the inclusion criteria for the OC group was an OCI-R total score of ≥21. The inclusion criteria for Control participants was a total OCI-R score of ≤20. Potential OC group volunteers who reported hoarding as their primary OC symptom were excluded from the study. The OCI-R has good internal consistency and construct validity (Foa et al., 2002).

Participants were also assessed for potential colour-blindness using the Tests for Colour-Blindness (Ishihara, 1951) in advance of taking part in the study. All participants were required to have normal or corrected-to-normal vision and have no history of a neurological or neuropsychological disorder. We aimed to recruit groups which were as closely age-matched as possible.

2.2.1.3. Additional questionnaire measure

In order to record levels of depression and anxiety in the groups, participants completed the Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) prior to taking part in the lab-based experiment. The HADS is a 14-item, self-report scale. It is designed to measure levels of anxiety and depression using four-point Likert scales, with differing anchor points for each item. Both the anxiety and depression scales have seven items, and scores can range from 0-21. Scores of 0-7 are said to indicate normal levels of anxiety and/or depression, scores of 8-10 indicate borderline enhanced anxiety/depression and scores of 11-21 indicate enhanced anxiety/depression levels. The HADS has been demonstrated to have good internal consistency and construct validity (e.g., Lin & Pakpour, 2017).

2.2.1.4. Normality

Tests of normality were carried out on descriptive and questionnaire data by assessing z-scores for skew and kurtosis. Age, OCI-R total, anxiety and depression scores were all normally distributed.
2.2.1.5. Recruited participant groups – descriptive and questionnaire data
A total of 19 OC participants and 18 Controls were recruited to take part in the study. Five OC participants and four Controls were removed from the analysis for the following reasons. Of the OC participants, two were removed because hoarding was their primary OC symptom, and one because of failure to understand the task (50% error rate in both conditions). Two Control participants were removed because of group age-matching issues. When age was analysed, these two participants (39 and 41 years old) were significant outliers in the Control group. Additionally, following screening of the data, it was decided that participants in both groups with extreme borderline scores around the OCI-R total cut-off of 21 would be excluded from the analysis (scores: OC = 21; Control = 20). This was to provide clearer differentiation between the groups in terms of obsessive-compulsiveness. Two OC participants (both scoring an OCI-R total of 21) and two Controls (both scoring an OCI-R total of 20) were removed. Following the exclusions, the dataset of this study comprised 14 OC and 14 Control participants. As can be seen in Table 2.1, the OC group comprised 14 females and 0 males, while the Control group comprised 11 females and 3 males. The OC group had a mean age of 19.8 ± 0.4 (range: 18-23 years). The Control group had a mean age of 21.8 ± 0.8 (range: 18-28 years). These figures were numerically similar, but the difference was marginally significant \((t(26)=2.102, p=0.049, d=0.8)\). As expected, the OC group mean total OCI-R score (34.1 ± 2.4) was significantly higher than that of the Control group (9.6 ± 1.3) – \((t(26)=8.833, p<0.001, d=3.3)\). Likewise, the OC group mean HADS anxiety score (9.8 ± 0.9) was higher than the equivalent Control group score (5.1 ± 0.5) – \((t(26)=4.519, p<0.001, d=1.7)\). The OC mean anxiety score was in the measure’s borderline enhanced range (scores between 8 and 10), while the Control mean was in the normal range (scores between 0 and 7). However, there was no difference in depression between the groups \((t(21.132)=1.284, p=0.213, d=0.4)\), and the scores for both groups were in the measure’s ‘normal’ range (scores between 0 and 7) – OC: 3.1 ± 0.7; Control: 2.1 ± 0.4.
Table 2.1. OC and Control group descriptive details and questionnaire scores (mean ± SE). Score ranges reported in brackets.

<table>
<thead>
<tr>
<th></th>
<th>OC</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of participants</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Age</td>
<td>19.8 ± 0.4 (18-23)</td>
<td>21.8 ± 0.8 (18-28)</td>
</tr>
<tr>
<td>Gender</td>
<td>14f/0m</td>
<td>11f/3m</td>
</tr>
</tbody>
</table>

OCI-R

<table>
<thead>
<tr>
<th></th>
<th>OC</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>34.1 ± 2.4 (24-54)</td>
<td>9.6 ± 1.3 (1-18)</td>
</tr>
</tbody>
</table>

HADS

<table>
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<tr>
<th></th>
<th>OC</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety</td>
<td>9.8 ± 0.9 (3-16)</td>
<td>5.1 ± 0.5 (2-8)</td>
</tr>
<tr>
<td>Depression</td>
<td>3.1 ± 0.7 (0-9)</td>
<td>2.1 ± 0.4 (0-5)</td>
</tr>
</tbody>
</table>

2.2.2. Overall Procedure

The participants completed the OCI-R screening questionnaire via email in advance of being assigned to one of the two experimental groups. Before the study, they were also emailed an information sheet giving details about the experiment.

The experiment took place in a Brain and Behaviour Group laboratory at the University of Surrey. On arrival, the participants were asked to confirm that they had read the information sheet and were asked to sign an informed consent form. Following this, they completed the HADS questionnaire. The participants then took part in the main experiment, which lasted approximately 45 minutes. On completion, the participants were paid or given lab tokens to compensate for their time. A flowchart representation of the overall study procedure is in Figure 2.1.
2.2.2.1. Piloting
The experimental task used Study 1 had been used previously in a Master’s degree dissertation project carried out by the thesis author. A total of 19 participants took part in this study.

2.2.3. PoP experiment

2.2.3.1. Experimental stimuli and task
The experiment was presented using Experimental Run Time System (ERTS) software. Stimuli were presented on a computer monitor against a black background. They consisted of search arrays comprising four coloured diamond shapes (all 1.5° x 1.5°). These were positioned at equal distance from a central white fixation cross, forming a square shape (5.6° x 5.6°). The stimuli colours used were red, green and blue. Stimuli in each array comprised one target and three distractors. The three distractors were uniformly coloured, but always a different colour than the target – for example, when an array contained green distractors, the target was either red or blue. Each diamond had a cut (0.5°) to either its top or bottom point. This cut position (either top or bottom) was equiprobable for each stimulus in every trial presentation. The task of the participants was to locate the odd-coloured target in each search array. They were then asked to state whether the cut on this target was at the top or the bottom of the shape. They did this via a key pad with corresponding top and bottom buttons, responding using a finger press. Participants were asked to perform as quickly and accurately as they could. The position of the target diamond was equiprobable and random for each trial. Stimuli were of equal luminescence. Participants viewed the stimuli at a distance of one metre. Search arrays were presented for 150ms. The inter-trial interval was two seconds. The central fixation cross remained on-screen throughout each block of trials. Participant key-press responses to each trial were recorded in the two seconds from stimulus onset to the appearance of the following presentation.
2.2.3.2. Experimental conditions

There were two conditions in the task – a Pure condition and a Mixed condition.

*Figure 2.2. The structure of an inter-trial sequence in the Pure condition.*

**Pure condition:** In the Pure condition, trials were presented in six blocks, with 48 presentations per block. In 24 of these trials, the target diamond was cut at its top point. In the remaining 24, it was cut at its bottom point. In each set of 24, there were six trials for each of the four possible different target positions. In each block, the target and distractor colours remained the same, although target shape and position randomly changed between trials. However, the colour of the target and distractors changed with each block. Participants were told by an on-screen message, presented in advance of each block, which colours the target and distractors would be during that block. Block order was counterbalanced across participants. The Pure condition trial sequence is in Figure 2.2.
Figure 2.3. The structure of the sequences in the Mixed condition, showing versions of the six inter-trial types (note, this figure also appears in Section 1.11.2).

Mixed condition: In the Mixed condition, trials were presented in eight blocks of 96 trials. In each trial in these blocks, the colour of the target could be any of the three colours used in the study (red, green or blue). One of the two other colours was then used for the distractors. All colour combinations and target positions were presented randomly and equiprobably. These manipulations resulted in the creation of a six inter-trial types (see Figure 2.3. and Table 2.2.). In 48 of the 96 trials per block, the target diamond was cut at its top point. In the other 48, it was cut at its bottom point. Participants were told by an on-screen message, presented in advance of each block, that the colours of target and distractors could be drawn from any of the three possible colours and would change randomly in that block. As such, participants had less information available to them about the exact nature of the targets and distractors in the Mixed condition blocks than in Pure condition blocks (in which they were told what colour the targets and distractors would be in each block in advance of each block).
Table 2.2. Distractor/target characteristics, in relation to trial N-1, of the six inter-trial types in the Mixed condition. Shortened titles for inter-trial types used in this report are in brackets.

<table>
<thead>
<tr>
<th>Inter-trial type</th>
<th>Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Repetition (FR)</td>
<td>Target/distractor colour remains the same</td>
</tr>
<tr>
<td>Partial Repetition 1 (PRnewD)</td>
<td>Target same, new distractor</td>
</tr>
<tr>
<td>Partial Repetition 2 (PRnewT)</td>
<td>Distractor same, new target</td>
</tr>
<tr>
<td>Partial Swap 1 (PSnewD)</td>
<td>Old distractor is new target, new distractor (third colour)</td>
</tr>
<tr>
<td>Partial Swap 2 (PSnewT)</td>
<td>Old target is new distractor, new target (third colour)</td>
</tr>
<tr>
<td>Full Swap (FS)</td>
<td>Old distractor is new target, old target is new distractor</td>
</tr>
</tbody>
</table>

Prior to data collection, participants completed two practice blocks – 32 Pure trials (red target, green distractors), and 48 Mixed trials. The order in which the Pure and Mixed conditions were presented in the experiment was counterbalanced across participants.

2.2.3.3. Target activation and distractor inhibition trials

Following Eimer et al., (2010), target activation trials in the Mixed condition were considered to be PRnewD and PSnewT presentations. Distractor inhibition trials were considered to be PRnewT and PSnewD presentations – see Figure 2.4.

**Figure 2.4.** A – Example target activation sequences in the Mixed condition. In PRnewD trials, the target is repeated, but distractors change. In PSnewT trials, the distractors are the same colour as the previous target and the distractors change. B - Example distractor inhibition sequences in the Mixed condition. In PRnewT trials, the distractors are repeated, but the target changes colour. In PSnewD trials, the target is the same colour as the previous distractors, but the new distractors change. (note, these figures also appear in Section 1.11.2).
2.2.4. Data analysis

The reaction times (RTs) of correct responses were analysed, along with rates of choice errors. These data were recorded in time window between 100ms and 1,500ms. Numbers of early responses (0-100ms), late responses (1,500-2,000ms) and omissions were also recorded. In all analyses, the alpha level of \( p=0.05 \) was used to determine significance. Where ANOVA analysis was carried out, Huynh-Feldt values were used to correct for violations of sphericity. Bonferroni corrections were applied to the post-hoc analysis where necessary. Where Bonferroni-corrected \( p \) values are reported (e.g., \( p_s=0.003 \)), results were calculated using the following formula: \( \alpha=0.05/\text{number of post-hoc tests} \).

Effect size values for Cohen’s \( d \) are reported following \( t \)-test analysis. Effect size values for \( \eta^2_p \) are reported following ANOVA analysis. Following Cohen (1988), the magnitude of effect sizes were considered to be the following – \( d \): small=0.2, medium=0.5, large=0.8; \( \eta^2_p \): small=0.01, medium=0.09, large=0.25. All reported figures and tables display mean values accompanied by standard errors.

PoP effects: These were examined, firstly, by comparing RTs and choice error rates in the Pure and Mixed conditions using mixed two-way 2x2 ANOVAs. In this analysis, condition (Pure, Mixed) was the within-participants factor and group (OC, Control) was the between-participants factor. Secondly, PoP effects within the Mixed condition were analysed with mixed two-way 2x2 ANOVAs. In these analyses, inter-trial type (FR, FS) was the within-participants factor and group (OC, Control) was the between-participants factor.

Target activation and distractor inhibition effects: Following Eimer et al. (2010), target activation and distractor inhibition effects were examined by comparing data from the two partial repetition inter-trial types, as well as from the two partial swap inter-trial types. These were analysed using two mixed two-way 2x2 ANOVAs. The first ANOVA had the within-participants factor of inter-trial type (PRnewD, PRnewT) and the between-participants factor of group (OC, Control). The second had the within-participants factor of inter-trial type (PSnewD, PSnewT) and the between-participants factor of group (OC, Control).

Correlational analysis: As already reported (see Section 2.2.1.5), significant differences in anxiety scores between the groups were recorded. Possible relationships between anxiety scores and experimental findings were examined using Pearson’s \( r \) where group differences in experimental findings were recorded.
2.3. Results

2.3.1 Re-statement of hypotheses

It was predicted that faster reaction times would be recorded by Control participants in repetition sequences than swap sequences (the PoP effect) – **Hypothesis 1.** But it was not known if the PoP effect would be altered in the OC group. If selective attention deficits were apparent, it was expected that the OC group would record different reaction times to those of the Controls – **Hypothesis 2a.** Furthermore, this might have been particularly notable in the six-level Mixed condition because it involved increased demand on attentional resources – **Hypothesis 2b.** However, if selective attention deficits were not apparent among OC participants, there should be no differences in reaction times between the groups – **Hypothesis 2c.** No specific predictions were made in relation to the operation of target activation and distractor inhibition processes.

2.3.2. PoP effect

The basic PoP was demonstrated. As can be seen in Figure 2.5, participants recorded faster mean reaction times in Pure trials (534 ± 13ms) than in Mixed trials (632 ± 16ms). OC participants were slower than Controls in both the Pure condition (OC: 566 ± 20ms; Controls: 502 ± 18ms) and the Mixed condition (OC: 674 ± 29ms; Controls: 590 ± 16ms). This was confirmed in the statistical analysis. A mixed 2x2 ANOVA, with the factors condition (Pure, Mixed) and group (OCs, Controls), revealed a main effect of condition ($F(1,26)=101.797, p<0.001, \eta_p^2=0.797$) and a main effect of group ($F(1,26)=6.456, p=0.017, \eta_p^2=0.199$). The main effect of condition had a very large effect size, while the main effect of group had a medium-to-large effect size. These findings confirmed **Hypothesis 1** and **Hypothesis 2a.** However, the interaction between group and condition was not significant ($F<1$), indicating that there was no enhancement of the PoP effect in the OC group with the increased attentional demands of the Mixed condition. This meant **Hypothesis 2b** could be rejected.
Figure 2.5. Mean reaction times recorded by OC and Control participants in the Pure and Mixed conditions (main effect of group: $p=0.017$).

As can be seen in Figure 2.6, participants were faster in Mixed condition full repetition trials (600 ± 15ms) than they were in Mixed condition full swap trials (664 ± 17ms). OC and Control groups recorded their fastest Mixed condition reaction times in the FR trials, and their slowest reaction times.
in the FS trials. However, OC participants were slower than Controls in both FR (OC: 642 ± 28ms; Controls: 559 ± 15ms) and FS trials in the Mixed condition (OC: 711 ± 30; Controls: 619 ± 19ms). This finding was confirmed with a mixed 2x2 ANOVA, with the factors inter-trial type (FR, FS) and group (OCs, Controls). This revealed a main effect of inter-trial type ($F(1,26)=190.087$, $p<0.001$, $\eta^2_p=0.88$) and a main effect of group ($F(1,26)=6.875$, $p=0.014$, $\eta^2_p=0.209$). The main effect of group, again, had a medium-to-large effect size. The main effect of inter-trial type had a very large effect size. There was no interaction between both factors ($F<1$) which means that no enhancement of the PoP effect in the OC group was demonstrated. Notably, OC participants were slower than Controls in all six Mixed condition inter-trial types – see Figure 2.7. These findings further confirmed Hypotheses 1 and 2a, but suggested Hypothesis 2b should be rejected.

![Figure 2.7](image)

**Figure 2.7.** Mean reaction times recorded by OC and Control participants in each Mixed condition inter-level sequence type.

### 2.3.3. Target Activation vs. Distractor Inhibition

In the Mixed condition, target activation (TA) levels were considered to be the PRnewD and PSnewT inter-trial types. Distractor inhibition (DI) levels were considered to be the PRnewT and PSnewD inter-trial types. Following Eimer et al. (2010), planned comparisons were carried out to examine possible target activation and distractor inhibition effects in the partial repetition and partial swap levels of the Mixed condition
2.3.3.1. Partial repetition analysis – PRnewD (TA) vs. PRnewT (DI)

When the partial repetition levels were examined, OC participants were found to have recorded numerically faster reaction times when presented with distractor inhibition arrays (PRnewT – 642 ± 28ms) than when shown target activation trials (PRnewD – 659 ± 31ms). However, Controls were numerically faster in target activation trials (PRnewD – 571 ± 17ms) than distractor inhibition equivalents (PRnewT – 576 ± 16ms) – see Figure 2.8. A mixed 2x2 ANOVA, with the factors inter-trial type (PRnewD, PRnewT) and group (OCs, Controls), revealed a significant main effect of group ($F(1,26)=5.245, p=0.03, \eta^2_p=0.168$) and a significant interaction between group and inter-trial type ($F(1,26)=6.33, p=0.018, \eta^2_p=0.196$). A post-hoc paired samples t-test revealed that OC participants were significantly slower in the PRnewD inter-trial type (TA) than in the PRnewT inter-trial type (DI) – $t(13)=2.939, p_c=0.012, d=0.12$ (Bonferroni corrected at $p=0.025$). However, this effect size is very small. No such difference was found for the Control group ($t<1$).

2.3.3.2. Partial swap analysis – PSnewT (TA) vs. PSnewD (DI)

Comparison of reaction times between the partial swap inter-trial types using 2x2 mixed ANOVA analysis revealed the expected main effect of group ($F(1,26)=5.982, p=0.022, \eta^2_p=0.187$). However,
no significant main effect of inter-trial type \( (F(1,26)=1.209, p=0.282, \eta_p^2=0.044) \) was found, nor was there any interaction between group and inter-trial type \( (F<1) \), unlike in the analysis of the equivalent partial repetition inter-trial types – see Figure 2.8.

2.3.4. Choice error rates

No differences in mean choice error rates were found. OC participants recorded a mean choice error rate of 6.6 ± 1% in the Pure condition and 6.2 ± 2% in the Mixed condition. By comparison, the Control group mean choice error rate was 6 ± 1% in the Pure condition and 6.1 ± 1% in the Mixed condition. No differences in mean choice error rates were found when comparing conditions and groups. No deeper choice error rate comparisons (e.g., between FR and FS inter-trial types in the Mixed condition) were made because of low data numbers.

2.3.5. Correlational analysis

No relationship was found between OC group anxiety scores and the group’s reaction times in the Pure condition \( (r=-0.072, N=14, p=0.80) \), the Mixed condition \( (r=-0.099, N=14, p=0.73) \), Mixed FR trials \( (r=-0.12, N=14, p=0.68) \) or Mixed FS trials \( (r=-0.044, N=14, p=0.88) \). Likewise, there was no relationship was between Control group anxiety scores and their reaction times in the Pure condition \( (r=0.32, N=14, p=0.25) \), the Mixed condition \( (r=0.33, N=14, p=0.23) \), Mixed FR trials \( (r=0.35, N=14, p=0.21) \) or Mixed FS trials \( (r=0.24, N=14, p=0.39) \).

2.3.6. Early responses, late responses and omissions

OC participants recorded early responses (0-100ms) in 0.04% of trials, and Controls in 0.03% of trials. OC participants recorded late responses (1,500-2,000ms) in 0.6% of trials, and Controls in 0.2% of trials. The omission rate in the OC group was 0.3%, and in the Control group it was 0.1%. No further analysis was carried out because of the low data numbers.

2.4. Discussion

Study 1 aimed to look for evidence of possible selective attention dysfunction and bias in a non-clinical OC population. It used a PoP visual search design, which, as far as we can ascertain, has yet to be used with OC populations. This thesis argues that the PoP paradigm is more advantageous for
the examination of selective attention processes than those which have previously been used in the majority of research in this area.

2.4.1. Hypotheses and findings

In Hypothesis 1, it was predicted that the Control group would produce faster reaction times in repetition sequences than in swap sequences (the PoP effect). It was not known if an alteration of PoP effect would be recorded by the OC group. If selective attention deficits were apparent in this group, it was expected that they would record different reaction times to those of the Controls. This was Hypothesis 2a. Moreover, differentiated performance might have been particularly notable in the Mixed condition because of its elevated demands on attentional resources – Hypothesis 2b. However, if selective attention deficits were not apparent among OC participants, there would be no differences in reaction times between the groups – Hypothesis 2c. No direct predictions were made regarding group differences in target activation and distractor inhibition sequence performance.

The results of the study revealed that the PoP effect was recorded. As expected, the PoP effect was evident in the Control group, confirming Hypothesis 1. But it was also apparent in the OC group. Thus, participants responded significantly faster to targets in repetition-based inter-trial sequences than swap-based sequences. This was apparent when comparing both reaction times in Pure (repetition-based) and Mixed (swap-based) conditions and when comparing reaction times in FR and FS inter-trial sequences within the Mixed condition. Furthermore, the effect sizes for both these findings were very large. However, the OC group recorded significantly slower reaction times to targets than the Control group across the study. This was apparent in both the Pure and Mixed conditions, and in each of the six inter-trial sequences within the Mixed condition. The effect sizes for these findings were medium-to-large. Thus, although the operation of the PoP effect was in line with previous research using healthy participants (e.g., Eimer et al., 2010; Maljkovic & Nakayama, 1994), there was significant lag in task performance among OC participants. This, then, confirmed Hypothesis 2a, and suggested the presence of altered selective attention processing in the OC group. It also meant that Hypothesis 2c, which suggested that there would be no difference in performance between the groups, could be rejected. Interestingly, however, there was no enhancement of reaction times in the OC group with increased demands on attentional resources. Despite the extra requirements and greater unpredictability of the Mixed condition (three possible stimuli colours and no pre-task information about target colour), there was no additional increase in reaction times recorded by the OC group in this condition. As such, Hypothesis 2b was not confirmed. There was also no difference in choice error rates between the two groups, with both recording errors in approximately 6% of trials. Rates of early responses, late responses and omissions were extremely low in both groups.
The study found evidence of differentiated performance in the OC group in target activation and distractor inhibition inter-trial sequences in the Mixed condition. No specific predictions were made for this part of the study. However, when the partial repetition sequences were analysed, OC participants were found to have recorded significantly slower reaction times in PRnewD trials (target activation sequences) than PRnewT trials (distractor inhibition sequences). The equivalent reaction times for the Control group, by contrast, were not significantly different. This is an interesting finding, as it suggests that the hypothesised equal balance of target activation and distractor inhibition processes which are believed to underpin the PoP effect in healthy populations (Eimer et al., 2010; Lamy et al., 2008) could be altered in OC populations. However, the circumstances in which such altered reaction time performance occurs might be specific. No equivalent differences in OC group reaction times were found when partial swap sequences were analysed. Additionally, the magnitude of effect size for this finding was very small ($d=0.12$). Consequently, caution needs to be exercised here when considering the meaning of this result.

2.4.2. Interpretation and implications

The findings of the present study are supportive of previous PoP research using healthy populations, while also providing new evidence in favour of theories of altered selective attention and bias in OC populations. The study used a paradigm design based on those deployed by Maljkovic and Nakayama (1994) and Eimer et al. (2010) in their examinations of PoP in healthy populations. Both these studies, along with substantial additional research (e.g., Lamy et al., 2010), have demonstrated the robustness and replicability of the PoP effect, and its utility as a tool for assessing the operation of selective attention processes. Additionally, the study by Eimer et al. (2010), further demonstrated the equal functioning of two independent mechanisms – target activation and distractor inhibition – underpinning the operation of PoP (see also Lamy et al., 2010). In the present study, the PoP effect was clearly apparent in the Control group, as expected. Meanwhile, the performance of the Control group in the six-level Mixed condition was also in line with the findings of Eimer et al. (2010) – no differences between target activation and distractor inhibition performance were found in this group, suggesting the operation of an equal balance of the two mechanisms.

However, the OC group performance was different to that of the Controls. Not only were they slower in their reaction times than the Controls across the whole study, they were also specifically slow in Mixed condition partial repetition sequences based on target activation when compared to those based on distractor inhibition. Given the robustness of the PoP paradigm as a measure of selective attention, these findings are, at the very least, suggestive of an alteration of selective attention in the OC group. Caution should be applied because little visual research study has been carried out in this area, and PoP is a new approach to take in understanding selective attention and OCD. However, given the
mixed nature of previous research in OCD and selective attention, the findings of the present study highlight how the PoP paradigm could be considered an extremely useful method of examining selective attention and OC behaviour in the future.

The study found no evidence that OC participants were additionally impaired in their performance by the increased attentional demands of the Mixed condition. In this condition, targets and distractors were drawn randomly from three colours, and the only information presented to participants in advance of each block was that target colour would be randomly red, green or blue. This is in comparison to the relatively lower attentional demands of the Pure condition, in which only two stimuli colours were used per block. Additionally, clear information was given to participants in advance of each Pure block about what colour targets and distractors to expect. While the OC group was significantly slower in their reaction times than Controls in this condition, this difference of slowness was only equivalent to that between the groups in the Pure condition.

However, it may also be the case that the performance of the OC group was particularly altered in only specific sequences in the Mixed condition. The study found that the OC group were particularly slow in PRnewD inter-trial sequences (target activation) when compared with their performance in PRnewT inter-trial sequences (distractor inhibition). It is notable that PRnewD sequences involved new distractors but a repeated target. It could be concluded that the OC group made less gain from target activation in these sequences because of a need to first rule-out the new distractors as targets – reflecting an attentional bias in the OC group, but not Controls, towards irrelevant information. Slowed performance then occurred because the distracting information had been changed from the previous trial. However, in PRnewT sequences the distracting information remained the same in successive trials, enabling a speedier process of elimination of these items as potential targets by the OC group in comparison to their performance in the PRnewD sequences. This argument would suggest that a difficulty in inhibiting distracting information in the OC group might be at the root of this particular finding – a conclusion which would be in line with some previous research examining selective attention and OCD (e.g., Clayton et al., 1999; Enright & Beech 1990, 1993; Kaplan et al., 2006; Swerdlow et al., 1999). However, it is unclear to what extent the differentiated OC group reaction times in the partial repetition sequences reflect slowed performance in PRnewD trials or faster performance in PRnewT trials. Moreover, and as is stated Section 2.4.1, although the difference in PRnewD and PRnewT reaction times recorded by the OC group was significant, the size of this effect was very small (d=0.12). This may indicate that this particular finding has little clinical or theoretical value. However, it is also possible that this might reflect the use of simple, coloured-shape stimuli in the study, and the choice to recruit a homogenous OC group. It could be the case that larger effects might be achieved in visual search studies which tighten their focus of examination to specific
OC subtypes, and which use stimuli which have symptom-specific meaning to the participants recruited. This needs further examination.

It should be noted that differing OC group performance was not found in the partial swap target activation (PSnewT) and distractor inhibition (PSnewD) sequences. However, it is notable that in both the partial swap sequences the distractors change in the successive trials. Among OC participants, the deleterious effect of needing to attend to the distractors prior to switching to the target might have resulted in more equal performance in the partial swap sequences than in the partial repetition equivalents.

The findings of the present study are in line with studies which have suggested that OC populations can be distracted by irrelevant information in cognitive tests (e.g., Clayton et al., 1999; Enright & Beech 1990, 1993; Kaplan et al., 2006; Swerdlow et al., 1999). No relationship was found between anxiety levels and reaction times in either group, while levels of depression did not differ between the groups. This suggests that comorbid anxiety and depression, as measured by the HADS, had no confounding effect on the study. The results also provide behavioural support for biological models of OCD which have consistently found evidence of dysfunction in brain areas associated with attentional processing, particularly the DLPFC circuitry (Menzies et al, 2008). Although stimuli used in the present study were neither emotional nor symptom-salient, participants were clearly instructed to ignore distractors – they therefore become a problem to be overcome in the task. It is possible that the OC group were overly focussed on the problem aspect of the task, rather than the goal (the target).

Such conclusions fit with theories of attentional biasing in OC populations (e.g., Bar-Haim et al., 2007 – see Section 1.5). Cognitive-behavioural models of OCD (Salkovskis,1985; Salkovskis & Maguire, 2002) suggest that such biasing is rooted in an exaggerated sense of personal responsibility – and it has an important function in the maintenance of the condition. Furthermore, the findings might be supportive of the hyper-vigilance hypothesis of OCD (e.g., Armstrong & Olatunji, 2012 – see Section 1.5.1.1) in that current trial distractor stimuli may have been overly attended to by the OC group – resulting in slowed reaction times. However, there might also be some support in the findings for the delayed disengagement hypothesis of OCD (e.g., Georgiou et al., 2005; Bradley et al., 2016 – see Section 1.5.1.1), which argues that OC individuals have problems extinguishing a negative focus on stimuli. In the present study, this could have been reflected in the comparatively poor performance by the OC group in the PRnewD inter-trial sequences – in which distractors changed colour in successive trials, but targets remained the same. Such conclusions, however, are tentative because the stimuli used in the present study had no threat or symptom-salient content.
2.4.3. Limitations

The study has a number of limitations. The sample size \((N=28)\) was small – there were 14 participants in both groups. Small sample sizes raise the risk of Type II error (Muller & Roberts, 2005). Post-hoc power analysis, using G*power software, revealed that in order to achieve a small between-groups effect \((\eta_p^2 = 0.01)\) at a recommended statistical power of 0.8 (Cohen, 1988), a sample of size of 780 participants would be required for the present study. For a medium effect \((\eta_p^2 = 0.09)\) the equivalent sample size would need to be \(N=82\), and for a large effect \((\eta_p^2 = 0.25)\) it would need to be \(N=26\). In this study, the effect size observed for the significant group difference in overall reaction times \((\eta_p^2 = 0.199)\) had a power of 0.71, while the effect size for the OC group reaction time difference in PRnewD and PRnewT sequences \((d = 0.12)\) had a power of 0.11. Using Cohen’s (1988) recommended power value of 0.8 as a guide, this suggests the results of this study would have benefitted from the use of a greater number of participants.

Additionally, although individuals with hoarding concerns were excluded from participation in the study, the OC group was otherwise homogenous. Given the evidence of behavioural and neurological differences between OC subtypes (e.g., Bragdon et al, 2018), the studies reported in this thesis which follow (Studies 2, 3 and 4) looked to examine specific OC populations (e.g., checkers) in order to further assess the significance of these findings reported in the present study.

A further limitation of the present study is that, as highlighted in the previous section, the stimuli used were neither symptom-salient nor emotional. Reviewers (e.g., Abramovitch et al, 2013; Muller & Roberts, 2005) have consistently recommended the use of stimuli which has been tailored to specific obsessive-compulsive concerns when studying OC populations. It is interesting that despite the use of only coloured shape stimuli in the present study, performance differences were found between the OC and the Control groups. Given that the PoP effect is considered to be a largely automatic process, this may be reflective of pre-conscious dysfunction in the OC group. However, it is notable that there was no enhancement of reaction times in the OC group with the increased bottom-up demands of the Mixed condition. Additionally, the significant difference in PRnewD and PRnewT reaction times recorded by the OC group was a very small effect. One possibility for this could be that the coloured shape stimuli were not concerning, or threatening, enough to the OC group. The lack of ecological validity in this study perhaps raises questions over what these findings mean in real-world settings. The studies which follow in this thesis look to address such limitations by incorporating emotional stimuli within their designs.
2.4.4. Future research

The present study demonstrates that the PoP paradigm, and visual search experimentation more broadly, are useful ways to gain detailed insights into the operation of selective attention processes in OC populations. In the light of recommendations of reviews (e.g., Abramovitch et al, 2013; Muller & Roberts, 2005), future studies in this area should aim to examine specific OC subtypes (e.g., checkers), while emotional and symptom-salient should be incorporated into the experimental designs. In particular, further examination of the altered balance between target activation and distractor inhibition processes which was found in the OC group in this study, and the relationship of this to attentional and memory bias, is required. Consequently, the studies which follow in this thesis looked to build on the findings of Study 1, examining how far the operation of selective attention in PoP is affected by the presence of emotional stimuli (Study 2), and assessing distractor bias and inhibitory dysfunction when emotional stimuli are presented as targets and distractors in trial sequences (Study 3). In these two studies a Checker population was examined. The final study (Study 4) then looked to assess how far any evidence of attentional biasing reported in the first three studies was reflected in possible biasing in long-term memory. This study looked to further build on the first three studies by examining Checker, Washer and general OC populations, alongside Controls, to assess how far any task performance differences might be reflected in differing OC profiles.

2.4.5. Conclusions

In conclusion, this study has found new evidence of a selective attention deficit in non-clinical OCD. Previous research examining this area has produced inconsistent patterns of results, which may, at least in part, be attributable to design and paradigm-choice issues. This has been the first study to use the PoP paradigm to assess selective attention in an OC population. The present study demonstrated that selective attention processes operate more slowly in OC participants than Controls. This occurs independently of the nature of the inter-trial task – either repetition or swap. However, there are also certain circumstances in which such selective attention deficits may be particularly apparent, as indicated by the slowed reaction times in the OC group when presented with partially-repeated inter-trial sequences featuring new distractors (PRnewD sequences). The results support theories of both attentional biasing towards distracting or task-irrelevant information in OC populations. Further research, with emotional and symptom-salient, is needed to examine these findings in more depth. The studies which follow in this thesis looked to address this.
Chapter 3

Study 2:

The impact of emotional stimuli on the PoP performance of Checkers and Non-Checkers
3.1. Introduction

Study 1 showed that the standard PoP effect (facilitated visual search performance with the repetition of feature-defining aspects of a target from the previous trial) could be demonstrated in a non-clinical OC population, as well as in otherwise healthy individuals. However, the findings of Study 1 revealed that OC participants operated at a differing performance level to that of Controls. Like the Controls, their reaction times were faster in repetition-based inter-trial sequences (repeated target colour across two trials) than in swap-based inter-trial sequences (change of target colour across two trials). But they were significantly slower than Controls in both of these inter-trial sequence types. Additionally, when the PoP effect was examined further by using three rather than two stimuli colours and creating six inter-trial repetition and swap sequence variations, OC participants appeared particularly slow in trials when the target colour had been repeated from the previous trial but the distractor colour had been changed (this finding is examined further in Study 3).

The findings of Study 1 are supportive of theories positing a selective attention deficit and attentional bias with OCD, and it extended evidence of these theories to visual search tasks. The results suggest that, independent of the nature of the inter-trial task (repetition or swap), selective attention processes operate more slowly in OC populations than in otherwise healthy controls. The magnitude of this effect size was medium-to-large. While the stimuli used contained no threat or emotional content, these results are in line with previous research suggesting attentional biasing towards distracting or task-irrelevant material in OC populations.

It is interesting, however, that the study found no additional enhancement of the PoP effect in the OC group in trials which involved heightened attentional demand and bottom-up processing (e.g., trials in the Mixed condition – see Chapter 2). Some theories of OCD suggest that the balance between top-down control and bottom-up processing may be altered with the condition, and OC participants may perform poorly in tasks which place increased demands on attentional resources (De Putter & Koster, 2017). One explanation could lie in the choice of stimuli used. It is argued (e.g., Abramovitch et al, 2013; Muller & Roberts, 2005) that the deployment of simple feature stimuli in experimental tasks (such as the coloured-shapes used in Study 1) may limit the ability of a study to access the deeper operations of OC cognitive processes. This is because such stimuli have no direct relevance to the specific concerns of OC participants. As stated in Chapter 1, attentional bias towards threatening and symptom-specific stimuli has commonly been demonstrated in individuals with OCD (e.g., Armstrong & Olutunji, 2012; Bradley et al., 2016; Moritz et al., 2009; Tata et al., 1996). Indeed, both attentional bias and emotional dysregulation are considered to have roles in the maintenance of the condition (Bar-Haim et al., 2007; Salkovskis & Maguire, 2002). Thus, while Study 1 found evidence
of a general selective attention deficit in a homogeneous OC population, it is possible that more specific findings could be uncovered by increasing the salience and ecological validity of the PoP paradigm to the individuals who are taking part. One way this could be done is by adapting the paradigm for the use of emotional picture stimuli. This was the aim of Study 2.

As already stated in Chapter 1, no previous research appears to have been carried out using the standard PoP paradigm to examine OC populations. However, Kristjánsson et al. (2013) examined the possible impact of neutral and negatively-valanced pictures on the performance of healthy participants in a standard PoP task. In this study, a neutral or a negative emotional picture was shown on screen prior to the presentation of each search array. Search arrays comprised non-emotional, coloured-shape targets and distractors. The PoP effect was recorded (speeded reaction times with target feature repetition), despite the presence of the emotional stimuli. However, the presence of negative stimuli did act to slow reaction times in search arrays when compared with the impact of neutral pictures.

Study 2 looked to adopt a similar approach to that of Kristjánsson et al. (2013). But it looked to examine the impact of symptom-salient emotional stimuli on the performance of a non-clinical OC group in a PoP task. As has already been stated in Chapter 1, a particular concern with some previous cognitive studies into OC behaviour has been the failure to acknowledge the heterogeneity of the condition. As such, Study 2 looked to focus its investigations on an OC Checker population, using visual picture stimuli tailored to checking concerns. In the study, participants were asked to carry out a classic two-colour (red vs. green) PoP task. However, before the presentation of each search array, a single picture from one of three categories (checking, negative or neutral) was shown on screen. Multiple exemplars of each category \(N=16\) pictures) were used. It is conceivable that a single checking picture might be particularly relevant for one Checker, but less salient for another. However, checking-related emotions would be more likely to be triggered in all Checkers with the use of multiple images. Additionally, this approach might lessen the possibility of habituation to stimuli, which has been demonstrated in previous studies of attentional bias in OCD (Amir et al., 2009). A total of 21 non-clinical Checkers took part in the study, along with 22 Non-Checkers. In order to control for comorbid conditions, potential participants with a history of neurological or neuropsychological disorder were excluded from participation.

### 3.1.1. Hypotheses

Following Study 1, it was predicted that faster reaction times would be recorded in repetition-based inter-trial sequences than in swap-based sequences (the PoP effect). This would be apparent for both Checkers and Non-Checkers—**Hypothesis 1**. The study examined whether the PoP effect would be modulated by group and/or picture type. Additionally, it was expected that Checkers would record
slower reaction times than Non-Checkers in all conditions of the task – Hypothesis 2. It was further predicted that slower reaction times would be recorded by both groups in trials following the presentation of negative pictures than in trials following neutral pictures – Hypothesis 3. But it was expected that Checkers would be particularly slow in trials immediately following the presentation of checking pictures. This would not be apparent for Non-Checkers – Hypothesis 4. The study examined whether the effects predicted in Hypotheses 3 & 4 varied according to condition.

3.2. Methods

3.2.1. Participants

Participants were recruited via an advert on the University of Surrey’s Sona Systems participant recruitment website, and also via poster adverts placed around the University of Surrey campus. All participants were University of Surrey students. They received £7.50 for taking part (first or second year Psychology students could opt to receive lab tokens instead of payment). The study received a favourable ethical opinion from the University of Surrey Ethics Committee (see Appendix 2). With the exception of one Checker, all participants had previously taken part in Study 3 (see Chapter 4). Consequently, these two studies have a strongly overlapping sample.

3.2.1.1. Pre-study participant screening

In order to recruit distinct Checker and Non-Checker groups, all potential participants were asked to complete a series of online questionnaires in advance of taking part in the main experiment. They were told that the answers they gave would determine their eligibility for the study. We aimed to recruit age-matched groups. Everyone completing the online questionnaires was entered into a prize draw to win a £30 Amazon voucher. The online questionnaires were programmed in Qualtrics software (Qualtrics, Provo, UT). They included the following:

(i). Demographics and health questionnaire: General questions relating to participant demographics and neuropsychological, neurological and/or psychiatric health history. Potential participants were asked to report whether they had a history of neuropsychological, neurological or psychiatric disorder, any history of clinically diagnosed anxiety or depression, or if they would be uncomfortable in a small, enclosed room (the main computer task took place in a small laboratory room).
(ii). Obsessive-Compulsive Inventory – Revised (OCI-R; Foa et al., 2002): Details of this scale have been provided in Section 1.14.1.2 and Section 2.2.1.2. A total OCI-R score of 21 or above is said to be indicative of OC tendencies (Foa et al., 2002). The OCI-R is composed of six subscales, including a checking subscale – the others being obsessing, washing, ordering, hoarding and neutralising. The present study collected data from the checking subscale (max. score=12).

(iii). Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983): Details of this scale have been provided in Section 2.2.1.3. Scores of 0-7 are said to indicate normal levels of anxiety and/or depression, scores of 8-10 indicate borderline enhanced anxiety/depression and scores of 11-21 indicate enhanced anxiety/depression levels.

3.2.1.2. Inclusion and exclusion criteria
The inclusion criterion for the Checker group was an OCI-R subscale score of ≥5 on the checking subscale. The inclusion criteria for the Non-Checker group were an OCI-R subscale score of ≤1 on the checking subscale and a total OCI-R score of ≤14. This is in line with previous research (e.g., Foa et al., 2002; Hajcak, Huppert, Simons, & Foa, 2004). In order to control for the effects of comorbid conditions, anyone reporting an enhanced score (≥11) on the depression subscale of the HADS questionnaire, or anyone declaring a history of neuropsychological, psychiatric or neurological disorder, or a history of clinically diagnosed depression or anxiety, was excluded from participation. This also applied to anyone who declared that they would be uncomfortable in a small, enclosed room (the experiment took place in small laboratory room). Additionally, anyone reporting a history of colour-blindness, or colour discrimination difficulties, was excluded from taking part. This was because the study involved the differentiation of coloured stimuli. Participants were also checked for possible colour discrimination difficulties prior to taking part in the experiment using the Tests for Colour-Blindness (Ishihara, 1951).

3.2.1.3. Participant data collected from screening
A total of 130 people took part in the online questionnaires. Of these, 25 people were identified as potential candidates for the Checker group, and 38 were potential Non-Checker group members. These people were invited to take part in the main experiment. A total of 67 exclusions were made for the following reasons: (1) failure to meet inclusion criteria in demographic and health questionnaire (N=21); (2) reporting an OCI-R checking subscale score of ≥2 but ≤4 (N=44); and (3) reporting an OCI-R checking subscale score of ≤1 but a total OCI-R score of ≥14 (N=2). No potential participants were excluded because of enhanced scores on the HADS depression subscale.
3.2.1.4. Recruited participants

Forty-six participants took part in the main, lab-based experiment. Two participants (one Checker, one Non-Checker) were excluded from the analysis because of failure to understand the task. A second Checker participant was also excluded because of an extreme outlying choice error rate score (23% choice error rate). This left a total of 21 participants in the Checker group and 22 participants in the Non-Checker group (see Table 3.1).

Tests of normality were carried out on descriptive and questionnaire data by assessing z-scores for skew and kurtosis. OCI-R checking and total scores were all normally distributed. Age, anxiety and depression scores were not normally distributed. The Checker group (17 females, 4 males) had a mean age of 21.48 ± 0.8 years (range: 18-32 years). The Non-Checker group (22 females) had a mean age of 20.45 ± 0.8 years (range: 18-32 years). This age difference was not significant (U(N=43)=174.5, z=-1.408, p=0.159, d=0.4).

Table 3.1. Descriptive details and questionnaire scores (mean ± SE) for the Checker and Non-Checker groups. Score ranges reported in brackets.

<table>
<thead>
<tr>
<th></th>
<th>Checker</th>
<th>Non-Checker</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of participants</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Age</td>
<td>21.48 ± 0.8 (18-32)</td>
<td>20.45 ± 0.8 (18-32)</td>
</tr>
<tr>
<td>Gender</td>
<td>17f/4m</td>
<td>22f/0m</td>
</tr>
<tr>
<td>OCI-R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checking subscale</td>
<td>7.38 ± 0.5 (5-12)</td>
<td>0.36 ± 0.1 (0-1)</td>
</tr>
<tr>
<td>Total</td>
<td>31 ± 2.3 (14-50)</td>
<td>5.8 ± 0.7 (1-13)</td>
</tr>
<tr>
<td>HADS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anxiety</td>
<td>9.86 ± 0.7 (2-16)</td>
<td>5.04 ± 0.5 (0-11)</td>
</tr>
<tr>
<td>Depression</td>
<td>4.71 ± 0.6 (0-10)</td>
<td>2.04 ± 0.4 (0-7)</td>
</tr>
</tbody>
</table>
As expected because of the recruitment inclusion/exclusion criteria, the Checker group mean OCI-R checking score (7.38 ± 0.5) was significantly higher than that of the Non-Checker group (0.36 ± 0.1) – ($t(21.371)=12.173$, $p<0.001$, $d=3.7$). Additionally, the Checker group mean total OCI-R score (31 ± 2.3) was significantly higher than that of the Non-Checker group (5.8 ± 0.7) – ($t(23.716)=9.989$, $p<0.001$, $d=3$). The Checker group mean HADS anxiety score (9.86 ± 0.7) was higher than that of the Non-Checker group score (5.04 ± 0.5) – ($U(N=43)=63$, $z=-4.101$, $p<0.001$, $d=1.5$). The Checker group mean anxiety score was within the measure’s borderline enhanced range (scores between 8 and 10), while the Non-Checker group mean was in the normal range (scores between 0 and 7). The mean depression score was higher in the Checker group (4.71 ± 0.6) than the Non-Checker group (2.04 ± 0.4). While this difference was significant ($U(N=43)=106.5$, $z=-3.05$, $p=0.002$, $d=1$), the mean scores for both groups fell within the normal range of the measure (scores between 0 and 7).

### 3.2.2. Procedure

#### 3.2.2.1. Overall procedure

The experiment took place in the Brain and Behaviour laboratory at the University of Surrey. On arrival, participants were asked to read an information sheet which detailed what they would be asked to do during the task. Once this was completed, they signed an informed consent form. They then carried out a computer-based task lasting around 45 minutes. On completion, participants were fully debriefed about the experiment, and were given the opportunity to ask any questions they had. They were then compensated for their time, and thanked for their participation (note, participants were also debriefed about the experiment reported Study 3 at this time point. This debriefing had been delayed because of the similar nature of the tasks). A flowchart representation of the overall study procedure is in Figure 3.1.
3.2.2.2. PoP task

The experiment was programmed using Presentation software (Version 16.5, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com). Stimuli were presented on a flat-screen desktop PC monitor against a black background at a distance of one metre. Search arrays comprised four coloured diamond shapes (all 1.5° x 1.5°), positioned at equal distance from a central white fixation cross. This formed a square shape (5.6° x 5.6°). The stimulus colours used were red and green. There was one target and three distractors in every search array presentation. The three distractors were uniformly coloured, and always the alternative colour to the target. Thus, when an array contained red distractors, the target was always green. Each search array diamond had a cut to either its top or bottom point. There were equal numbers of target presentations in each of the four possible search array positions in each block of the experiment, and there were equal numbers of top cut and bottom cut target presentations in each block of the experiment. Distractor cut position was randomised for each of three diamond shapes in each trial. The experiment was piloted with two participants.
Figure 3.2. A single trial structure from the present study. A picture image (in this example, a checking image) was presented for 1,000ms, followed by a fixation cross for 80ms. A search array was then presented for 150ms. The task of the participant was to report whether the ‘odd-one-out’ target is cut to the top or the bottom.

3.2.2.3. Picture stimuli

The present study presented photographic pictures on-screen. Three categories of pictures were used – checking, negative and neutral. Each category comprised 16 picture exemplars. The checking picture stimuli used in the study are part of a larger stimuli set of images which has been developed for the experimental assessment of aspects of OCD and OC subtypes (Simon, Kischkel, Spielberg, & Kathmann, 2012). The negative and neutral picture stimuli were taken from the International Affective Picture System database (Lang, Bradley, & Cuthbert, 2008).

All the pictures used in the present study, along with additional exemplars of each category, had previously been rated for valence and arousal by both Checker and Non-Checker participants (N=11 per group) in a validation study by Gomes-Victorino (2017). The specific pictures selected for the present study from this larger stimuli set were chosen following analysis of the ratings data recorded by Gomes-Victorino (2017). This analysis revealed that the checking pictures used in the present study were rated as significantly more negatively-valenced by Checkers than by Non-Checkers. A mixed 3x2 ANOVA, with the factors picture category (checking, negative, neutral) and group...
(Checkers, Non-Checkers), revealed a significant interaction between group and picture type
\[ F(1.899, 56.978) = 4.2, \ p = 0.022, \ \eta^2_p = 0.123 \]. Post-hoc \( t \)-tests found a significant difference in higher negative valence scores given for checking pictures by Checkers than those by Non-Checkers
\( (p = 0.003, \ d = 1.1) \). There were no group differences in valence ratings for the selected negative and neutral pictures. Similar analysis found that Checkers gave significantly higher arousal ratings for the checking \( (p < 0.001, \ d = 1.8) \) and negative pictures \( (p = 0.001, \ d = 1.2) \) used in the present study than Non-Checkers (post-hoc tests carried out following a significant group/picture type interaction – \[ F(2.60) = 4.247, \ p = 0.019, \ \eta^2_p = 0.124 \]). There were no differences in arousal ratings given by Checkers and Non-Checkers for the selected neutral pictures. For figures and further details relating to these analyses see Appendix 3.

3.2.2.4. Trial structure and experimental conditions

A typical trial structure is shown in Figure 3.2. Prior to the presentation of each search array, participants were shown a single rectangular landscape photographic picture on the screen. This image was centrally-presented, at a visual angle of 8.6° x 6.3°. The picture could be drawn randomly from one of the three categories – checking, negative or neutral pictures. Each picture appeared twice per block. Pictures were presented for 1,000ms. They then disappeared, and a fixation cross was shown for 80ms. Search arrays were then presented for 150ms. There was a jittered interval of 1,500-2,000ms. The central fixation cross remained on-screen throughout, except during the presentation of the picture images. Participant responses were recorded in a 1,500ms period from search array stimulus onset. Participants were asked to find the odd-coloured diamond target in each search array. They were then asked to state where the cut on this target was located – whether it was at the top or the bottom of the shape. This was done using a key pad with corresponding top and bottom buttons, with responses made via finger press. Participants were asked to perform this task as quickly and accurately as they could.

There were three conditions in the experiment. In the Repetition condition, the colours of the targets and the distractors in each trial remained the same throughout a block of trials. In the Swap condition, the colours of the targets and distractors alternated with each successive trial throughout a block of trials. Finally, in the Mixed condition, the colours of the targets and distractors repeated or alternated randomly with every successive trial in a block. Before each block, information was presented to participants on-screen detailing what to expect in the upcoming trials. Before repetition blocks, participants were told what colour the target would be (red or green). Before swap blocks, they were told that the target colour would alternate between red and green with each trial. Finally, before the mixed blocks, participants were informed that targets could be randomly either red or green.
3.2.2.5. Block design

The experiment comprised eight blocks, with 96 trials per block. This gave a total of 768 trials. There were two Repetition condition blocks of trials (one with red targets, one with green targets), two Swap condition blocks (one starting with red targets, one starting with green targets) and four Mixed condition blocks. We used four Mixed condition blocks rather than two (as with the repetition and swap conditions) for the following reasons. In each of the Repetition and Swap blocks, there were 32 trials for each of the three picture image category types. But because the Mixed blocks included both repetition and swap trial types, there would be only half as many trials per level (repetition vs. swap) for each picture image category type in each of these blocks. Thus, the number of Mixed blocks was doubled to enable the same amount of repetition and swap trial presentations per picture type as there were in the repetition and swap blocks. Each picture image in all three categories appeared twice per block. Presentation of pictures was randomised, and they could be selected from any of the three categories. The order of presentation of the blocks was randomised for each participant.

An additional ‘dummy’ search array was added to the beginning of each block. This was in order to provide an inter-trial sequence for first proper trial. This was fixed for each block and reflected the particular content of each block. Thus, the repetition block in which targets were red began with a dummy search array featuring a red target. The repetition block in which targets were green began with a dummy search array featuring a green target. The swap block featuring a red target in its first proper trial began with a dummy search array featuring a green target – with the opposite occurring for the swap block featuring a green target in its first proper trial. The mixed blocks always began with dummy search arrays featuring red targets. No picture images were presented before the dummy search arrays. Data relating to the dummy search arrays has not been included in the analysis.

3.2.3. Data analysis

The reaction times (RTs) of correct responses and rates of choice errors were analysed. Data were recorded in a time window between 100ms and 1,500ms. Numbers of early responses (0-100ms) were recorded, while late responses (1,400-1,500ms) and omission rates were also examined. The alpha level of $p=0.05$ was used to determine significance in all analyses. In ANOVA analysis of data, Huynh-Feldt values were used to correct for violations of sphericity. Bonferroni corrections were used in post-hoc analysis. Where Bonferroni-corrected $p$ values are reported (e.g., $p=0.003$), results were calculated using the following formula: $\alpha = 0.05/\text{number of post-hoc tests}$. Effect size values for Cohen’s $d$ (following $t$-test analysis) and for $\eta_p^2$ (following ANOVA analysis) are reported. Following Cohen (1988), the magnitude of effect sizes were considered to be the following – $d$: small=0.2, medium=0.5, large=0.8; $\eta_p^2$: small=0.01, medium=0.09, large=0.25. All figures and tables display mean and standard error values.
**PoP effects:** PoP effects were examined by comparing RTs and choice error rates in the Pure, Swap and Mixed conditions using mixed 3x2 ANOVAs. In these analyses, condition (Pure, Swap, Mixed) was the within-participants factor and group (Checker, Non-Checker) was the between-participants factor. Additionally, PoP effects within the Mixed condition were analysed with mixed 2x2 ANOVAs. In these analyses, Mixed inter-trial type (repetition, swap) was the within-participants factor and group (Checker, Non-Checker) was the between-participants factor.

**Impact of picture type:** The impact of picture type was examined by comparing RTs in the Pure, Swap and Mixed conditions using mixed 3x3x2 ANOVAs. These featured the within-participants factors condition (Repetition, Swap, Mixed) and picture type (neutral, negative, checking), and the between-participants factor group (Checker, Non-Checker). Impact of picture type was also examined within the Mixed condition using mixed 2x3x2 ANOVAs. These featured the within-participants factors Mixed inter-trial type (repetition vs. swap) and picture type (neutral, negative, checking), and the between-participants factor group (Checker, Non-Checker). Analysis of choice error rates for each picture type in each condition was not carried out due to low data numbers. As such, choice error rates for each picture type were combined across conditions and analysed with a mixed 3x2 ANOVA. This featured the within-participants factor picture type (neutral, negative, checking) and the between-participants factor group (Checkers, Non-Checkers).

**Correlational analysis:** As reported (see Section 3.2.1.4), significant differences in anxiety and depression scores between the groups were recorded. Possible correlations between these scores and experimental findings were examined using Kendall’s tau (τ) where group differences in experimental findings were recorded.

### 3.3. Results

#### 3.3.1. Re-statement of hypotheses

It was predicted that all participants would record faster reaction times in repetition-based inter-trial sequences than in swap-based sequences – **Hypothesis 1.** But Checkers were expected to record slower reaction times than Non-Checkers in all task conditions – **Hypothesis 2.** The study examined the possibility of modulations of the PoP effect by group and/ picture type. It was further predicted that all participants would record slower reaction times in trials following the presentation of negative pictures than in trials following neutral pictures – **Hypothesis 3.** However, it was expected that Checkers (but not Non-Checkers) would be particularly slow in trials immediately following the
presentation of checking pictures – Hypothesis 4. The study explored whether the effects predicted in Hypotheses 3 and 4 varied with condition.

3.3.2. PoP effects

Analysis revealed that the PoP effect had been recorded, confirming Hypothesis 1. Figure 3.3 shows the mean reaction times for all three conditions and for the Checker and Non-Checker group separately. As can be seen, all participants recorded faster reaction times in the Repetition condition (689 ± 13.9ms) than the Swap condition (770 ± 17.2ms). They were also faster in the Repetition condition when compared with their performance in the Mixed condition (767 ± 16.4ms). Both these findings are indicative of the PoP effect.

![Figure 3.3](image)

*Figure 3.3. Mean RTs recorded in the Repetition, Swap and Mixed conditions. Dotted lines indicate significant effects of condition following post-hoc tests (main effect of condition: *p*<0.001). Note, the comparison of Repetition versus Swap conditions, and Repetition versus Mixed conditions, constitutes the PoP effect.*

This finding was confirmed with a mixed 3x2 ANOVA, with the factors condition (Repetition, Swap, Mixed) and group (Checkers, Non-Checkers). The analysis revealed a significant main effect of condition (*F*(1.8, 73.9)=104.4, *p*<0.001, η_p^2=0.718). Follow-up Bonferroni post-hoc *t*-tests confirmed that reaction times in the Repetition condition were significantly faster than in the Swap condition.
(\(p_c<0.001, d=0.7\)) and significantly faster than in the Mixed condition (\(p_c<0.001, d=0.7\)) – both medium-to-large effect sizes. No differences were found when comparing the Swap and Mixed conditions. Unexpectedly, however, the same ANOVA revealed that there was an absence of group differences in reaction times between conditions. No main effect of group was recorded (\(F<1\)). This was contrary to the prediction of Hypothesis 2. There was also no interaction between task and group (\(F<1\)), meaning the PoP effect was not modulated by group.

As can be seen in Figure 3.4, when taking part in Mixed condition blocks, participants also recorded faster reaction times in repetition trials (748 ± 15.9ms) than swap trials (787 ± 17.1ms) – a further demonstration of the PoP effect and confirmation of Hypothesis 1. A mixed 2x2 ANOVA, with the factors Mixed inter-trial type (repetition, swap) and group (Checkers, Non-Checkers), revealed a significant main effect of condition (\(F(1,41)=148.731, p<0.001, \eta^2_p=0.784\)) – a very large effect size. However, the same 2x2 ANOVA also revealed that no main effect of group, or any interaction between task and group (both \(F<1\)), had been recorded. Again this indicated that, contrary to expectations (Hypothesis 2), the reaction times of the Checker group were no different to those recorded by the Non-Checkers, and that there was no alteration of the PoP effect in the Checker group.

![Figure 3.4](image.png)

*Figure 3.4.* Mean RTs recorded in Mixed block repetition trials and Mixed block swap trials. Dotted lines indicate significant effect of condition.
3.3.3. Effect of picture type on reaction times

Contrary to expectations (Hypotheses 3 & 4), the manipulation of picture type had no differentiating effect on the reaction times recorded by Checker and Non-Checker participants – see Figures 3.5A-C. A 3x3x2 ANOVA, with the factors condition (Repetition, Swap, Mixed), picture type (neutral, negative, checking) and group (Checkers, Non-Checkers), revealed no main effect of group, no interaction between condition and group, no effect of picture type, no interaction between picture type and group, and no interaction between condition, picture type and group were found (all $F<1$).

A significant interaction between condition and picture type ($F(3.95,161.932)=2.745$, $p=0.031$, $\eta_p^2=0.063$) was recorded. Post-hoc $t$-tests revealed these findings were driven by the significantly quicker reaction times recorded in the Repetition condition for all three different picture types when compared with RTs for these picture types in the Swap condition and in the Mixed condition. Participants responded faster in neutral Repetition trials than neutral Swap and neutral Mixed trials (both $d=0.8$), negative Repetition trials than negative Swap and negative Mixed (both $d=0.7$) trials, and in checking Repetition trials than checking Swap and checking Mixed (both $d=0.7$) trials (all $p<0.001$). No differences were found when comparing RTs for different picture types within individual conditions – for example, RTs for neutral pictures vs. checking pictures in the Repetition condition.

Picture type also had no influence on reaction times in Mixed condition repetition and swap trials. A mixed 2x3x2 ANOVA, with the factors Mixed inter-trial type (repetition, swap), picture type (neutral, negative, checking) and group (Checkers, Non-Checkers), revealed only the expected significant main effect of Mixed inter-trial type ($F(1,41)=149.818$, $p<0.001$, $\eta_p^2=0.785$). There was no main effect of group, no interaction between Mixed inter-trial type and group, no effect of picture type, no interaction between picture type and group, no interaction between Mixed inter-trial type and picture type, and no interaction between Mixed inter-trial type, picture type and group (all $F<1$). These findings meant that the predictions of Hypothesis 3 (slowed reaction times by all participants with negative picture presentations) and Hypothesis 4 (slowed Checker reaction times with checking picture presentations) were not met.
Figure 3.5. Mean RTs recorded in each condition for each picture type. A = checking, B = negative, C = neutral.
3.3.4. Choice errors

As can be seen in Figure 3.6, Checkers made significantly fewer incorrect responses (3.94 ± 0.69%) than Non-Checkers (6.23 ± 0.86%). Checkers also made, numerically, fewer choice errors than Non-Checkers in each of the three conditions – see Figure 3.7. A mixed 3x2 ANOVA, with the factors condition (Repetition, Swap, Mixed) and group (Checkers, Non-Checkers), revealed a significant main effect of condition ($F(1.989,81.968)=3.68$, $p=0.03$, $\eta_p^2=0.082$), along with a significant main effect of group ($F(1,41)=4.613$, $p=0.038$, $\eta_p^2=0.101$). A borderline significant interaction between group and condition was also recorded ($F(1.989,81.968)=3.024$, $p=0.054$, $\eta_p^2=0.069$). Post-hoc tests revealed that Checkers made significantly fewer incorrect responses in the Swap condition than Non-Checkers ($p_c=0.007$, $d=0.9$ – corrected at $\alpha=0.0083$). The magnitude of this effect size was large. Group differences were not significant for the Repetition and the Mixed conditions – see Figure 3.7.

*Figure 3.6. Mean choice error rate (incorrect responses).*
Further analysis of the Mixed condition revealed that participants made significantly more incorrect responses in swap trials (6.127 ± 0.73%) than repetition trials (4.343 ± 0.5%). However, there was no difference in performance between the groups. A 2x2 ANOVA, with the factors Mixed inter-trial type (repetition, swap) and group (Checkers, Non-Checkers), revealed a significant main effect of inter-trial type ($F(1,41)=18.22$, $p<0.001$, $\eta_p^2=0.308$). No effect of group ($F(1,41)=2.515$, $p=0.12$, $\eta_p^2=0.058$), or interaction between group and Mixed inter-trial type ($F<1$), was found.

*Figure 3.7.* Mean choice error rate in each condition (main effect of group: $p=0.038$; main effect of condition: $p=0.03$, group x condition interaction: $p=0.054$).

*Figure 3.8.* Mean choice error rates in Mixed condition repetition and swap trials.
3.3.5. Effect of picture type on choice errors

Manipulation of picture type had no effect on overall choice error rates. As can be seen in Figure 3.9, Checkers made fewer incorrect responses in trials involving each of the three picture types. A mixed 3x2 ANOVA, with the factors picture type (neutral, negative, checking) and group (Checkers, Non-Checkers), found a significant main effect of group \((F(1,41)=4.156, p=0.048, \eta^2_p=0.092)\), but no effect of picture type \((F(2,82)=1.275, p=0.285, \eta^2_p=0.03)\), or any interaction between group and picture type \((F<1)\). Analysis of choice error rates for each picture type in each condition was not carried out due to low data numbers.

![Figure 3.9. Mean choice error rates by picture type (main effect of group: \(p=0.048\)).](image)

3.3.6. Correlational analysis

No relationship was found between Checker anxiety scores and the overall choice error rates or swap condition choice error rates recorded by that group (overall choice errors: \(\tau=0.076, N=21, p=0.646\); swap choice errors: \(\tau=0.142, N=21, p=0.391\)). There was also no relationship between Checker depression scores and the group’s choice error rates \((\tau=0.165, N=21, p=0.314)\) or swap condition choice error rates \((\tau=0.03, N=21, p=0.854)\). Similarly, there was no relationship between anxiety scores in the Non-Checker group and their choice error rates \((\tau=-0.051, N=22, p=0.751)\) or swap condition choice error rates \((\tau=0.104, N=22, p=0.525)\). Likewise, no relationship was found between Non-Checker depression scores and the group’s choice error rates \((\tau=0.047, N=22, p=0.773)\) or swap condition choice error rates \((\tau=0.18, N=22, p=0.272)\).
3.3.7. Analysis of response behaviour – omissions, early responses, late responses and correct responses

As can be seen in Figure 3.10, very few early and late responses were recorded by both Checkers and Non-Checkers. Only one response was recorded under 99ms in the entire analysis. Meanwhile, the rate of late responses (as a percentage of the total trials) was also low – Checkers, 0.48 ± 0.5%; Non-Checkers, 0.26 ± 0.25%.

![Figure 3.10](image_url)

*Figure 3.10. Mean response rates (% of total trials) recorded by Checkers and Non-Checkers between 0ms and 99ms (Early responses) and between 1,400ms and 1,500ms (Late responses).*

![Figure 3.11](image_url)

*Figure 3.11. Mean rates of correct responses, omissions and choice errors (% of total trials) recorded by Checkers and Non-Checkers.*
A high variation in rates of omissions was recorded in both the Checker (range: 2% - 58%) and Non-Checker (range: 2% - 61%) groups – see Figure 3.11. Possible explanations for this variation are addressed in the Discussion. A checklist assessment of possible confounds is in Appendix 4.

It was decided to have a closer look at the correct response and omission rates to see whether they differed between groups and conditions. This was because there were enough trial numbers for an additional analysis for both, and also because the data could possibly influence the interpretation of the previously reported results.

Numerically, more correct responses were recorded by Checkers (74.839 ± 3.65%) than Non-Checkers (66.469 ± 3.57%), although this difference was not significant. A mixed 3x2 ANOVA, with the factors condition (Repetition, Swap, Mixed) and group (Checkers, Non-Checkers), found no main effect of condition ($F<1$), no main effect of group ($F(1,41)=2.683, p=0.108, \eta_p^2=0.061$) and no interaction between condition and group ($F<1$) – see Figure 3.12. Meanwhile, a numerically-lower overall omission rate was recorded by Checkers (21.325 ± 3.83%) when compared to that of Non-Checkers (27.281 ± 3.74%) – see Figure 3.12. But this apparent difference was not significant. A mixed 3x2 ANOVA, with the factors condition (Repetition, Swap, Mixed) and group (Checkers, Non-Checkers), found no main effect of condition type ($F<1$), no main effect of group ($F(1,41)=1.233, p=0.273, \eta_p^2=0.029$) and no interaction between condition and group ($F<1$).

Thus, although omission rates were high in this task, the lack of group or condition differences in these rates, and in the rates of correct responses, early responses and late responses, means these variables cannot be said to have had an explanatory influence on the PoP effect findings already reported.

![Figure 3.12. Mean omission rate in each condition by group.](image)
3.4. Discussion

Study 1 had provided some evidence of a selective attention deficit and attentional bias in an OC population. A key finding from Study 1 was that the PoP effect (facilitated visual search performance with the repetition of feature-defining aspects of a target from the previous trial) operated similarly in non-clinical OC and Control groups – but it operated significantly more slowly in the OC group. The present study looked to examine whether more specific, or stronger, differences in visual search performance and the PoP effect would emerge between Checker and Non-Checker participants when the ecological validity of the paradigm was increased via the use of emotional and symptom-salient. Focussing on a specific OC subtype is in line with reviewer recommendations and previous research suggesting different behavioural profiles with different subtypes (see Abramovitch et al, 2013), and it allowed for the use of very specific symptom-salient picture stimuli in the task.

3.4.1. Hypotheses and findings

Following Study 1, it was expected that both groups would record faster reaction times in repetition-based inter-trial sequences than in swap-based sequences – Hypothesis 1. However, it was predicted that Checkers would record slower reaction times than Non-Checkers in all task conditions – Hypothesis 2. The study examined whether the PoP effect would be modulated by group and/or picture type. Additionally, it was predicted that both groups would record slower reaction times in trials immediately following the presentation of negative pictures than in trials immediately following the presentation of neutral pictures – Hypothesis 3. However, it was thought that Checkers (but not Non-Checkers) would be particularly slow in trials following the presentation of checking pictures – Hypothesis 4. The study examined whether the effects predicted in Hypotheses 3 and 4 varied with condition.

As expected (Hypothesis 1), the PoP effect was recorded in both the Checker and Non-Checker groups. Participants in both groups produced significantly faster reaction times in the Repetition condition than in both the Swap and the Mixed conditions. Both groups also recorded significantly faster reaction times in repetition-based inter-trial sequences in the Mixed condition than in swap-based inter-trial sequences. As in Study 1, the PoP effect did not differ between groups. The between-conditions findings were both medium-to-large effect sizes, while the within-Mixed condition effect was very large. These results, then, replicate the findings of Study 1 relating to the PoP effect, and are in line with considerable previous research demonstrating the robustness of the PoP effect as a measure of selective attention processes in healthy populations (e.g., Eimer et al., 2010; Lamy et al., 2008; Maljkovic & Nakayama, 1994). Indeed, it is notable that the PoP effect was unimpaired, despite
the addition of picture imagery between trials (in line with Kristjánsonn et al., 2013). This further demonstrates what Maljkovic and Nakayama (1994) called the ‘surprisingly machine-like’ (p.657) nature of PoP.

However, unlike in Study 1, there were no group differences in reaction times in any of the conditions in the present study. This finding was contrary to the predictions of Hypothesis 2. In Study 1, OC participants produced consistently slower reaction times than Controls in both conditions of the experiment. This was taken to indicate the presence of a general selective attention deficit among the OC participants. However, in the present study, the mean reaction times recorded by Checkers and Non-Checkers were, numerically, remarkably similar.

Also contrary to our predictions in Hypotheses 3 and 4, the manipulation of picture type between trials had no differentiating effect on the performance of Checkers and Non-Checkers. Reaction times were compared for trials following the presentation of the three different picture types (checking, negative and neutral). Both groups were found to be faster after viewing of all three picture types in the Repetition condition than they were in the Swap and Mixed conditions. However, there was no evidence that reaction times were slower following the presentation of negative pictures than they were following the presentation of neutral pictures (contrary to Hypothesis 3). Equally unexpectedly, there were no differences in reaction times recorded by Checkers and Non-Checkers following the between-trial presentation of checking pictures (contrary to Hypothesis 4). This applied when comparing reaction times in the Repetition and Swap conditions, the Repetition and Mixed conditions, and in repetition-based inter-trial sequences and swap-based sequences within the Mixed condition. There were also no differences between the groups when the equivalent reaction times were examined following the presentation of negative and neutral pictures.

The study found that Checkers made fewer choice errors than Non-Checkers, although no predictions had been made regarding error rate performance. On closer examination, it was found that Checkers also made fewer choice errors in the Swap condition than Non-Checkers – and this finding had a large effect size.

### 3.4.2. Interpretation and implications

A number of studies which have examined selective attention in OC populations using emotional stimuli have pointed to attentional bias towards threat in OC populations (e.g., Moritz et al., 2009). Such biasing is considered to be crucial in the maintenance of OCD (Bar-Haim et al., 2007). Furthermore, reviews of OCD research (e.g., Abramovitch et al., 2013) have consistently stated that the use of emotional and symptom-salient in experimental paradigms is a must for researchers who
are looking to tease out the depths of OC cognition. In this sense, the findings of the present study are intriguing, particularly as evidence of altered selective attention processes and attentional bias in an OC population were found in Study 1 – an experiment which used only standard coloured-shape stimuli.

It is notable from the literature that attentional bias effects with OCD have not always been found by researchers (e.g., Moritz & von Mühlenen, 2008). There may be methodological explanations for such inconsistency, such as the failure to consider comorbid conditions and acknowledge the heterogeneity of OCD (Abramovitch et al., 2013; Muller & Roberts, 2005). Although the present study attempted to address some of these issues, it is possible that aspects of the design of Study 2 remained problematic. Firstly, participants could have become habituated to the picture content during the task. Amir et al. (2009) found that the attentional bias of OC participants was attenuated over the course of an experiment, suggesting that the implied threat of the stimuli dropped with repeated exposure. In the present study, we attempted to control for this by using multiple picture exemplars of each category. However, we cannot rule out that habituation with the task may have developed. Secondly, it is possible also that the content of the pictures may not have been fully processed by the participants. The images (all photographs) may have too complex and not on-screen long enough for the participants to fully engage with their meanings or what they represented. Indeed, short presentation times may, in turn, have aided strategizing during task. It may have been too easy for participants to actively avoid paying attention to the content of the pictures. Thirdly, sampling and participant selection may also have played a part. It is possible that the differences between the Checking and Non-Checking groups, as assessed by the subscale of a single questionnaire (the OCI-R), were not profound enough (note, though, that this argument is weakened by some of the findings of Study 3, reported in Chapter 4). Finally, a number of the images used in Study 2 contained facial content. Research suggests that greater attentional resources are allocated to facial expressions and, in particular, emotional facial expressions, which may result in altered performance in goal-orientated tasks (e.g., Lamy et al., 2008). In Study 2, images of people and faces (along with visual scenes without people or faces) were included in all three picture categories. However, it is possible that the presence of these pictures may have had some confounding effects.

However, there may be an alternative interpretation of the findings in the present study. There is evidence that the presence of threat can result in heightened attention and perception processing (Phelps & LeDoux, 2005). In the present study, the classic PoP effect was recorded – as it was in Study 1. As such, it can be concluded that the basic visual search paradigm, shared by both studies, functions as a measure of selective attention. The major difference between the paradigm designs of both studies is the addition of emotional and symptom-salient pictures prior to the presentation of search arrays in the present study. Consequently, it is possible to draw conclusion that the presence of
these pictures could have served to equalise performance between groups. From this perspective, the effects of slowed PoP performance by OC participants (as evidenced in Study 1) may be diluted by the introduction of emotional and symptom-salient – rather than being exaggerated. This explanation might be somewhat in line with Becker (2009), who found that visual search reaction times for non-threatening stimuli recorded by healthy participants were improved with the presentation of emotional face pictures prior to search arrays. Taking this suggestion, in the present study, the arousal of the attentional system via the presence of emotional, symptom-salient may have served to normalise boost, or at least normalise, aspects of cognitive performance in the Checker group. There are a number of caveats to this explanation. Becker (2009) used facial images rather than pictures of visual scenes – although a number of pictures used Study 2 included people and faces. Additionally, they found a facilitating effect on visual search for threat pictures but not neutral pictures. In the present study, picture type had no modulating effect on task performance. However, it is conceivable that the presence of multiple emotional and symptom-salient pictures in Study 2 resulted in sustained attentional arousal levels that persisted over the course of the task, rather than changing on a trial-to-trial basis. This is somewhat speculative, though, and needs further examination.

It is also possible that, in the present study, group differences could have been eliminated because of the performance of the Non-Checkers. Reaction times recorded by the Non-Checker group could have been slowed during the task in a way that they were not in Study 1. Or there could have been some Non-Checker slowing and some Checker performance improvement. This is difficult to disentangle in the present study. However, the study used stimuli which were specific to Checker concerns – and which, therefore, should not have had a deleterious effect on performance of the Non-Checkers, nor should they have had any particular arousing effects. As reported in Section 3.2.2.3, the pictures used in this study had previously been rated for valence and arousal by both Checker and Non-Checker participants in a validation study by Gomes-Victorino (2017). Checkers gave the checking pictures significantly higher negative valence scores and arousal scores than Non-Checkers. Both these group differences had large effect sizes. Checkers also gave higher arousal ratings to the negative pictures used in Study 2 than Non-Checkers – also a very large effect. There were no differences in arousal ratings given by Checkers and Non-Checkers for the selected neutral pictures. Moreover, the Non-Checkers reported significantly lower anxiety levels than Checkers (as measured by the HADS – see Section 3.2.1.4), so it is conceivable that their performance could have been less impacted by the negative pictures too. Meanwhile, Checkers made fewer choice errors in the task. This was an unexpected outcome of the present study. Again, this finding stands in contrast to those in Study 1, in which no group differences in choice error rates were found. But it is possible that the Checkers were more engaged with the task in the present study than the Non-Checkers because their attentional systems were more active as a result of engaging with the picture stimuli. Additionally, no relationship was found between anxiety or depression levels and error rates in either group. Like with
Study 1, this suggests that comorbid anxiety and depression, as measured by the HADS, had no confounding effect on this aspect of study.

In terms of theories of OCD, Study 2 provides no evidence of cognitive dysfunction in Checkers as a result of specific attentional bias towards symptom-salient pictures. In contrast, performances may have improved because of presence of symptom-salient – or at least led to performance that was equal with that of Non-Checkers. Cognitive-behavioural models of OCD (e.g., Salkovskis, 1985) highlight a key role for emotions in the mechanics and symptomology of the condition, while there is a good deal of evidence linking OC behaviours with emotional dysregulation (e.g., Yap et al., 2018). Poor emotional regulation has been linked to impaired performance in goal-orientated tasks (e.g., Gray, 2004). This was not the case in the present study. At the same time, however, raised intensity of emotions is also one of the main components of emotional dysregulation (Mennin et al., 2005). It is conceivable that the Checkers in Study 2 experienced the stimuli more intensely than the Non-Checkers, but this led to improved task performance. An important model of attentional bias with OCD suggests that argues that individuals with condition have problems extinguishing their fixations on salient, negative stimuli (Bradley et al., 2016). It is possible that, in Study 2, difficulty disengaging from previously presented emotional stimuli, may have aided, and normalised, selective attention performance among Checkers in the non-emotional visual search task. Such conclusions need deeper examination.

### 3.4.3. Limitations

Though larger than in Study 1, the sample size in the present study (N=43) was still relatively small – totalling 21 Checkers and 22 Non-Checkers. Post-hoc power analysis, using G*power software, revealed that in order to achieve a small between-groups effect ($\eta_p^2 = 0.01$) at a recommended statistical power of 0.8 (Cohen, 1988), a sample of size of 956 participants would be required for this study. For a medium effect ($\eta_p^2 = 0.09$) the equivalent sample size would need to be $N=100$, and for a large effect ($\eta_p^2 = 0.25$) it would need to be $N=32$. In this study, the effect size observed for the significant group difference in overall choice error rates ($\eta_p^2 = 0.101$) had a power of 0.47. However, the effect size for the group difference in Swap condition choice error rates ($d = 0.9$) had a power of 0.89. When considering Cohen’s (1988) recommended power value of 0.8, this suggests that, overall, this study would have benefitted from the use of a greater number of participants – although enough power was present to support the large effect size in the Swap condition group difference rates. Like with Study 1, a priori power calculations were not carried out when designing the present study (note, that this also has consequences for Study 3, which used the same participant pool as Study 2 and which was designed and run concurrently with Study 2 – see Chapter 4). It should be added, however, that in sampling for the present study and Study 3, extremely strict criteria for both our Checker and
Non-Checker groups were adopted, meaning a high number of potential volunteers were rejected. However, the advantage of this approach was that both groups comprised participants with similar characteristics as defined by the inclusion criteria measures used.

A high level of omissions was recorded in the present study. It is difficult to say why this occurred. Potential confounding reasons (e.g., technical error, inadequate instructions to participants) have been examined and ruled out (a checklist examination of possible confounds is included in Appendix 4). The high omission rate occurred in both groups. It is possible that the task required of the participant was too cognitively complicated for the time window allowed for each trial. However, although omission rates were high in this task, the lack of group or condition differences in these rates, and in the rates of correct responses, early responses and late responses, means these variables cannot be said to have had an explanatory influence on the reported PoP effect findings.

As stated, stimuli containing facial content were used in the present study. Although stimuli with facial content were present in all three picture categories, in order to limit the possible confounding effects of such images, the study may have been improved with the use only of visual scenes featuring no individuals or faces. It should be noted that this issue also applies to Study 3 (Chapter 4), which used picture imagery from the same stimuli resources.

Although the present study was a follow-up to Study 1, it remains somewhat novel. The PoP paradigm has not, to the best of our knowledge, been used previously to assess selective attention in OC populations, other than in Study 1. In the present study, we added emotional stimuli to the paradigm and recruited an OC group whose concerns were primarily checking. Some caution must, therefore, be exercised when considering the findings of this study.

3.4.4. Future research

Future researchers could look at designing a within-participants PoP study, encompassing both the standard paradigm (as in Study 1) and the emotional version used in the present study. This could better ascertain whether the performance of Checkers improves or that of Non-Checkers worsens with addition of emotional stimuli. Additionally, the examination of whether PoP performance is modulated by the repetition or swapping of picture images prior to trials might give further insights into the operation of selective attention processes in OCD.

In line with the findings of the post-hoc G*Power analyses, it would be useful to replicate the present study with a greater number of participants in each group. The addition of a second OC subtype group and/or an anxious control group would help establish whether findings were Checker-specific or more...
reflective of general disorder. It should be noted that, as will be discussed in Chapter 4, these particular suggestions also apply to Study 3, as this was designed and run concurrently with the present study.

In the final study of this thesis (Study 4 – Chapter 5) some of these criticisms are accounted-for. This study tested of multiple OC populations, and it used emotional verbal, rather than pictorial, stimuli – which thus featured no facial content.

### 3.4.5. Conclusions

The present study reports no evidence of particular impairments in visual search performance in Checkers when emotional and symptom-salient pictures are introduced to the PoP task. By contrast, the findings suggest the possibility that selective attention deficits in individuals with participants, as reported in Study 1, may be eliminated by activation of emotion triggered by the inclusion of emotional picture stimuli in the standard PoP paradigm. These are tentative and novel findings, however, and further examination of the influence of emotional stimuli on the PoP effect in OC populations is required.
Chapter 4

Study 3:

*Investigating emotional visual search in non-clinical Checkers and Non-Checkers*
4.1. Introduction

Study 1 found new evidence of a selective attention deficit in a non-clinical OC population using the PoP visual search paradigm. In the study, OC participants and Controls recorded faster reaction times in repetition-based inter-trial sequences (repeated target colour in successive trials) than in swap-based inter-trial sequences (change of target colour in successive trials). This is the PoP effect. But the OC group was significantly slower than the Control group in both of these sequence types. This finding was further examined in Study 2, in which emotional and symptom-salient picture stimuli were added to the task and the performance of a group of Checker participants was examined. Single pictures were shown immediately before the presentation of each PoP search array. Interestingly, the group differences in reaction times which were evident in Study 1 were not found in Study 2. It is possible that the emotional and symptom-salient component of the task in Study 2 served to boost the attentional performance.

An additional finding from Study 1 was that, in version of the PoP task which used three stimuli colours and six inter-trial repetition and swap sequences (the Mixed condition – see Chapter 2), OC participants appeared particularly slow in trial sequences in which the target colour was repeated but the distractor colour was changed. Following Eimer et al., (2010), this Mixed condition had been designed to assess the relative contributions of two processes which it is assumed underpin the PoP effect – target activation and distractor inhibition. Research suggests that in healthy participants both processes make an equal contribution to the PoP effect (Eimer et al., 2010). Indeed, the Control group in Study 1 performed in line with this thinking. By contrast, however, there was a significant difference in OC performance in specific target activation sequences (slowed reaction times) compared to the equivalent distractor inhibition sequences (faster reaction times). In these target activation sequences, target colour had been repeated from the previous trial but the distractor colour had been changed. However, in the distractor inhibition sequences, distractor colour remained the same across successive trials, but target colour changed.

An interpretation of this finding is that the OC participants in Study 1 demonstrated an attentional bias towards irrelevant distractor information. Ruling out the distractors as non-targets was a heightened priority than the main goal of the task – locate the target. This resulted in excessively slower reaction times in trials in which distractor information was changed from the immediately preceding presentation. These results are in line with previous research pointing to attentional biasing towards distracting stimuli in OC populations (e.g., Moritz et al., 2006; Swerdlow et al., 1999). In terms of models of attentional bias in OCD, the findings point to both excessive vigilance towards task-
irrelevant stimuli in current-trial performance and a heightened failure to disengage from the distractors of the previous trial (see Section 1.5 for a discussion of these models).

However, one of the problems with this finding from Study 1 is that, while the difference in OC group performance in target activation and distractor inhibition sequences was significant, the size of the effect was very small ($d=0.12$). It could be concluded that this result lacks any real meaning in terms of understanding the mechanics of OCD. However, it is also possible that the small effect size reflected the use of non-emotional, coloured-shape stimuli in the Study 1 paradigm. As already stated, reviewers (e.g., Abramovitch et al., 2013; Muller & Roberts, 2005) recommend the use of emotional and symptom-salient in experiments designed to examine OC cognition because of the very particular sensitivities of the condition.

In the present study, we looked to further examine this attentional biasing effect from Study 1 via the use of a visual search paradigm which focussed on the particular trial sequences in which the effect was recorded, and which used symptom-salient and emotional stimuli. The aim was to see if the use of such an experimental design would result in stronger effects in OC individuals and new evidence of attentional bias in visual search with the condition. Like in Study 2, we also decided to look at a specific OC subtype – Checkers – rather than a homogenous OC group, as was used in Study 1. Again, this was in line with studies pointing to differing behavioural and neurological functioning between OC subtypes (Abramovitch et al., 2013; Bragdon et al., 2018). Participants in the present study were recruited from the same sampling pool as used in Study 2.

The present study used three categories of pictures – checking, negative and neutral. These pictures took the roles of the coloured-shape stimuli in the search arrays in Studies 1 and 2 – as targets and distractors. The task of the participant was to respond to the shape of the odd picture out while ignoring three identical distractor pictures. The emotional content of the target and distractor pictures was manipulated systematically in two conditions. In the first (Target Neutral condition), target pictures remained neutral, but distractors changed picture categories. In the second (Target Change condition), distractor pictures remained neutral, but targets changed category. This, then, was a visual search study with a partial repetition inter-trial component. The design enabled the examination of both non-sequential effects (possible group differences when emotional pictures were presented as targets or distractors) and sequential effects (possible group differences following changes in picture content from previous trial). The latter was of particular interest as it would enable a more ecologically-valid assessment of the findings of Study 1 relating to possible attentional bias in target activation and distractor inhibition sequences.
Like in Study 2, the present study used picture categories with multiple exemplars (N=12 pictures per category). It was believed that this would more likely trigger a specific response in the relevant group. A single checking picture might be only particularly salient for one individual with checking behaviour, but less significant for another Checker. Averaged across several different pictures, checking-related emotions would be more likely to be triggered in all Checkers. Additionally, the repeated use of a single picture might result in habituation to the stimuli (Amir et al., 2009). This would be less likely with multiple exemplars. The pictures used in the present study were from the same stimuli resources as those used in Study 2.

In the present study, initial examination of data focussed on non-sequential effects. Assessments were made about whether there were differences between Checkers and Non-Checkers when emotional and symptom-salient pictures were presented as distractors and when they were presented as targets. Thus, the first aim was to investigate whether Checkers had overall slowed visual search responses. The analysis then focussed on whether the presence of emotional distractors slowed down reaction times in the Target Neutral condition, but, by contrast, sped up reaction times in the Target Change condition, in which targets featured emotional information. Assessments were made about whether this was modulated by group. Specifically, the study looked to examine how far any group differences occurred for neutral pictures (enhanced attentional bias independent of emotion), emotional pictures (emotional attentional bias) or checking-related pictures (ideographic attentional bias). Focus then turned to examining sequential effects – the impact of emotion presented in the previous trial on the performance in the current trial. This part of the analysis assessed whether task-irrelevant emotions from the previous trial still influenced behaviour in the current trial, and if this differed between groups. This question is theoretically relevant because anxious people and people with OCD typically experience enhanced emotional responses to threatening stimuli (Salkovskis & Maguire, 2002).

4.1.1. Hypotheses

In line with Study 1, it was predicted that slower reaction times would be recorded by Checkers than Non-Checkers throughout the task – Hypothesis 1. It was expected that emotional and symptom-salient pictures (checking and negative stimuli) would slow down reaction times in the Target Neutral condition, but speed up reaction times in the Target Change condition – Hypothesis 2. However, it was also expected that enhanced attentional bias effects (especially in the Target Neutral condition) would be found in the Checker group, with the strongest effects being for checking pictures – Hypothesis 3. Finally, in line with Study 1, it was thought that inter-trial sequential effects would be more pronounced in the Checker group than the Non-Checker group. It was expected that sequential effects for Checkers would be more pronounced for checking and negative pictures than for neutral pictures – Hypothesis 4.
4.2. Methods

4.2.1. Participants

The majority of participants who completed Study 2 also took part in the present study (N=45). Participation in the present study was in advance of participation in Study 2. The present study included five participants (2 Checkers, 3 Non-Checkers) who subsequently chose not to take part in Study 2. All participants were University of Surrey students. They received £7.50 for taking part (first or second year Psychology students could opt to receive lab tokens instead of payment). The study received a favourable ethical opinion from the University of Surrey Ethics Committee (see Appendix 2).

The process by which participants were recruited and screened for both these studies is detailed in the Study 2 Methods section (Section 3.2). Inclusion and exclusion criteria were the same for both studies. The only exception to this was that self-report of colour discrimination difficulties, or history, was not an exclusion criterion in the present study. This was because, unlike the Studies 2 and 3, the task requirements of the present study did not centre on the differentiation of coloured stimuli.

Fifty participants took part in the main, lab-based experiment. However, two Checkers and two Non-Checkers were removed from the analysis because of likely failure to understand the task. This left a total of 23 participants in the Checker group and 23 participants in the Non-Checker group.

Tests of normality were carried out on descriptive and questionnaire data by assessing z-scores for skew and kurtosis. Anxiety, depression and OCI-R total scores were all normally distributed. Age and OCI-R checking scores were not normally distributed.

The Checker group (19 females, 4 males) had a mean age of 21.26 ± 0.8 years (range: 18-32 years). The Non-Checker group (23 females) had a mean age of 19.39 ± 0.3 years (range: 18-24 years). This age difference was borderline significant (U(N=46)=180.5, z=-1.906, p=0.057, d=0.6).

As expected due to the requirements of the recruitment inclusion/exclusion criteria, the Checker group mean OCI-R checking score (7.43 ± 0.5) was significantly higher than that of the Non-Checker group (0.43 ± 0.1) – (U(N=46)=0.00, z=-5.934, p<0.001, d=3.3). The Checker group mean total OCI-R score (32.04 ± 2.3) was also significantly higher than that of the Non-Checker group (5.74 ± 0.7) – (t(26.608)=10.494, p<0.001, d=7.8). The Checker group mean HADS anxiety score (9.87 ± 0.7) was higher than that of the Non-Checker group score (5.39 ± 0.6) – (t(44)=4.656, p<0.001, d=1.4). The
Checker mean anxiety score was within the measure’s borderline enhanced range (scores between 8 and 10), while the Non-Checker mean was in the normal range (scores between 0 and 7). The mean depression score was higher in the Checker group (4.61 ± 0.6) than the Non-Checker group (2.26 ± 0.4). Although this difference was significant ($t(44)=3.134, p=0.003, d=0.9$), the mean scores for both groups were within the normal range of the measure (scores between 0 and 7).

Table 4.1. Descriptive details and questionnaire scores (mean ± SE) for the Checker and Non-Checker groups. Score ranges reported in brackets.

<table>
<thead>
<tr>
<th></th>
<th>Checker</th>
<th>Non-Checker</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of participants</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Age</td>
<td>21.26 ± 0.8 (18-32)</td>
<td>19.39 ± 0.3 (18-24)</td>
</tr>
<tr>
<td>Gender</td>
<td>19f/4m</td>
<td>23f/0m</td>
</tr>
</tbody>
</table>

OCI-R

<table>
<thead>
<tr>
<th></th>
<th>Checker</th>
<th>Non-Checker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checking subscale</td>
<td>7.43 ± 0.5 (5-12)</td>
<td>0.43 ± 0.1 (0-1)</td>
</tr>
<tr>
<td>Total</td>
<td>32.04 ± 2.3 (14-50)</td>
<td>5.74 ± 0.7 (1-13)</td>
</tr>
</tbody>
</table>

HADS

<table>
<thead>
<tr>
<th></th>
<th>Checker</th>
<th>Non-Checker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety</td>
<td>9.87 ± 0.7 (2-16)</td>
<td>5.39 ± 0.6 (0-12)</td>
</tr>
<tr>
<td>Depression</td>
<td>4.61 ± 0.6 (0-10)</td>
<td>2.26 ± 0.4 (0-7)</td>
</tr>
</tbody>
</table>

4.2.2. Overall procedure

The experiment took place in the Brain and Behaviour laboratory at the University of Surrey. On arrival, participants were asked to read an information sheet which detailed what they would be asked to do during the task. Once this was completed, they signed an informed consent form. They then carried out a computer-based task which lasted approximately 45 minutes. On completion, participants were asked to confirm whether or not they wanted to take part in Study 2. Those taking part in the Study 2 were informed that a full debriefing would take place after the completion of both studies. Those not taking part in Study 2 were fully debriefed about the experiment they had just
completed, and were given the opportunity to ask any questions they had. All participants were then compensated for their time completing the present study. A flowchart representation of the overall study procedure is in Figure 4.1.

![Flowchart](image)

*Figure 4.1. A schematic representation of the overall procedure of Study 3.*

### 4.2.2.1. Visual search task

The experiment was programmed using Presentation software (Version 16.5, Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com). Stimuli were presented on a flat-screen desktop PC monitor against a black background at a distance of 1 metre. They consisted of search arrays comprising four rectangular landscape photographic picture images. These were placed at equal distances from a centrally-positioned, white fixation cross, forming a landscape rectangle (10.84° x 9.43°). Three categories of photographic picture stimuli were used – checking, negative and neutral. Each array contained a single target picture and three distractor pictures. The three distractors were always the same picture, and the target was always a different picture. Each picture had a visual angle of 5.1° x 3.72°. In every search array, each picture had 45° cuts to either its top or bottom corners. There were equal numbers of target presentations in each of the four possible search array positions in each block of the experiment. Target cut position (top v. bottom), and position of the target picture in the search array, were equiprobable in each trial condition. Distractor cut position was randomised for each of three distractor pictures in each trial. The experiment was piloted with two participants.
Figure 4.2. A schematic display of a typical trial structure from the Target Neutral condition, with checking distractors (the cooker followed by the toaster) in two successive trials.

4.2.2.2. Picture stimuli

The present study used categories of photographic pictures presented on-screen. Each of the three categories (checking, negative and neutral) comprised 12 exemplars. A separate group of secondary neutral picture images was also created to act as targets in the Target Neutral condition and distractors in the Target Change condition. This group also contained 12 picture exemplars, all of which were unique to the secondary neutral group. The checking picture stimuli used in the study are part of a broader set of stimuli specifically developed for the experimental assessment of aspects of OCD and subtypes of OCD (Simon et al., 2012). Negative and neutral images were taken from the database of the International Affective Picture System (Lang et al., 2008).

As with the study reported in Chapter 3, all the pictures used in the present study had previously been rated for valence and arousal by both Checker and Non-Checker participants in a validation study by Gomes-Victorino (2017). The specific pictures selected for the present study were chosen following analysis of the ratings data for a larger stimuli set recorded by Gomes-Victorino (2017). This analysis revealed that the checking pictures used in the present study were rated as significantly more negatively-valenced by Checkers than by Non-Checkers. A mixed 3x2 ANOVA, with the factors
picture category (checking, negative, neutral) and group (Checkers, Non-Checkers), revealed a significant interaction between group and picture type \( (F(1.761,38.75)=6.018, p=0.007, \eta^2_p=0.215) \). Post-hoc \( t \)-tests found a significant difference in higher negative valence scores given for checking pictures by Checkers than those by Non-Checkers \( (p_c=0.002, d=1.5) \). There were no group differences in valence ratings for the selected negative and neutral pictures. Checkers also gave significantly higher arousal ratings for all pictures selected for the present study than Non-Checkers. A mixed 3x2 ANOVA, with the factors picture category (checking, negative, neutral) and group (Checkers, Non-Checkers), found a significant main effect of picture type \( (F(2,44)=68.448, p<0.001, \eta^2_p=0.757) \) and a significant main effect of group \( (F(1,22)=16.208, p=0.001, \eta^2_p=0.424) \). There was no interaction between group and picture type \( (F(2,44)=1.724, p=0.19, \eta^2_p=0.073) \). There were no group differences in valence ratings for the secondary neutral set of pictures \( (t(22)=1.753, p=0.094, d=0.7) \). Checkers gave the selected pictures higher ratings of arousal than Non-Checkers \( (t(22)=3.001, p=0.007, d=1.2) \). Importantly, however, the mean scores recorded by both groups were very similar (Checker: 5.2 ± 0.12; Non-Checker: 5.7 ± 0.11) and were indicative of neutral ratings of arousal. For figures and further detail relating to these analyses see Appendix 5.

4.2.2.3. Trial structure and experimental conditions

A typical trial structure is shown in Figure 4.2. Search arrays were presented for 1,200ms. There was a jittered inter-trial interval of between 450ms and 950ms. Participant responses to each trial were recorded in a 1,500ms period from stimulus onset. A central fixation cross remained on-screen throughout each block of trials. Participants were asked to find the odd picture target in each search array. They were then asked to state where the cuts on this picture were located (top vs. bottom). This was done via finger press using a response unit with corresponding top and bottom pads. Participants were asked to complete this task as quickly and accurately as they could. The experiment was divided into two conditions – Target Neutral condition and the Target Change condition. In Target Neutral condition, the odd picture targets in each search array were always a neutral image. However, the distractors could be drawn from any of the three possible picture categories – checking, negative or neutral. This resulted in nine possible sequences of distractor presentations across successive trials – see Table 5.2. The Target Change condition was identical in structure to the Target Neutral condition. However, in this condition the distractors were always a neutral image and the targets could be drawn from any of the three possible picture categories. This, then, resulted in the same nine possible sequences of presentations across successive trials found in the Target Neutral condition, but with the changing aspect of the trial being the target rather than the distractor – see Table 4.2.
Table 4.2. Possible inter-trial sequences in the Target Neutral and Target Change conditions. In the Target Neutral condition, targets were always neutral. In the Target Change condition, distractors were always neutral.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Trial N-1</th>
<th>Trial N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Neutral</td>
<td>Checking distractors</td>
<td>Checking distractors</td>
</tr>
<tr>
<td></td>
<td>Checking distractors</td>
<td>Negative distractors</td>
</tr>
<tr>
<td></td>
<td>Checking distractors</td>
<td>Neutral distractors</td>
</tr>
<tr>
<td></td>
<td>Negative distractors</td>
<td>Negative distractors</td>
</tr>
<tr>
<td></td>
<td>Negative distractors</td>
<td>Neutral distractors</td>
</tr>
<tr>
<td></td>
<td>Negative distractors</td>
<td>Checking distractors</td>
</tr>
<tr>
<td></td>
<td>Neutral distractors</td>
<td>Neutral distractors</td>
</tr>
<tr>
<td></td>
<td>Neutral distractors</td>
<td>Negative distractors</td>
</tr>
<tr>
<td></td>
<td>Neutral distractors</td>
<td>Checking distractors</td>
</tr>
<tr>
<td>Target Change</td>
<td>Checking target</td>
<td>Checking target</td>
</tr>
<tr>
<td></td>
<td>Checking target</td>
<td>Negative target</td>
</tr>
<tr>
<td></td>
<td>Checking target</td>
<td>Neutral target</td>
</tr>
<tr>
<td></td>
<td>Negative target</td>
<td>Negative target</td>
</tr>
<tr>
<td></td>
<td>Negative target</td>
<td>Neutral target</td>
</tr>
<tr>
<td></td>
<td>Negative target</td>
<td>Checking target</td>
</tr>
<tr>
<td></td>
<td>Neutral target</td>
<td>Neutral target</td>
</tr>
<tr>
<td></td>
<td>Neutral target</td>
<td>Negative target</td>
</tr>
<tr>
<td></td>
<td>Neutral target</td>
<td>Checking target</td>
</tr>
</tbody>
</table>

4.2.2.4. Block design

The experiment consisted of 12 blocks. There were 72 trials in each block, giving a total of 864 trials across the whole experiment. There were six blocks per condition. This ensured that there was an even number of blocks starting with exemplars from the different categories (i.e. two blocks per category). In both conditions, there were 48 trials for each of the nine possible inter-trial sequences. Trials in both conditions were presented in a pseudo-random order to ensure the equal presentation of these sequences. Each checking, negative and neutral picture exemplar appeared twice in each block. The secondary neutral pictures (Target Neutral targets/Target Change distractors) were presented randomly. Each secondary neutral picture appeared six times per block.
Blocks from each condition were presented in alternating order. The choice of block from each condition was randomised in order to vary the order of starting trials for each participant. An additional ‘dummy trial’ was added to the beginning of each block in order to give meaning to participant responses to the first proper trial. This was fixed for each block and programmed as part of the pseudo-random trial sequence. There were two dummy trials per picture category in both the conditions. Data relating to the dummy trials has not been included in the analysis.

4.2.3. Data analysis

The reaction times of correct responses and rates of choice errors were analysed. Data were recorded in a time window between 100ms and 1,500ms. Numbers of early responses (0-100ms) and late responses (1,400-1,500ms), along with omission rates, were examined. In all analyses, the alpha level of \( p = 0.05 \) was used to determine significance. In ANOVA analysis, Huynh-Feldt values were used to correct for violations of sphericity. Bonferroni corrections were used in post-hoc analysis. Bonferroni-corrected \( p \) values were calculated using the following formula: \( \alpha = 0.05/\text{number of post-hoc tests} \).

Effect size values for Cohen’s \( d \) are reported following \( t \)-test analysis. Effect size values for \( \eta^2 \) are reported following ANOVA analysis. Following Cohen (1988), the magnitude of effect sizes were considered to be the following – \( d \): small=0.2, medium=0.5, large=0.8; \( \eta^2 \): small=0.01, medium=0.09, large=0.25. All reported figures and tables display mean values accompanied by standard errors.

**Reaction times and choice errors:** Reaction times were analysed with a mixed 2x3x3x2 ANOVA. This featured the within-participants factors of condition (Target Neutral, Target Change), previous picture (checking, negative, neutral) and current picture (checking, negative, neutral), and the between-participants factor of group (Checkers, Non-Checkers). Choice error rates were analysed with a mixed 2x3x2 ANOVA. This featured the within-participants factors of condition (Target Neutral, Target Change) and current picture (checking, negative, neutral), and the between-participants factor of group (Checkers, Non-Checkers). Error rates were not high enough to include the additional factor of previous trial.

**Correlational analysis:** Significant differences in anxiety and depression scores between the groups were recorded (see Section 4.2.1). Possible correlations between these scores and experimental findings were examined using Pearson’s \( r \) where group differences in experimental findings were recorded.
4.3. Results

4.3.1. Re-statement of hypotheses

Hypothesis 1 predicted that slower reaction times would be recorded by Checkers than Non-Checkers. It was expected that the presence of emotional and symptom-salient pictures would slow reaction times in the Target Neutral condition, but speed up reaction times in the Target Change condition. This was Hypothesis 2. But it was predicted that enhanced attentional bias effects, particularly in the Target Neutral condition and particularly for checking pictures, would be found in the Checker group – Hypothesis 3. It was further expected that inter-trial sequential effects would be more pronounced in the Checker group than in the Non-Checker group (Hypothesis 4), and that, among Checkers, sequential effects would be more pronounced for checking and negative pictures than for neutral pictures – Hypothesis 5.

4.3.2. Reaction times in Target Neutral and Target Change conditions

Unlike predicted in Hypothesis 1, there was no difference in overall reaction times recorded by Checker and Non-Checker participants. The mean Checker reaction time was 864 ± 13.6 ms, while the mean Non-Checker reaction time was 869 ± 13.7 ms. Independent of group, participants recorded faster reaction times in the Target Change condition (861 ± 9.5 ms) than the Target Neutral condition (872 ± 9.8 ms) – see Figure 4.3. ANOVA analysis revealed a significant main effect of condition \((F(1,44)=23.346, p<0.001, \eta^2=0.347)\). However, although Checkers actually appeared to be quicker rather than slower than Non-Checkers in both conditions, this difference was only numerical. No main effect of group, or the predicted interaction between group and condition, were found (both \(F<1\)).
Figure 4.3. Mean reaction times for Checker and Non-Checker groups in the Target Neutral (TN) and Target Change (TC) conditions.

4.3.3. Processing of picture types in Target Neutral and Target Change conditions

Figure 4.4 shows that, in the Target Neutral condition, responses to emotional pictures appeared to have been slower than responses to neutral pictures. By contrast, participants seemed to respond equally fast across all picture categories in the Target Change condition. Reaction times were numerically faster for each of the picture types in the Target Change condition than they were in the Target Neutral condition. ANOVA analysis revealed a significant interaction between condition and current trial ($F(2,88)=7.352$, $p=0.001$, $\eta^2_p=0.143$). Bonferroni-corrected post-hoc $t$-tests ($\alpha=0.005$) revealed no reaction time differences between conditions when trials featured neutral pictures ($t<1$). However, differences between the conditions were recorded for emotional pictures (negative: $p=0.002$, $d=0.2$; checking: $p<0.001$, $d=0.3$) where Target Neutral emotional trials were slower than Target Change neutral trials. Within the Target Neutral condition, participants were significantly slower in checking picture trials compared to the neutral picture trials ($p<0.001$, $d=0.2$). No differences were found between negative and neutral trials, or between negative and checking trials (negative vs. neutral: $p=0.012$, $d=0.1$; negative vs. checking: $p=0.62$, $d=0.03$). By comparison, there were no significant reaction time differences between picture types in the Target Change condition (neutral vs. checking: $p=0.01$, $d=0.1$; neutral vs. negative: $p=0.252$, $d=0.04$; negative vs. checking: $p=0.094$, $d=0.08$). This finding means that, in line with Hypothesis 2, responses in the Target Neutral
condition were slower than in the Target Change condition when emotional pictures were presented. This was not the case for neutral stimuli.

![Figure 4.4](image.png)

Figure 4.4. Mean reaction times for trials featuring different picture types (neutral, negative and checking) in Target Neutral and Target Change conditions.

However, the significant interaction between condition and current trial was not further modulated by group. There was no significant three-way interaction between condition, current trial and group ($F<1$). This means that while the emotional content of the pictures influenced performance in the conditions differently, attentional bias towards emotional information was not enhanced in Checkers compared to Non-Checkers – see Figure 4.5. This was contrary to Hypothesis 3.
Figure 4.5. Mean reaction times by group for trials featuring different picture types (neutral, negative and checking) in Target Neutral and Target Change conditions. A = Checkers, B = Non-Checkers.

4.3.4. Influence of previous trial on current trial – inter-trial effects

The factor previous trial was included in the analysis because we predicted that it would potentially have an influence on the current trial-performance of participants. However, the main effect of previous trial was not significant ($F(2,88)=1.335$, $p=0.269$, $\eta^2_p=0.029$). There were also no significant interactions between condition and previous trial ($F<1$), previous and current trial ($F(3.984,175.299)=1.513$, $p=0.2$, $\eta^2_p=0.033$) and condition, previous trial and current trial ($F<1$). This
shows that, when both groups were combined, previous trial information did not have an influence on current trial-performance of the task. It also means that there were no repetition or change effects present in this task. This is illustrated in Figure 4.6, which shows the mean reaction times for repetition and change inter-trial sequences in each condition.

![Figure 4.6](image)

*Figure 4.6. Mean reaction times in repetition and change trials in each condition (both groups combined).*

However, the influence of the previous trial on current trial did differ between groups when their performance in the conditions was compared. This was reflected in a significant interaction between condition, previous trial and group \( (F(2,88)=3.225, p=0.044, \eta^2_p=0.068) \). No other interaction with the factors previous trial and group was significant (all \( F<1 \)). Figure 4.7 shows the mean reaction times for each condition, each previous picture category type and each group separately. For the Checker group, it shows clearly that the reaction time difference between conditions for sequences in which the previous trial was neutral was the smallest. However, it increased when sequences involved emotional pictures, with the largest difference being for checking picture sequences (Figure 4.7A). In contrast, reaction time differences between Target Neutral and Target Change conditions seemed to be consistent across previous picture category types for Non-Checkers.
Figure 4.7. Mean reaction times for Checker (A) and Non-Checker (B) groups in each condition following presentation of different picture types in previous trial.

To investigate this, two follow up ANOVAs were conducted for each group separately. For the Checker group, the ANOVA revealed a significant interaction between condition and previous trial
Bonferroni corrected post-hoc t-tests ($\alpha=0.0055$) revealed highly significant reaction time differences between conditions for checking pictures ($p=0.001$, $d=0.3$) and for negative pictures ($p=0.001$, $d=0.2$) in the previous trial. This was caused by slower reaction times in the Target Neutral condition compared to the Target Change condition. The effect size for checking pictures was small-to-medium, and for negative pictures was small. However, this condition difference was not significant for previously presented neutral pictures ($p=0.319$, $d=0.06$). When comparing previous picture types within tasks, none of the post-hoc t-tests were significant. For the Non-Checker group, the interaction between the condition and previous trial was not significant ($F<1$). This finding means that negative and, especially, checking-related information displayed in the previous trial slowed Checkers down in the Target Neutral condition, and sped them up in the Target Change condition. By contrast, emotional content from previous trials had no influence on the performance of Non-Checkers. This is in line with the prediction of Hypotheses 4 & 5.

4.3.5. Choice error rates

As can be seen in Figure 4.8, Checkers recorded a mean choice error rate of $3.7 \pm 0.68\%$ in the Target Neutral condition and $3.8 \pm 0.67\%$ in the Target Change task. Non-Checkers had similar error rates with $4.41 \pm 0.64\%$ in the Target Neutral condition and $4.23 \pm 0.65\%$ in the Target Change condition. ANOVA analysis revealed no main effect of condition, current trial or group (all $F<1$). None of the interactions were significant (all $F<1$).

Figure 4.8. Choice error rate by group in each condition (TN = Target Neutral; TC = Target Change).
4.3.6. Correlational analysis

As reported in Section 4.3.4, Checkers recorded significantly slower reaction times when checking and negative pictures were presented in immediately previous trials in the Target Neutral condition than in equivalent sequences in the Target Change condition. These findings were further examined by assessing possible correlations between anxiety and depression scores, which differed between the groups (see Section 4.2.1), and reaction time performance by both Checkers and Non-Checkers in these inter-trial sequences. Analysis revealed that anxiety in the Checker group was positively related to their reaction time performance in the Target Neutral condition, both when the previous picture was checking-related \((r=0.474, N=23, p=0.022)\) and when they were negative \((r=0.487, N=23, p=0.018)\). Likewise, in the Target Change condition, Checker anxiety was also positively related to that reaction time performance when the previous picture was a checking image \((r=0.527, N=23, p=0.01)\) and when it was negative \((r=0.497, N=23, p=0.016)\). However, no such relationships were found in equivalent reaction time analysis of previous trial sequences for the Non-Checker group (Target Neutral condition: previous checking picture, \(r=0.001, N=23, p=0.99\); previous negative picture, \(r=0.034, N=23, p=0.87\); Target Change condition: previous checking picture, \(r=-0.01, N=23, p=0.96\); previous negative picture, \(r=-0.08, N=23, p=0.71\)).

No relationships were found between depression scores and reaction times in these inter-trial sequences in either the Checker or the Non-Checker groups.

4.3.7. Analysis of response behaviour – omissions, early responses, late responses and correct responses

As can be seen in Figure 4.9, very few early responses were recorded by both Checkers \((0.1 \pm 0.05\%)\) and Non-Checkers \((0.02 \pm 0.01\%)\). The rate of late responses (as a percentage of the total trials) was also low – Checkers, \(0.7 \pm 0.19\%\); Non-Checkers, \(0.67 \pm 0.13\%).
A high variation in rates of omissions was recorded in the study. This was apparent in both the Checker (range: 0.8%-56%) and Non-Checker (range: 2%-51%) groups. The potential reasons for, and implications of, these variations are considered in the Discussion (Section 4.4). A checklist assessment of possible confounds is in Appendix 4.

It was decided to have a closer look at the correct response and omission rates to see whether they differed between groups and conditions. This was because there were enough trial numbers for an additional analysis for both, and also because the data could possibly influence the interpretation of
the previously reported results. Numerically, Checkers recorded marginally more correct responses in the Target Neutral condition (78.321 ± 3.01%) than in the Target Change condition (77.97 ± 2.86%). By comparison, Non-Checkers appeared to record more correct responses in the Target Change condition (79.12 ± 2.33%) than in the Target Neutral condition (77.82 ± 2.42%). A mixed 2x2 ANOVA, with the factors condition (Target Neutral, Target Change) and group (Checkers, Non-Checkers), found no main effects of group \( (F<1) \) or condition \( (F(1,44)=1.349, p=0.252, \eta_p^2=0.03) \). A borderline significant interaction between group and condition was recorded \( (F(1,44)=3.97, p=0.053, \eta_p^2=0.083) \). There was no difference between the groups in the mean correct response rates recorded for each picture type. A mixed 2x3x2 ANOVA, with the factors condition (Target Neutral, Target Change), picture type (neutral, negative, checking) and group (Checkers, Non-Checkers), revealed no group differences or main effects. No interactions were found, other than the same group/condition interaction detailed in the previous paragraph.

There was no difference between the mean omission rate recorded Checkers and that recorded by Non-Checkers – see Figure 4.10. Checkers produced a mean omission rate of 17.84 ± 3.15% in Target Neutral condition, and 18.15 ± 3.02% in Target Change condition. The Non-Checker group mean omission rate was 17.74 ± 2.6% in Target Neutral condition, and 16.26 ± 2.43% in Target Change condition. A mixed 2x2 ANOVA, with the factors condition (Target Neutral, Target Change) and group (Checkers, Non-Checkers), found no main effects of group or condition (both \( F<1 \)), and no interaction between group and condition \( (F(1,44)=2.741, p=0.105, \eta_p^2=0.059) \). There was no difference between groups in mean omission rates recorded for each picture type. This applied to both conditions. A mixed 2x3x2 ANOVA, with the factors condition (Target Neutral, Target Change), picture type (neutral, negative, checking) and group (Checkers Non-Checker), found a borderline effect of picture type \( (F(1.987,87.426)=2.912, p=0.06, \eta_p^2=0.062) \), but no main effect of group or condition (both \( F<1 \)). There were also no interactions between group and picture type \( (F<1) \), group and condition \( (F(1,44)=2.741, p=0.105, \eta_p^2=0.059) \), picture type and condition \( (F<1) \) or group, picture type and condition \( (F(2,88)=1.632, p=0.201, \eta_p^2=0.036) \).

Thus, although omission rates were high in this task, the lack of group or condition differences in these rates, and in the rates of correct responses, early responses and late responses, means these variables cannot be said to have an explanatory influence on the findings reported.
4.4. Discussion

The present study examined attentional bias towards emotional and symptom-salient in a non-clinical Checker population using a visual search paradigm. Its design was derived from the PoP task used in Study 1. The study looked to further examine the finding reported in Study 1 that OC performance was significantly slower in trial sequences involving repeated targets and changed distractors than in sequences involving repeated distractors and changed targets. This difference was not apparent for Control participants. The aim was to see if stronger evidence of attentional biasing might be found by refining the focus of the study through the use of emotional and symptom-salient as targets and distractors, and by examining a specific OC population (Checkers) rather than a homogeneous group.

4.4.1. Hypotheses and findings

It was expected that Checkers would record slower reaction times than Non-Checkers – Hypothesis 1. At the same time, it was predicted that emotional and symptom-salient pictures (checking and negative stimuli) would slow down reaction times in the Target Neutral condition, but speed up reaction times in the Target Change condition – Hypothesis 2. Furthermore, it was predicted that attentional bias effects (especially in the Target Neutral condition) would be enhanced in the Checker group. It was expected that the strongest of these effects would be for checking pictures – Hypothesis 3. Following Study 1, it was thought that Checkers would demonstrate more pronounced inter-trial sequential effects than Non-Checkers. It was predicted that, for Checkers, sequential effects would be more pronounced for checking and negative pictures than for neutral pictures – Hypothesis 4.

Contrary to the prediction of Hypothesis 1, there was no overall difference in reaction times between Checkers and Non-Checkers in the present study. In the present study, reaction times in the Target Neutral condition were slower than in the Target Change condition when emotional pictures were presented. This was not the case for neutral stimuli. This was in line with Hypothesis 2. However, unexpectedly, this was not modulated by group. This was contrary to Hypothesis 3. However, this changed when sequential effects in the two conditions were examined. It was found that, as predicted in Hypothesis 4, that the impact of the previous trial picture on current trial performance differed between Checkers and Non-Checkers. Negative and checking pictures displayed in the previous trial slowed Checkers down in the Target Neutral condition, and sped them up in the Target Change condition. By contrast, emotional content from previous trials had no influence on the performance of Non-Checkers.
4.4.2. Interpretation and implications

The results of the present study highlight the utility of inter-trial visual search paradigms in OCD research and provide further evidence of the interaction between emotion and cognition in the mechanics of the condition. Furthermore, the findings demonstrate the importance of using emotional and symptom-salient in experimental designs in order to tease out deeper aspects of cognitive processing in OC populations. In the present study, the value of inter-trial visual search designs for examining selective attention with OCD is underlined by the fact that the results fall into two camps. In those related to non-sequential effects (Hypotheses 1-3), no group differences were recorded. However, in those related to sequential effects (Hypothesis 4), group differences and attentional bias towards emotional and symptom-salient in the Checker group were found. Although some caution needs to be exercised over the results, this is a novel and interesting finding, and one which could be highly relevant for OCD research. It highlights the importance, not only of the use of a participant-centric approach to stimuli-choice in study design, but also of taking a more refined experimental approach to the examination of a complex, heterogeneous condition like OCD. Examination of sequential inter-trial effects in visual search may be particularly useful for gaining a more nuanced picture of selective attention processing in people with the condition.

4.4.2.1. Non-sequential effects

In Study 1, OC participants produced consistently slower reaction times than Controls in a non-emotional PoP experiment. This was taken to indicate the presence of a selective attention deficit among the OC participants. However, in the present study there were no differences in reaction times recorded by Checkers and those recorded by Non-Checkers. Indeed, the mean reaction times recorded by groups were, numerically, very similar. Of course, the designs of the present study and Study 1 do not map directly on to each other. The present study used a visual search design which was a derivation of the PoP paradigm, with complex picture stimuli. Its design did not measure the PoP effect. At no stage, for example, were any trials presented to participants in which both target and distracter content was swapped from the previous trial. Additionally, the present study examined a Checker OC population, while Study 1 examined a homogeneous OC group. However, a similar absence of difference in performance between Checker and Non-Checker groups was also found in the study reported in Chapter 3. This study did use a classic PoP paradigm, with visual search stimuli comprising coloured-shape targets and distractors – like Study 1. However, in Study 2, this task was manipulated via the use of single emotional pictures (checking, negative and neutral – the same categories used in the present study) which were presented to participants in advance of each search array. In Study 2, we predicted that the presence of these pictures, in particular the checking pictures, would be disruptive to the performance of Checkers, resulting in slower reaction times in comparison to those of Non-Checkers. In fact, the results showed that the reaction times recorded by each group
were the same. Although Study 2 has limitations and caution must be exercised regarding the results, one explanation for this finding is that the emotional content of the pictures used in the task served to boost the attentional faculties of the Checker participants, to the point where it was normalised or differences between the groups were eliminated. The findings of similar overall reaction time performance between Checkers and Non-Checkers in the present study tally with those reported in Study 2. Furthermore, in the present study, while reaction times for negative and checking pictures were slower in the Target Neutral condition than they were in the Target Change condition (in line with **Hypothesis 2**), no differences were found when these findings were examined in relation to group (contrary to **Hypothesis 3**). This meant that, when data relating only to current trial reaction times was examined, there was no evidence of attentional bias towards any of the picture categories (including checking pictures) among Checker participants. As already stated, not all previous research examining possible attentional bias in OC populations has found differences in performance between OC and non-OC groups (Harkness et al., 2009; Moritz & von Mühlenen, 2008). It could be argued that habituation to the task may have taken place (see Amir et al., 2009), or that the pictures may have been too complex and not presented for long enough to allow-for appropriate cognitive processing by participants. However, the suggestion that the presence of emotion in the task may have acted to improve the reaction times of Checkers, or eliminate the difference in performance between Checkers and Non-Checkers, is supportive of the findings of Becker (2009), who reported that visual search performance was aided by presentation of emotional face pictures prior to search arrays.

### 4.4.2.2. Sequential effects

However, the present study also looked to further examine inter-trial findings in Study 1 relating to the operation of target activation and distractor inhibition processes – specifically that the balance of these processes appeared to be altered in OC participants. In Study 1, OC participants suffered impaired performance in target activation sequences which involved changed distractors and repeated targets. This was in comparison to their speedier performance in distractor inhibition sequences which involved changed targets but repeated distractors. One interpretation of this finding is that the OC participants in Study 1 demonstrated an attentional bias towards the irrelevant distractor information. This resulted in excessively slower reaction times in trials in which distractor information was changed from the immediately preceding presentation. Models of attentional bias in OCD point to both excessive vigilance towards, and disengagement difficulty from, distracting and threatening stimuli in people with OCD (Armstrong & Olatunji, 2012; Bradley et al., 2016). In the present study, we looked to further examine how far this finding in Study 1 could be understood in relation to such models through the use of two conditions – one involving changes of distractor across inter-trial sequences (Target Neutral condition) and one involving changes of target across sequences (Target Change condition).
When the impact of previous trial picture category on current trial performance was examined an interesting picture emerged. Previously-presented checking and negative pictures impaired Checker performance in the Target Neutral condition, but facilitated performance in the Target Change condition (confirming the prediction of Hypothesis 4). By contrast, emotional content from previous trials had no influence on the performance of Non-Checkers. This finding is significant, as it suggests that by looking beyond immediate, current trial reaction data, a more nuanced picture of attentional bias with OCD might emerge. Indeed, these results suggest that, while the heightened arousal caused by the presence of emotional stimuli may have an effect of eliminating overall reaction differences between Checker and Non-Checker groups, the effect of emotion in a previously presented trial may still have an effect on Checker performance that is not seen in Non-Checker performance. However, this differential effect within the Checker group would have been missed had sequential effects not been examined.

Importantly, the sequential effects for emotional and symptom-salient pictures in the Checker group that are reported here are in line with those found in Study 1 using non-emotional stimuli. However, the p values reported for the findings of the present study were highly significant, and more significant than that reported in Study 1. Furthermore, the effect sizes for the findings of the present study, while not large, are bigger than that reported in Study 1. Thus, in Study 1, Checkers were slower in sequences featuring changed distractors and repeated targets than they were in sequences featuring repeated distractors and changed targets. The effect size for this finding was very small (p=0.012, d=0.12), but worthy of further examination. In the present study, Checkers were found to be slower in the Target Neutral condition (changed distractor category pictures, repeated target category pictures) than in the Target Change condition (change target category pictures, repeated distractor category pictures) when both checking and negative pictures featured in the previous trial. The effect size for the checking picture finding was small-to-medium (p=0.001, d=0.3) and for the negative picture finding was small (p=0.001, d=0.2). This suggests that the use of emotional and symptom-salient, while not resulting in huge magnitudes of difference, has resulted in stronger differences between groups in Study 3 when compared with Study 1.

Interestingly, a positive correlation was found between anxiety in the Checker group and reaction times in both the Target Neutral and Target Change conditions when previous trial pictures whether either checking or negative images. This contrasts with the findings of Study 1, in which no relationship was found between anxiety and group reaction time differences. Moreover, it also particularly contrasts with Study 2, in which no relationship was found between anxiety and group error rate differences, because of the strong overlap in samples between Study 2 and the present study. What the correlation findings in the present study do suggest is that Checkers who are more prone to anxiety may be more likely to display delayed disengagement difficulty in cognitive tasks of this
nature. But, again, this highlights the importance of looking beyond current trial reaction data to generate a deeper picture of attentional bias with OCD.

The findings of the present study, then, are in line with research pointing to both an impaired ability to inhibit irrelevant information (e.g., Kaplan et al., 2006; Swerdlow et al., 1999) and an attentional bias towards threatening material, particularly if it is directly relevant to checking concerns (e.g., Moritz et al., 2009). Furthermore, they are supportive of a model of attentional biasing which suggests cognitive disengagement from emotional and symptom-salient material (as demonstrated here with the effect of previous trial presentations) is a feature of OC checking (Bradley et al., 2016; Georgiou et al., 2005). However, it is possible the speedier reaction times in the Target Change condition following the previous presentation of checking and negative pictures may also reflect heightened vigilance (Armstrong & Olatunji, 2012) to emotional stimuli when they appear as targets. The findings also suggest that habituation to the stimuli in the Checking group was unlikely to have occurred.

Interestingly, however, there was no difference between the conditions when previously-presented neutral pictures were examined. If Study 3 is taken in isolation, this is relatively simple to account for – the impact of the emotional and symptom-salient content in the checking and negative pictures resulted in differentiated performance in those particular sequences. However, in Study 1, the stimuli used, while not pictorial, were effectively neutral – comprising coloured-shapes. Yet, group differences were found with the use of these stimuli. However, the stimuli used in Study 1 placed little demands on attentional processing by comparison with the detailed picture content of the present study. Thus, differences in Checker performance in the present study became enhanced when stimuli were meaningful or threatening. It is interesting, also, that no repetition vs. swap effects were found in the present study (see Figure 4.6), which again is likely to be reflective of the use of picture categories with multiple exemplars. Category repetition and category swap may not function in the same way and simple colour-shape repetition and swap. This needs further investigation.

4.4.3. Limitations

There are a number of limitations to the present study. Like with Studies 1 and 2, an a priori analysis was not carried out in advance to assess the amount of participants needed to obtain appropriate power. As with these two studies, the sample size in the present study (N=46) was relatively small – 23 participants in each group. A post-hoc G*power analysis revealed that in order to achieve a small group effect ($\eta_p^2 = 0.01$) in performance between both task conditions, at a recommended statistical power of 0.8 (Cohen, 1988), a sample of size of 780 participants would be required for this study. For a medium effect ($\eta_p^2 = 0.09$) the equivalent sample size would need to be $N=82$, and for a large effect ($\eta_p^2 = 0.25$) it would need to be $N=26$. Meanwhile, to achieve a small differential effect ($d = 0.2$) in
performance by one group in different levels of both conditions – as was recorded by the Checker group performance in the previous trial analysis detailed in Section 4.3.4 – a sample of 156 participants was required. For a medium effect \((d = 0.5)\), the necessary sample size was \(N=27\), and for a large effect \((d = 0.8)\) the appropriate number of participants would be \(N=12\). The effect size for the Checker group reaction time difference between conditions when previous trial pictures were checking images \((d = 0.3)\) had a power of 0.64. The equivalent effect size when previous trial pictures were negative \((d = 0.2)\) had a power of 0.37. Like with Studies 1 and 2, this suggests that the use of a greater number of participants would have boosted the statistical robustness of the findings in Study 3. However, sampling for the present study and Study 2 involved the use of explicit inclusion and exclusion criteria relating to the presence or non-presence of checking symptoms. This meant that a high number of potential volunteers were rejected. But, and as with Study 2, the advantage of this approach is that both groups featured participants with very similar OC characteristics – as defined by the strict inclusion/exclusion criteria.

The present study took a novel approach to the study of selective attention in OC individuals. We designed an emotional visual search task, which borrowed aspects of the PoP paradigm to examine target activation/distractor inhibition processes in checkers and non-checkers. As far can be ascertained from the literature, this has not been attempted by researchers previously. Caution must, therefore, be exercised when considering the findings of this study. Although we looked to further examine findings relating to target activation and distracter inhibition and attentional bias reported in Study 1, different OC populations were recruited for both studies. There were also different inclusion criteria in both studies for the control groups (non-checking in the present study vs. non-OCD in Study 1). Like in Study 2, some stimuli images contained facial content. Although such images were included in all three picture categories, it is possible that the presence of such visual content could have had a confounding effect on findings. As such, some caution must be exercised over the conclusions drawn from the present study in relation to the findings of Study 1.

Like in Study 2, a high level of omissions was recorded in the present study. Again, it is not clear why this occurred. Potential confounding reasons (e.g., technical error, inadequate instructions to participants) have been examined and ruled out (a checklist examination of possible confounds is included in Appendix 4). The high omission rate occurred in both groups – also like Study 2. One possibility is possible that search arrays contained too much information to be processed appropriately in order for the task to be completed within the allowed time window. The picture stimuli might have been too complex. However, the lack of group or condition differences in omission rates, and in the rates of correct responses, early responses and late responses, means these variables did not impact the overall findings of the present study.
4.4.4. Future research

This was a novel study. However the findings, alongside those from Studies 1 and 2, suggest that visual search, and particularly inter-trial, paradigms could play a role in future research investigating selective attention, attentional bias and OCD. In order to assess the validity of the effects reported here, larger samples need to be recruited. The additional of anxious non-OCD groups would help establish how far such effects could be said to be specific to Checkers. From this perspective, other OC subtypes should also be examined, given the evidence of differing cognitive and neuropsychological profiles among subtypes (e.g., Leopold & Backenstrauss, 2015; Mataix-Cols et al., 2004). Would Washers, for example, be equally, or more, responsive to picture stimuli which related to their concerns? It is notable from the literature that much of previous research looking at attentional bias with emotion has used verbal rather than picture stimuli. The paradigm in the present study could be adapted to incorporate word stimuli as targets and distractors, which might aid comparisons with previous research and enable assessment of possible differences in the processing of verbal and picture stimuli in OC populations. Finally, an assessment of how visual search paradigms translates to use with clinical populations should be made, with a possible view to examining whether such paradigms could have a role in attentional bias modification (ABM) treatments.

The final study of this thesis (Study 4), which follows in the next chapter, looked to examine how far altered Checker performance in selective attention and attentional bias tasks might also be reflected in altered performance and bias in tasks assessing long-term memory. Rather than just assessing the performance of Checkers, this study including Washer and generalised OC populations, alongside Checkers and non-OC controls. The aim was to examine how far bias could be understood as a checking-associated symptom. Additionally, the study used verbal rather than picture stimuli, which overcame the possible confounding issues of facial content which may have been a feature of Studies 2 and 3.

4.4.5. Conclusions

The present study demonstrates potential of inter-trial visual search paradigms in study of OC selective attention and attentional bias. It emphasises the utility of the study of sequential effects, and how the use of refined experimental designs with emotional, symptom-salient can reveal characteristics of OC selective attention that may be highly specific – and which would otherwise not be exposed by more traditionally-used paradigms (e.g., Stroop).
Chapter 5

Study 4:

*Examining long-term memory for emotional verbal stimuli in non-clinical Checker, Washer and generalised OC populations*
5.1. Introduction

Studies 1, 2 and 3 reported in this thesis have provided novel evidence in support of theories which suggest such symptomology is underpinned by altered selective attention processing and attentional bias. However, it is conceivable that OC repetitive behaviours and ritual may also be informed by dysfunction and bias in cognitive recall and recognition operations. People with OCD often report doubt over whether they have carried out an action or not (Cougle et al., 2008; Harkin & Kessler, 2009; Rachman, 2002). This doubt – which is regarded as a fundamental to the maintenance of OCD (Salkovskis, 1985; Rachman, 2002) – may reflect altered memory processing of some kind, in addition to reflecting dysfunction in attentional systems.

As already stated, dysfunction in attention and memory is not necessarily mutually exclusive. Bias and/or deficits in one may feed the functioning of the other. Attentional bias to threat may act to trigger a person’s problems in suppressing threatening memories. Consequently, this could further reinforce an attentional bias to threat (Muller & Roberts, 2005). Study 4 looked to examine how far, and in what ways, altered cognitive processing and bias could be understood as a feature of OC long-term memory.

Although a good deal of research has examined possible memory dysfunction with OCD, the findings have been mixed. As stated in Section 1.13, this has particularly been the case when verbal stimuli – rather than non-verbal stimuli – have been used in experiments (Muller & Roberts, 2005). Deficits with the condition have been reported by some researchers (e.g., Sher et al., 1984; Zitterel et al., 2001), but others have failed to find similar results (e.g., MacDonald et al, 1997; Radomsky & Rachman, 1999). The lack of consistent evidence for a global deficit in memory with OCD has led to the development of more nuanced theories, notably that executive dysfunction is the likely primary root of differentiated OC performance on experimental tasks (Greisburg & McKay, 2003).

However, it may also be the case that the failure to find robust support for a memory dysfunction theory – particularly in relation to verbal stimuli – lies in the choice of paradigms used for testing, and aspects of the experimental design. Many of the established neuropsychological tests used in earlier studies of OCD may be useful for examining clear-cut cognitive disorders, but may not be sensitive enough to flag-up memory dysfunction in OC populations (Klump et al., 2009; Kuelz et al., 2004). Furthermore, the heterogeneity of OCD suggests that neutral or generalised threat-related stimuli, as used in some previous OCD research, may have little utility in triggering OC symptoms, because such stimuli have little relevance to explicit concerns of the participants of a particular study (Abramovitch et al., 2013; Muller & Roberts, 2005). Additionally, the presence of comorbid conditions are likely to
have been compromised the findings of some previous studies (Muller & Roberts 2005; Kuelz et al., 2004; Woods et al., 2002).

More recently, researchers have begun examining the effects that repetitive behaviours have on memory (e.g., Klumpp et al., 2009; Hansmeier et al., 2015; Harkin & Kessler, 2009; Harkin & Kessler, 2011b). Studies suggest, for example, that repeated checking actually has the effect of reducing, rather than improving, memory clarity and certainty (Coles et al., 2006; van den Hout & Kindt, 2003a, 2003b, 2004; Radomsky et al., 2014). Additionally, OC participants demonstrate reduced confidence in their memory (Alcolado & Radomsky, 2016; Cougle et al., 2008; Hermans et al., 2003; Tolin et al., 2001). This appears to occur even when accuracy is unaffected. However, in particular circumstances, OC memory might be strengthened rather than weakened – notably when participants view emotional stimuli. Indeed, Checkers have been found to have enhanced recall abilities for material which is directly relevant to their concerns (Hansmeier et al., 2015), while personally-relevant stimuli has been shown to be difficult to forget for OC participants (Tolin, 2002).

One way of examining the idiosyncrasies of OC memory is through the remember/know paradigm (Tulving, 1985). This suggests that memories can be firmly recollected (‘remember’ memories) or they can have a looser sense of familiarity about them (‘know’ memories). Importantly, the paradigm enables the examination of possible differences in the way memories are processed even when accuracy is unimpaired (Tulving, 1985). In a series of non-verbal memory studies, van den Hout & Kindt (2003a, 2003b, 2004) found that repeated checking made recollections less detailed. It was argued that continued checking resulted in increased conceptual processing over perceptual processing. Among participants, this resulted in a less firm sense of recollection and greater distrust of what could be remembered (van den Hout & Kindt, 2004). Meanwhile, Klumpp et al., (2009) assessed false memories for verbal material in non-clinical Washers and Checkers using a remember/know paradigm. The study found that OC participants recorded heightened numbers of false memories relating to OC-salient stimuli, and that these memories were more often rooted in familiarity rather than firm recollection.

Although reviews (e.g., Kuelz et al. 2004; Muller & Roberts, 2005; Woods 2002) have recommended that experimenters need to be more mindful of the sensitivity of their paradigms when testing OC participants, there remains limited research examining verbal memory in OCD using designs which can access more subtle aspects of OC cognition, such as those based on remember/know theory. Furthermore, there has been little, if any, remember/know-based research examining OC subtype populations (e.g., Checkers and Washers) and which uses verbal stimuli which has been selected because of its saliency to the particular concerns of those subtypes. It remains unclear whether OC verbal memory may be understood to be altered – and whether, and under what circumstances, such
alterations might reflect impairment or enhancement of memory. Additionally, few studies have examined attentional priming effects and implicit memory in OC populations. Again, there is little agreement among those which have as to whether implicit memory is altered in OCD (Kim et al., 2006).

In the present study, we looked address these issues. The design of the study enabled assessment of several memory-related measures, including attentional priming (reaction times), accuracy (discriminatory sensitivity, hits and false alarms), response bias, use of remember/know memory and confidence ratings. We included signal detection methodology in our data analysis for detailed examination of participant performance. There is a gap in the literature for a comprehensive examination of multiple aspects of long-term verbal memory with OCD. The aim of the present study was to fill that gap.

The present study used a continuous identification with recognition (CID-R) paradigm. This design has previously been used with healthy populations (e.g., Berry et al., 2008), but, to the best of our knowledge, it has not yet been used with OC populations. A basic CID-R experiment involves two phases. In the study phase, participants are shown a series of individual words on the screen. The words are initially masked and gradually revealed. Participants report the name of the word when they recognise it. Then in the test phase, they perform the same task, but new words are included. The participants are asked to report whether they think a given word is old or new. The present study extended the standard design to incorporate measures allowing analysis of both remember/know memory and confidence ratings.

One of the conclusions drawn from the findings of Studies 1, 2 and 3 was that the findings – particularly those related to performance by Checkers – might have been strengthened with the use of multiple OC subtype populations. This is in line with evidence that differing OC populations have different cognitive and neuropsychological profiles (e.g., Bragdon et al, 2018; Mataix-Cols et al., 2004). Study 4 looked to test non-clinical Checkers and Washers, alongside a general non-clinical OC group and non-OC controls. There is a good deal of evidence of differentiated cognitive performance across a number of areas between Checkers and Washers, including some reporting differences in verbal memory (Leopold & Backenstrass, 2015). Moreover, it is suggested that memory bias may be more fundamental to checking behaviour than other forms of OC behaviour – notably, washing behaviours (Rachman, 2002; Woods, 2002).

A second issue that was highlighted in Studies 2 and 3 was the inclusion of facial content in the picture stimuli used in these studies, which may have acted as a confound. In Study 4, this was not a concern as the experiment used verbal rather than non-verbal stimuli in the design. In order to
increase the OC-relevance of the present study, and to address criticisms of previous research in this area, we used a bespoke written word stimuli dataset which included categories of words tailored to checking and washing concerns, alongside generalised negative and neutral word stimuli. All the word stimuli, apart from the neutral exemplars, were negatively-valenced, in line with research that suggests obsessive-compulsive participants may be biased towards stimuli which is threatening, particularly if it salient to personal concerns (e.g., Harkin et al., 2011; Moritz et al., 2009; Muller & Roberts, 2005).

5.1.1. Hypotheses

Firstly, it was expected that repetition priming effects would be apparent in test phase reaction times for word targets which had previously been presented in the study phase – Hypothesis 1. Secondly, it was predicted that Checkers and Washers would make more false alarms than Controls, and that this would occur particularly for checking and washing word types – Hypothesis 2. Thirdly, it was expected to find that both Checkers and Washers would be more reliant on know memory than Controls – Hypothesis 3. Finally, it was predicted that Checkers and Washers would demonstrate less confidence than Controls – Hypothesis 4. Additionally, the study also explored the possibility of group differences (Checkers vs Washers vs. OCGs vs. Controls) in repetition priming, as well as hit rates, discriminatory sensitivity ($d'$) and bias ($C$), and whether these might be impacted by manipulations of word category type (checking vs. washing vs. negative vs. neutral).

5.2. Methods

5.2.1. Participants

Participants were recruited via an advert on the Sona Systems research participant recruitment website, hosted by the University of Surrey. They were given £7.50 as compensation for taking part, although psychology students could receive course credit in the form of two lab tokens. The study received a favourable ethical opinion from the University of Surrey Ethics Committee (see Appendix 6).

5.2.1.1. Participant screening

Prior to the lab-based study, potential participants were screened for checking and /or washing tendencies using the OCI-R (Foa et al., 2002). Details relating to this measure have been provided in Section 1.14.1.2 and Section 2.2.1.2.
5.2.1.2. Inclusion and exclusion criteria
The inclusion criteria for the OC groups were an OCI-R subscale score of $\geq 5$ on the checking subscale and/or $\geq 4$ on the washing subscale (cut-scores in line with Foa et al., 2002; Hajcak, Huppert, Simons, & Foa, 2004). Participants were then put into one of three subtype groups – Checker, Washer or Obsessive-Compulsive General (OCG). Checker group participants reported a checking subscale score of $\geq 5$, but a washing subscale score of $\leq 3$. Washer group participants reported a washing score of $\geq 4$, but a checking score of $\leq 4$. Finally, participants who reported scores of $\geq 5$ for checking and $\geq 4$ for washing were put in the OCG group. All participants in the OCG group also reported an OCI total score of $\geq 21$. The inclusion criteria for Control participants was a total OCI-R score of $\leq 15$, a washing subscale score of $\leq 2$ and checking subscale score of $\leq 1$. All participants were required to speak English as their first language and have no history of a neurological or neuropsychological disorder.

5.2.1.3. Additional questionnaire measure
The Hospital Anxiety and Depression Scale was filled-in by participants (HADS; Zigmond & Snaith, 1983) prior to taking part in the experiment. Details relating to this measure have been provided in Section 2.2.1.3.

5.2.1.4. Recruited participant groups
In total, 15 Checkers, 11 Washers, 16 OCGs and 20 Controls were recruited. However following post-recording examination of the data, three participants were removed from the analysis. One participant (a Checker) had an unusually high error rate (>3 SD above the mean in both experimental phases), one participant (a Control) did not perform the word identification aspect of the task correctly, and the final participant (a Control) was excluded because of a technical fault with the E-prime programme. Consequently, the findings of this study are based on data from 14 Checkers, 11 Washers, 16 OCGs and 18 Controls.

The Checker group comprised 10 females and four males (mean age = $22 \pm 2.9$ years; range: 19-29 years), the Washer group were all females (mean age = $20.1 \pm 2.1$ years; range: 18-24 years) and the OCG group included 11 females and five males (mean age = $19.9 \pm 2$ years; range: 18-23 years). Meanwhile, the Control group comprised 11 females and seven males (mean age = $21.8 \pm 3.1$ years; range: 19-29 years).

Tests of normality were carried out on descriptive and questionnaire data by assessing $z$-scores for skew and kurtosis. OCI-R total score data were normally distributed. All other data were not normally distributed.
Table 5.1 shows the descriptive statistics for all groups. A one-way Kruskal-Wallis analysis of the age scores of the groups was significant ($\chi^2$(3)=8.31, $p=0.04$, $\eta^2=0.1$). However, no differences were found between any of the groups in post-hoc analysis. As expected, Checkers recorded significantly higher scores on the checking subscale than Controls ($U(N=32)=0.0$, $z=-4.91$, $p<0.001$, $d=3.2$). Likewise, Washers recorded significantly higher scores on the washing subscale than Controls ($U(N=29)=0.0$, $z=-4.88$, $p<0.001$, $d=2.9$). OCGs scored higher on both the checking ($U(N=34)=0.0$, $z=-5.08$, $p<0.001$, $d=3.3$) and washing ($U(N=34)=0.0$, $z=-5.28$, $p<0.001$, $d=3.3$) subscales than Controls. Importantly, Checkers differed significantly from Washers on the checking and washing subscales. Checkers had significantly higher checking subscale scores than Washers ($U(N=25)=0.0$, $z=-4.25$, $p<0.001$, $d=3.1$) and lower washing subscale scores than Washers ($U(N=25)=0.0$, $z=-4.26$, $p<0.001$, $d=3.1$). Checkers had also significantly lower scores than OCGs on the washing subscale ($U(N=30)=0.0$, $z=-4.72$, $p<0.001$, $d=3.2$), but there was no difference between the groups on the checking subscale ($U(N=30)=108$, $z=-0.17$, $p=0.865$, $d=0.06$). Washers had significantly higher washing scores ($U(N=27)=32$, $z=-2.81$, $p=0.005$, $d=1.3$) and lower checking scores than OCGs ($U(N=27)=0.0$, $z=-4.37$, $p<0.001$, $d=3$).

Table 5.1 also shows that Checkers scored below the OCI-R symptom-presece cut-off scores on every subscale except for checking (for cut-off score details see Foa et al., 2002; Hajcak et al., 2004). Likewise, Washers scored below the cut-off scores on every OCI-R subscale except for washing. The OCG group, by contrast, scored above the cut-off scores on every OCI-R subscale, except for hoarding. Notably, however, OCGs recorded significantly higher hoarding scores than Checkers ($U(N=30)=48.5$, $z=-2.69$, $p=0.007$, $d=1.1$). At the same time, they also recorded higher neutralising scores than Checkers ($U(N=30)=44.5$, $z=-2.83$, $p=0.005$, $d=1.2$) and Washers ($U(N=27)=19$, $z=-3.44$, $p=0.001$, $d=1.7$). All three OC groups scored above the OCI-R total cut-off score of 21. However, the OCG total score was significantly higher than that recorded by the Checker group and the Washer group. One-way ANOVA analysis of total OCI-R scores, with the factor group (Checkers, Washers, OCGs, Controls), revealed a significant main effect of group ($F(3,55)=52.323$, $p<0.001$, $\eta^2=0.74$). Post-hoc Bonferroni $t$-tests indicated that, in addition to significant differences between all three subtypes and Controls (all $p<0.001$ – Checkers vs. Controls, $d=2.8$; Washers vs. Controls, $d=1.6$, OCGs vs. Controls, $d=3.9$), this was also driven by the higher total scores recorded by OCGs in comparison to both Checkers ($p<0.001$, $d=1.8$) and Washers ($p<0.001$, $d=1.8$).
Table 5.1. Descriptive scores, total and subscale OCI-R scores and HADS scores (mean ± SE) for the Checker, Washer, OCG and Control groups (*=significant difference from Control group score). Score ranges are reported in brackets. Planned comparisons were carried out for the checking and washing subscale scores. Cut-off scores indicating symptom presence: Checking = ≥5; Washing = ≥4; Ordering = ≥7; Neutralising = ≥4; Obsessing = ≥5; Hoarding = ≥7; Total = ≥21 (Foa et al, 2002; Hajcak et al., 2004).

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Checker</th>
<th>Washer</th>
<th>OCG</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of participants</td>
<td>18</td>
<td>14</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Age</td>
<td>20.7 ± 2.5 (19-29)</td>
<td>22.0 ± 2.9 (19-29)</td>
<td>20.1 ± 2.1 (18-24)</td>
<td>19.9 ± 2.0 (18-23)</td>
</tr>
<tr>
<td>Gender</td>
<td>32f/9m</td>
<td>10f/4m</td>
<td>11f/-</td>
<td>11f/5m</td>
</tr>
<tr>
<td>Handedness</td>
<td>61.4</td>
<td>79.9</td>
<td>47.5</td>
<td>38.5</td>
</tr>
</tbody>
</table>

OCI-R

<table>
<thead>
<tr>
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<th>Control</th>
<th>Checker</th>
<th>Washer</th>
<th>OCG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checking</td>
<td>0.6 ± 0.5 (0-1)</td>
<td>6.8 ± 1.7* (5-9)</td>
<td>1.6 ± 1.4 (0-4)</td>
<td>6.8 ± 1.9* (5-12)</td>
</tr>
<tr>
<td>Washing</td>
<td>0.2 ± 0.5 (0-2)</td>
<td>2.0 ± 1.0* (0-3)</td>
<td>7.8 ± 2.4* (5-12)</td>
<td>5.4 ± 2.0* (4-11)</td>
</tr>
<tr>
<td>OCI-R total</td>
<td>7.0 ± 4.1 (1-15)</td>
<td>24.6 ± 7.9* (13-41)</td>
<td>22.7 ± 10.1* (9-42)</td>
<td>39.4 ± 8.2* (28-55)</td>
</tr>
</tbody>
</table>

Other subscales

<table>
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<th>Control</th>
<th>Checker</th>
<th>Washer</th>
<th>OCG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordering</td>
<td>2.1 ± 2.0 (0-8)</td>
<td>5.6 ± 3.4* (1-12)</td>
<td>5.6 ± 3.7 (0-12)</td>
<td>8.2 ± 2.7* (3-12)</td>
</tr>
<tr>
<td>Neutralising</td>
<td>0.4 ± 0.7 (0-2)</td>
<td>1.9 ± 1.7* (0-5)</td>
<td>0.8 ± 0.9 (0-2)</td>
<td>5.4 ± 3.6* (0-12)</td>
</tr>
<tr>
<td>Obsessing</td>
<td>1.3 ± 1.5 (0-5)</td>
<td>4.4 ± 3.7* (0-12)</td>
<td>3.4 ± 2.6 (0-8)</td>
<td>7.2 ± 3.9* (1-12)</td>
</tr>
<tr>
<td>Hoarding</td>
<td>2.6 ± 2.1 (0-9)</td>
<td>3.9 ± 2.5 (0-7)</td>
<td>3.6 ± 3.2 (0-8)</td>
<td>6.4 ± 1.5* (4-10)</td>
</tr>
</tbody>
</table>

HADS

<table>
<thead>
<tr>
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<th>Washer</th>
<th>OCG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety</td>
<td>4.4 ± 2.2 (1-9)</td>
<td>9.5 ± 3.2* (3-17)</td>
<td>8.8 ± 3.0* (3-12)</td>
<td>10.9 ± 3.8* (5-18)</td>
</tr>
<tr>
<td>Depression</td>
<td>1.9 ± 1.9 (0-8)</td>
<td>4.2 ± 3.1 (0-9)</td>
<td>3.6 ± 2.3 (0-8)</td>
<td>4.4 ± 3.3* (0-12)</td>
</tr>
</tbody>
</table>
In addition, the scores for HADS anxiety and depression are shown Table 5.1. A one-way Kruskal-Wallis analysis of the anxiety scores recorded by the groups was significant ($\chi^2(3)=26.13, p<0.001, \eta^2=0.42$). Post-hoc Mann-Whitney tests found that participants in all three OC groups had greater anxiety levels than Controls (Checkers: $p<0.001, d=1.9$; Washers: $p=0.001, d=1.5$; OCGs: $p<0.001, d=2.3$). There were no differences in anxiety between the three OC groups. The mean anxiety scores for each of these groups were within the borderline enhanced range of the measure. The mean score for the Control group was in the normal range. Meanwhile, a one-way Kruskal-Wallis analysis of the depression scores recorded by the groups was also significant ($\chi^2(3)=9.88, p=0.02, \eta^2=0.12$). Post-hoc Mann-Whitney tests found that this was driven by significantly higher depression scores recorded by OCGs in comparison to Controls ($p=0.005, d=1$). Note, though, that both the OCG and the Control mean depression scores are within the normal range of the HADS measure. No other differences between groups were found.

5.2.2. Overall Procedure

Participants completed the OCI-R questionnaire before taking part in the lab-based study. At the same time, participants were given an information sheet about the experiment. On arrival in the laboratory, participants were asked to confirm that they had read the information sheet and were happy to take part in the study. They then gave their informed consent to take part in the study. They then took part in a two-part, computer-presented memory experiment, lasting approximately 50 minutes. On completion, participants were thanked and compensated for their time. A flowchart representation of the overall study procedure is in Figure 5.1.

![Figure 5.1. A schematic representation of the overall procedure of Study 4.](image-url)
5.2.3. Memory experiment

5.2.3.1. General set-up
The lab-based memory experiment took place in a Brain and Behaviour Group laboratory recording booth at the University of Surrey. The experiment was programmed in E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, P.A.). During the experiment, visual stimuli were presented on a CRT monitor with a refreshment rate of 60Hz and a resolution was 1024 x 768. Participants sat one-metre from the screen. The room was darkened and an illuminated keyboard with chiclet keys (Perixx Periboard-311 model) was used to record participant responses. Auditory recordings, using a portable Olympus VN-3100PC digital voice recorder placed beside the computer monitor, were made of each recording session in order to establish whether or not participants had correctly identified the word stimuli presented to them on screen. The experiment was piloted with four participants.

5.2.3.2. Word list creation
Few previous studies examining OC verbal recollection have used word stimuli which have specific relevance to OC issues. Furthermore, the studies that have used tailored word lists have, in the main, only used a small number of stimuli exemplars. As such, in advance of the main experiment, a separate pre-study was carried out in order to collate a large, bespoke word stimuli data set that would be suitable for us in the main experiment. The aim was to collect word targets that were salient to checking and washing concerns, along with negative and neutral exemplars. The aim of using negative stimuli was to differentiate possible general negative effects from those related to specific checking and/or washing concerns. Potential word targets were selected following assessment of previous studies which had used word stimuli to examine OCD, consultation with Dr Laura Simonds and Dr Clara Strauss (lecturers in clinical psychology at the University of Surrey), and word searches using the English Lexicon Project (Balota et al., 2007) database.

The pre-study had two parts. In Part 1, four Checker and Washer participants rated a list of potential checking and washing word targets for valence and their relevance to checking/washing concerns. In Part 2, a refined list of potential words from Part 1, along with and possible negative and neutral exemplars, were rated for valence, imageability and concreteness by five Non-OC Control participants.

Following the analysis of Part 2 data, 156 word targets (26 checking-relevant, 26 washing-relevant, 52 negative and 52 neutral) were chosen for use in the main experiment. The targets were divided into two lists – List A and List B. Each contained 78 words, comprising of 13 checking, 13 washing, 26 negative neutral and 26 neutral words. Lists were carefully balanced for valence, concreteness and
imageability and frequency. All words were four to six-letters-long. Details of the pre-study, including a list of the word targets used in the present study, are in Appendix 7.

5.2.3.3. Word list presentation
All words were presented in the centre of the screen in black (lower case, 20pt Courier New font) on a medium grey background. For each participant, either List A or List B was used in the study phase of the experiment, and thus became that participant’s list of old words. The other list was then introduced in the test phase (along with the old words list), and thus became that participant’s list of new words. The selection of which list was used in which phase was counterbalanced across participants. A further 20 neutral words were used as ‘filler trials’ in the study phase to control for primacy and recency effects. Ten of these words formed the first 10 trials with the remaining 10 forming the final 10 trials of the study phase. No data from these trials was analysed and the words were not used in the test phase.

5.2.3.4. Procedure
The experiment had two parts – a study phase and a test phase. The study phase consisted of 98 trials. At the start of each trial (Figure 5.2), participants were presented with a mask comprising a row of hash symbols (#) for 500ms. The number of hash symbols used corresponded to the number of letters in the target word for that particular trial. A word was then presented for 17ms, followed by the hash symbol mask for 233ms, thus forming a 250ms unit. The stimulus was then re-displayed, but its on-screen time was increased by 17ms (17ms+17ms = 34ms), while the presentation time of the following mask was shortened by 17ms (233ms-17ms = 216ms), resulting in another word/mask unit that lasted 250ms. The trial continued in this manner, increasing the word duration by 17ms from presentation to presentation while decreasing the mask duration simultaneously. This created 15 consecutive word/mask units of 25ms duration that could be presented in each trial. Participants were informed that, in each trial, a word would be presented to them on-screen in a ‘flashing’ manner. They were told that this word would gradually become easier to identify. The task of the participants was to press a response key (the space bar) as soon as they were confident they recognised the word identity and, afterwards, to say the word out aloud. Participants were told to be as fast and accurate as possible. After participants responded with the key press, the trial was ended and a mask was presented on-screen for 2,000ms. In order to start the next trial, participants were asked to press the ‘c’ key. An on-screen message was shown to participants in the event of their failure to identify a word. This asked them to be faster in following trials. Response times were measured from the onset of the first word presentation up to key press in each trial.
Figure 5.2. A - Trial structure of an example Study phase trial. B - Trial structure of the additional screens and task requirements for an example Test phase trial.

The test phase followed the same procedure as the study phase, but the stimuli comprised all the words from both List A and List B (156 trials). Whichever word list was used in the study phase thus became the ‘old’ word list, while the other word list became a ‘new’ word list. As in the study phase, participants were asked to identify words, which were gradually unmasked on-screen, as quickly and accurately as possible, using a keyboard response press. However, following each trial, they were also asked, via on-screen instructions, to choose whether they firmly recollected the presented word (a ‘remember’ judgement; key press = ‘1’), whether it was familiar (a ‘know’ judgement; key press =  
‘2’) or whether they thought it was a new word (i.e., a word that was not presented in the study phase; key press = ‘3’). Afterwards, participants were asked to give an indication about their memory judgement confidence on a centrally presented on-screen horizontal sliding scale (10cm) using designated left/right keyboard keys. The confidence scale was from 0-100, with ‘Guess’ being equivalent to 0 (left side of the screen) and ‘Sure’ being equivalent to 100 (right side). The numbered data points did not appear on-screen. Once this this judgement was made, participants were then asked to press the ‘c’ key to start the next trial.

5.2.4. Data analysis

In all analyses, the alpha level of $p=0.05$ was used to determine significance. Where ANOVA analysis was carried out, Huynh-Feldt values were used to correct for sphericity. Bonferroni corrections were used in post-hoc analysis. Where Bonferroni corrected $p$ values are reported (e.g., $p_c=0.003$), results were calculated using the following formula: $\alpha = 0.05/\text{number of post-hoc tests}$. Effect size values for Cohen’s $d$ are reported following $t$-test analysis. Effect size values for $\eta^2_p$ are reported following ANOVA analysis. Following Cohen (1988), the magnitude of effect sizes were considered to be the following – $d$: small=0.2, medium=0.5, large=0.8; $\eta^2_p$: small=0.01, medium=0.09, large=0.25. All figures and tables display mean values accompanied by standard errors.

Verbal identification accuracy: The digital voice recordings taken during each participant’s study and test phase sessions were checked for verbal identification accuracy (i.e., whether, or not, they stated out loud the word target presented on-screen correctly). The digital files of each participant were examined trial by trial, with the participant’s verbal responses to each on-screen word target checked for accuracy against the order of word targets presented by the E-prime programme.

Preparation of study and test data: Data from primacy and recency trials in the study phase were not analysed. Trials in the study and test phase were considered to be errors in the following circumstances: when they finished without a key press response; when the name of the word target was verbalised before the key press response; when the target was verbally incorrectly identified; and when reaction times to targets were less than 200ms. These were excluded from the analysis. The final data which were analysed came only from trials that were correct in both the study and the test phases of the experiment with regard to these criteria.

Repetition priming: For the analysis of possible repetition priming effects in test phase reaction times, the following additional screening of data was carried out. For each participant, a mean reaction time for each word type (checking, negative, neutral and washing) was recorded. A mean standard deviation for each word type and subsequent value for two standard deviations from this mean were
calculated. Trials with reaction times greater than two standard deviations from the mean in each
category, for each participant individually, were eliminated from the analysis. Only trials less than
two standard deviations from the mean in both the study phase and the test phase of the experiment
entered the analysis. Repetition priming was examined firstly for all correctly identified words that
were presented in the study and test phase (all old words), and then separately for words that were
correctly memorised and identified as hits (an old word identified as an old word) in the test phase.
Mixed factorial ANOVAs, with the factors phase type, word type and group, were used to analyse
data, along with post-hoc Bonferroni t-tests to correct for multiple comparisons.

*Hits and false alarms:* Old/new choice responses by participants in the test phase were divided into
four types – hits, misses, false alarms and correct rejections. Hits were considered to be old words
reported as old; misses were defined as old words reported as new; false alarms were new words
reported as old; and correct rejections were new words reported as new. In the present study, an old
word was defined as any word previously presented to a participant in the study phase, while a new
word was defined as any word presented to the participant in the test phase which they had not seen in
the study phase. Hits and false alarm rates were analysed using mixed factorial ANOVAs, with the
factors word type and group, with follow-up one-way ANOVAS examining group differences for
individual word types and post-hoc Bonferroni t-tests where necessary. Additional analysis compared
baseline-corrected difference scores for three of the word types (checking, washing and negative),
with neutral scores used as baseline. This created three new variables (checking minus neutral;
washing minus neutral; and negative minus neutral). These were analysed using the same mixed
factorial ANOVA approach used for the previous analyses.

*Discriminatory sensitivity (d’):* To assess possible differences in discriminatory sensitivity (d’)
between groups, data from hits and false alarms were converted into probability values. In line with
Snodgrass and Corwin (1988), these were calculated by adding a value of 0.5 to each hit and false
alarm score for each participant, before dividing this new figure by the total number of trials presented
plus 1. This controls for problems of infinite z scores which are created when perfect hit rates or no
false alarms scores are recorded (Snodgrass & Corwin, 1988). Values for d’ were then calculated
using the following formula: 
\[ d' = z(\text{hits}) - z(\text{false alarms}). \]
Larger d’ scores indicate greater
discriminatory sensitivity. Scores for d’ were analysed using mixed factorial ANOVAs, with the
factors word type and group, with follow-up one-way ANOVAS examining group differences for
individual word types and post-hoc Bonferroni t-tests where necessary. Additional analysis compared
baseline-corrected difference scores for d’ for three of the word types (checking, washing and
negative), with neutral scores used as baseline.
Response bias (C): In line with previous research (e.g., Azzopardi & Cowey, 1998; Stanislaw & Toderov, 1999), C was calculated using the following formula: \( C = -\frac{z(\text{hits}) + z(\text{false alarms})}{2} \). More positive C scores were indicative of more conservative decision-making, while more negative scores indicated more liberal decision-making. As with the analysis of \( d' \), levels of bias were assessed using mixed factorial ANOVAs, follow-up one-way ANOVAs examining group differences for individual word types and post-hoc Bonferroni t-tests where necessary. Additional analysis compared baseline-corrected difference scores (calculated as previously detailed) for C.

Use of remember/know memory: Overall use of remember and know memory, and the rates of hits and false alarms which were recorded when remember and know responses were given, were also analysed. Separate \( d' \) and C scores were calculated for remember and know responses. Scores were compared using mixed factorial ANOVAs and post-hoc Bonferroni t-tests. Because trial numbers were reduced for this analysis, the effect of word type was not analysed for false alarms.

Remember/know bias (C) and confidence: Separate C scores were calculated for remember and know responses. Scores were compared were compared using mixed factorial ANOVAs, with follow-up one-way ANOVAs and post-hoc Bonferroni t-tests where necessary. The same methods of analysis were used to compare separate confidence ratings given for remember and know judgements.

Confidence: Ratings for confidence (for all words, hits, false alarms and correct rejections) were compared using t-tests and mixed factorial ANOVAs and post-hoc Bonferroni t-tests. Confidence when making remember and know responses was also assessed.

Correlational analysis: Significant differences in anxiety between the three OC groups and the Controls were recorded. There was also a significant difference in depression scores recorded by OCG participants and that recorded by the Controls (see Section 5.2.1.4). Possible correlations between these scores and experimental findings were examined using Kendal’s tau (\( \tau \)) where group differences in experimental findings were recorded.
5.3. Results

5.3.1. Structure of Results section

The Results section is divided in four sub-sections: (1) Identification and priming; (2) Accuracy and bias; (3) Use of remember/know memory; and (4) Confidence. Specific hypotheses were made in each part, with the possibility of additional effects also explored.

5.3.1.1. Re-statement of hypotheses

In (1), it was predicted that repetition priming effects would be apparent in test phase reaction times for old word targets (i.e., words previously presented in the study phase) independent of word type (Hypothesis 1). The possibility of group differences in repetition priming was explored. In (2), it was expected that Checkers and Washers would make more false alarms than Controls. This would be apparent for checking and washing word types (Hypothesis 2). The possibility of group differences in hit rates, discriminatory sensitivity ($d'$) and bias ($C$) were explored. In (3), it was predicted that both Checkers and Washers would be more reliant on know memory than Controls (Hypothesis 3). The possibility of group differences in false alarm rates, hits rates, discriminatory sensitivity ($d'$) and bias ($C$) when different memory judgements (remember vs know) were made was explored. Finally, in (4), it was expected that Checkers and Washers would be less confident than Controls (Hypothesis 4). The possibility of group differences in confidence when different memory judgements (remember vs know) were made was explored.

5.3.2. (1) Identification and priming

5.3.2.1. Specific hypothesis and areas of exploration

In this sub-section, it was predicted that repetition priming effects would be apparent in test phase reaction times for old word targets independent of word type (Hypothesis 1). The study explored the possibility of group differences in repetition priming.

5.3.2.2. Word identification rates

The mean rate of word stimuli identification errors (incorrect word name reported) in the study and test phase was very low for both groups. In the study phase, it was $1.64 \pm 0.41\%$ for Checkers, $2.33 \pm 0.64\%$ for Washers, $1.84 \pm 0.43\%$ for OCGs and $3.34 \pm 0.88\%$ for Controls. In the test phase, it was $1.83 \pm 0.48\%$ for Checkers, $3.43 \pm 0.53\%$ for Washers, $1.96 \pm 0.47\%$ for OCGs and $2.24 \pm 0.38\%$ for the Control group. These incorrectly identified trials were not included in the RT analysis that investigated priming effects.
5.3.2.3. Repetition priming effects

Repetition priming effects were analysed, firstly, for all correctly identified words that had been presented in both the study and test phases (all old words). They were also analysed separately only for words that were correctly identified in the test phase by participants as being old (hits). The findings from the all old words analysis were very similar to those from the hits analysis. As such, in the following section they are reported together. Figures displayed refer to the all old words analysis.

Two mixed 2x4x4 ANOVAs with the factors phase type (study, test), word type (checking, washing, negative, neutral) and group (Checker, Washer, OCG, Control) revealed a significant main effect of phase type – or a significant repetition priming effect (see Figure 5.3A). This confirmed Hypothesis 1. Word recognition was faster in the test compared to the study phase (all old words: $F(1,55)=138, p<0.001, \eta_p^2=0.71$; hits: $F(1,55)=139.6, p<0.001, \eta_p^2=0.72$ – both large effect sizes). The mean priming effect (all old words) was 502 ± 74ms for Checkers, 447 ± 109ms for Washers, 562 ± 48ms for OCGs and 486 ± 95ms for Controls (see Figure 5.3B). However, no significant main effect of group (all old words: $F(3,55)=1.42, p=0.247, \eta_p^2=0.072$; hits: $F(3,55)=1.432, p=0.243, \eta_p^2=0.072$) was found. There was no significant interaction between group and phase type ($F<1$ in both analyses), meaning that mean reaction times and priming effects were not different between groups.

However, both ANOVAs showed a significant main effect of word type (all old words: $F(2.7,148.6)=35.9, p<0.001, \eta_p^2=0.395$; hits: $F(2.6,145)=34.7, p<0.001, \eta_p^2=0.387$) along with an interaction between phase type and word type (all old words: $F(2.7,152.4)=8.84, p<0.001, \eta_p^2=0.138$; hits: $F(2.7,149.7)=7.92, p<0.001, \eta_p^2=0.126$). Further analysis of this finding revealed that, in the study phase, participants responded, numerically, most quickly to checking words (2,499 ± 73ms) and most slowly to neutral words (2,835 ± 72ms) – see Figure 5.4A. Post-hoc paired samples t-tests (all old words) revealed that participants were significantly faster in the study phase at responding to checking words than neutral ($p_c<0.001, d=0.6$), negative ($p_c<0.001, d=0.2$) and washing words ($p_c=0.001, d=0.3$) – all findings corrected at $\alpha=0.0083$. Additionally, they responded more quickly to washing words than neutral words ($p_c<0.001, d=0.3$). Meanwhile, in the test phase, the fastest numerical responses were to washing words (2,055 ± 85ms), while the slowest were to neutral words (2,339 ± 81ms) – see Figure 5.4B. The reaction time difference between washing and neutral words was significant ($p_c<0.001, d=0.4$), but there were no differences between washing word reaction times and those for either checking or negative words. As in the study phase, the difference between checking and neutral word reaction times in the test phase was significant ($p_c<0.001, d=0.4$), but there was no difference between checking and negative words. The difference between reaction times for negative words and those for neutral words was significant ($p_c<0.001, d=0.3$). In further examinations of these findings, additional post-hoc paired samples t-tests revealed that priming effects between two phases of the experiment were stronger for washing words than checking ($p_c<0.001, d=0.5$), negative
($p_c=0.007, d=0.3$) and neutral words ($p_c=0.004, d=0.3$) – see Figure 5.4C. But, as can be seen in Figure 5.4B, it is notable that the reaction times to all words types in the test phase, with the exception of neutral words, were not significantly different.

Figure 5.3. A – Mean reaction times by group for all old words in the study and test phases.
B – Difference score repetition priming effects (Study RT-Test RT) by group.
Figure 5.4. A – Mean reaction times for word types in the study phase. B – Mean reaction times for word types in the test phase. C – Difference score repetition priming effects (Study RT-Test RT) for word types.
5.3.2.4. Summary of sub-section (1)
As predicted (Hypothesis 1), repetition priming between the study and the test phase of the memory experiment was very strong. It varied between word types. The largest repetition priming effects were found for washing-related words, but there were no differences in reaction times to checking, washing and negative words in the test phase of the experiment. There were no group differences in repetition priming.

5.3.3. (2) Accuracy and bias

5.3.3.1. Specific hypothesis and areas of exploration
In this sub-section, it was predicted that Checkers and Washers would make more false alarms that Controls. This would be apparent for checking and washing word types (Hypothesis 2). The possibility of differences between the groups in hit rates, discriminatory sensitivity (d′) and bias (C) was explored.

5.3.3.2. False alarm rates
Contrary to predictions (Hypothesis 2), there were no significant differences in false alarm rates between any of the three OC subtype groups and Controls (Checkers: 32.96 ± 3.31%; Washers: 34.96 ± 2.11%; OCGs: 33.57 ± 2.89%; Controls: 27.99 ± 3.54%) – see Figure 5.5. A mixed 4x4 ANOVA, with the factors word type (checking, washing, negative, neutral) and group (Checkers, Washers, OCGs, Controls) found a main effect of word type (F(3,146)=67.45, p<0.001, η_p^2=0.551), but no main effect of group and no interaction between word type and group (both F<1). The highest mean number of false alarms was recorded for checking words (49.93 ± 2.69%) and the lowest was for neutral words (24.38 ± 1.47%). The false alarm rate for washing words was 32.85 ± 1.99% and for negative words was 30.18 ± 1.81%. Post-hoc paired samples t-tests revealed significant differences in false alarm rates for checking words compared to those for washing (d=0.9), negative (d=1.1) and neutral words (d=1.4), along with significant differences for false alarm rates between washing and neutral words (d=0.6), and negative and neutral words (d=0.4) – all p<0.001. There were no differences in false alarms between washing and negative words.
3.3.3. Hit rates

As can be seen in Figure 5.6A, the highest mean hit rate for checking-related words was recorded by Checkers (95.05 ± 1.73%), while the highest hit rate for washing-related words was recorded by Washers (94.40 ± 2.09%). We conducted a mixed 4x4 ANOVA, with the factors word type (checking, washing, negative, neutral) and group (Checkers, Washers, OCGs, Controls). The main effect of group was not significant ($F<1$), meaning that hit rates were similar across groups (Checkers: 81.59 ± 2.32%; Washers: 84.03 ± 2.42%; OCGs: 84.77 ± 1.88%; Controls: 81.41 ± 1.95%). However, the main effect of word type was significant ($F(3,163)=24.922$, $p<0.001$, $\eta^2_p=0.312$), and, furthermore, it was modulated by group (group/word type interaction: $F(3,163)=2.812$, $p=0.005$, $\eta^2_p=0.133$). Follow-up one-way ANOVAs for each word type separately revealed a significant group differences for hit rates for checking-related words ($F(3,58)=3.391$, $p=0.024$, $\eta^2=0.16$). This effect was driven by significant higher hit rates recorded by Checkers for checking-related words compared to Controls ($p=0.017$, $d=1.2$ – a very large effect size). To further explore the interaction between word type and group, we computed baseline-corrected word type difference hit rates (checking-neutral, washing-neutral, negative-neutral) – see Figure 5.6B. These were then analysed with a mixed 3x4 ANOVA, featuring the factors word type (checking-neutral, washing-neutral, negative-neutral) and group (Checkers, Washers, OCGs, Controls). Again, the findings revealed a significant group/word type interaction ($F(6,110)=4.367$, $p=0.001$, $\eta^2_p=0.192$), plus a main effect of word type ($F(2,110)=16.614$, $p<0.001$, $\eta^2_p=0.232$). Follow-up one-way ANOVA analyses for each word type separately found group differences for the checking-neutral word difference ($F(3,58)=3.537$, $p=0.02$, $\eta^2=0.16$). Post-hoc Bonferroni tests showed that this difference could be attributed to the significantly higher hit rates recorded by Checkers in comparison to Controls ($p=0.027$, $d=1.2$ – a very large effect size). There was also a borderline significant difference between the hit rate of Checkers and the lower rate recorded by OCGs ($p=0.061$, $d=1$), although this was a large effect size.

*Figure 5.5. False alarm rates recorded by each group.*
Figure 5.6. A - Mean overall hit rate (%) for each word type recorded by the groups. B - Mean overall hit rate difference score (%) for each word type recorded by the groups (% neutral hits used as baseline; % hits difference score = % hits word type-% hits neutral).
5.3.3.4. Discriminatory sensitivity ($d'$)

There were no apparent differences in discriminatory sensitivity ($d'$) between OC participants and Controls (Checkers: 1.44 ± 0.11; Washers: 1.43 ± 0.12; OCGs: 1.45 ± 0.1; Controls: 1.52 ± 0.09). This was confirmed with a mixed 4x4 ANOVA, featuring the factors word type (checking, washing, negative, neutral) and group (Checkers, Washers, OCGs, Controls). No main effect of group ($F<1$) or interaction with the factor group ($F(9,165)=1.308$, $p=0.236$, $\eta^2_p=0.067$) was found. However, a main effect of word type was recorded ($F(3,165)=11.04$, $p<0.001$, $\eta^2_p=0.167$). Post-hoc paired sample t-tests revealed significant differences in the lower $d'$ scores for checking words in comparison to washing ($p<0.001$, $d=0.9$) and negative ($p<0.001$, $d=0.6$) – all Bonferroni-corrected at $\alpha=0.0083$. A further mixed 3x4 ANOVA, with the factors word type (checking-neutral, washing-neutral and negative-neutral) and group (Checkers, Washers, OCGs, Controls), examined difference scores for the checking, washing and negative word types (neutral scores used as a baseline) for $d'$. This also revealed no main effect of group ($F<1$) and no interaction between group and word type ($F(6,110)=1.462$, $p=0.198$, $\eta^2_p=0.074$). Again, a main effect of word type was found ($F(2,110)=14.96$, $p<0.001$, $\eta^2_p=0.214$). Post-hoc paired sample t-tests revealed significant differences in the greater negative $d'$ difference scores for checking words in comparison to washing ($p<0.001$, $d=0.7$) – all Bonferroni-corrected at $\alpha=0.016$.

5.3.3.5. Response bias (C)

A mixed 4x4 ANOVA was carried out to see if response bias (C) differed significantly for the factors word type (checking, washing, negative, neutral) and group (Checkers, Washers, OCGs, Controls). This revealed a significant main effect of word type ($F(3,160)=61.907$, $p<0.001$, $\eta^2_p=0.53$) and a significant interaction between word type and group ($F(9,160)=2.536$, $p=0.01$, $\eta^2_p=0.121$) (see Figure 5.7A). Follow-up one-way ANOVAs were conducted for each word type separately, which revealed a marginally significant main effect of group for checking-related words ($F(3,58)=2.298$, $p=0.088$, $\eta^1_p=0.11$). Additional post-hoc Bonferroni tests suggested this could be explained by an enhanced negative response bias difference between Checkers and Controls for checking-related words ($p=0.083$, $d=0.9$). Although this $p$ value was only trending towards significance, the effect size was large. This suggested that the difference between the groups might be meaningful. No group differences were found for the other word types. However, after baseline-correcting the response bias scores for each word type relative to the neutral word condition, a mixed 4x3 ANOVA was conducted with factors baseline-corrected word type (checking-neutral, washing-neutral, negative-neutral) and group (Checkers, Washers, OCGs, Controls). As can be seen in Figure 5.7B, this revealed a significant main effect of word type ($F(2,104)=39.881$, $p<0.001$, $\eta^2_p=0.42$). Additionally, the interaction between word type and group was significant ($F(6,104)=3.028$, $p=0.01$, $\eta^2_p=0.142$). Follow-up one-way ANOVAs were conducted to look at group differences for each word type level separately. These revealed a significant effect of group for the checking-neutral difference type.
(F(3,58)=3.411, \( p=0.024, \eta^2=0.16 \)). Post-hoc Bonferroni tests showed this was driven by a significant enhanced negative response bias difference between Checkers and Controls (\( p=0.026, d=1.2 \)). A borderline significant difference between Checkers and OCGs was also found (\( p=0.075, d=1 \)). Both these effect sizes were large, particularly the value for the difference between Checkers and Controls. No group differences were present for the two other word type levels.

Figure 5.7. A – Mean response bias (C) scores by group for different word types. B – Mean response bias (C) difference scores by group for word types (C neutral = baseline; difference score = C word type-C neutral).
5.3.3.6. Summary of sub-section (2)
Unlike predicted (Hypothesis 2), there were no group differences in false alarm rates. There was no enhancement of false alarm rates recorded by Checkers and Washers for checking and washing-related words. However, Checkers had a higher hit rate for checking-related words compared to Controls and OCGs. No differences in discriminatory sensitivity ($d'$) were found between the groups. However, when looking at response bias ($C$), it was found that Checkers were more likely to think that checking word targets viewed in the test phase had been presented in the previous study phase than Controls. When checking words were presented, they made more ‘old’ response choices (i.e., remember or know) than ‘new’ response choices, in comparison to Controls and OCGs.

5.3.4. (3) Use of remember/know memory

5.3.4.1. Specific hypothesis and areas of exploration
In this sub-section, it was predicted that both Checkers and Washers would be more reliant on know memory than Controls (Hypothesis 3). The possibility of group differences in hit rates, false alarm rates, discriminatory sensitivity ($d'$) and bias ($C$) when different memory judgements (remember vs. know) were made was also explored. Note that, because of reduced trial numbers, the effect of word type was not analysed for false alarm rates.

5.3.4.2. Overall use of remember and know memory
In the test phase, Checker participants reported firmly recollecting a mean 31.6 ± 2.2% of words (remember judgements) and being familiar with a mean 25.6 ± 2.1% of targets (know judgements). They also made 40.2 ± 2% of judgements that a word was new. Washers reported a mean of 35.9 ± 2.7% remember judgements and 23.6 ± 2.2% know judgements, while they made 36.1 ± 1.2% new judgements. OCGs reported a mean 37.8 ± 2.1% remember judgements, 21.3 ± 1.6% know judgements and 38.1 ± 2.2% new judgements. Control participants reported a mean 37 ± 1.5% remember judgements, 17.7 ± 2.1% know judgements and 41.8 ± 2.4% new judgements.
Remember and know data was examined with a mixed 2x4x4 ANOVA, with the factors memory type (remember, know), word type (checking, washing, negative, neutral) and group (Checkers, Washers, OCGs, Controls). No significant main effect of group was found ($F<1$). However, the analysis revealed a main effect of memory type ($F(1,55)=60.28$, $p<0.001$, $\eta^2_p=0.523$) and a significant interaction between memory type and group ($F(3,55)=2.79$, $p=0.049$, $\eta^2_p=0.132$) – see Figure 5.8.

Separate, follow-up one-way ANOVAs on remember and know data revealed a significant group difference in know judgements ($F(3,58)=2.92$, $p=0.042$, $\eta^2_p=0.14$). Post-hoc Bonferroni $t$-tests showed that this was driven by a significant difference in the higher number of know judgements made by Checkers in comparison to Controls ($p=0.04$, $d=0.9$). The findings indicate that was a large effect size. No other group differences were significant. The one-way ANOVA on remember data was not significant. This, then partially confirms Hypothesis 3. Checkers demonstrated more reliance on know memory than Controls, supporting the hypothesis. However, this effect was not apparent for Washer or OCG participants. No other interaction with the factor group was significant.

*Figure 5.8.* Overall use of remember and know memory in the test phase by group.
Figure 5.9. A - Mean number of remember, know, and new memory judgements for old words by group. Remember and know judgements are classified as remember hits and know hits in the analysis. New judgements are missed responses. B - Mean number of remember, know, and new memory judgements for new words by group. Remember and know judgements are classified as remember false alarms and know false alarms in the analysis. New judgements are correct rejection responses.
5.3.4.3 Hit rates
Figure 5.9A displays the percentages of memory type judgements made when old word stimuli were presented. These judgements would have been either hits (remember and know judgements) or misses (new judgements). A mixed 2x4x4 ANOVA, with the factors memory type (remember, know), word type (checking, washing, negative, neutral) and group (Checkers, Washers, OCGs, Controls), was conducted on hit rates. It revealed a main effect of memory type ($F(1,144)=223.871, p<0.001, \eta_p^2=0.803$) but no significant main effect of group was found ($F<1$). The interaction between word type and group ($F(9,144)=2.812, p=0.005, \eta_p^2=0.133$) was significant (this effect has already been described in Results sub-section (2)). No other interaction with the factor group was significant.

5.3.4.4. False alarm rates
Figure 5.9B displays the percentages of memory type judgements made when new word stimuli were presented. These judgements would have been either false alarms (remember and know judgements) or correct rejections (new judgements). A mixed 2x4 ANOVA, with the factors memory type (remember, know) and group (Checkers, Washers, OCGs, Controls), was conducted on false alarm rates. This revealed a main effect of memory type ($F(1,55)=107.764, p<0.001, \eta_p^2=0.662$), and a marginally significant interaction between memory type and group ($F(3,55)=2.732, p=0.052, \eta_p^2=0.13$). No main effect of group was found ($F<1$). Separate follow-up one-way ANOVAs on the remember and know judgements data when false alarms were recorded found a trend towards a significant group difference for know judgements ($F(3,58)=2.221, p=0.096, \eta^2=0.11$). When recording false alarms, Washers made the highest numerical number of know memories judgements ($25.41 \pm 1.95\%$), followed by Checkers ($24.82 \pm 2.65\%$). Controls made the lowest numerical number of know memory judgements when reporting false alarms ($17.95 \pm 2.52\%$). However, additional Bonferroni t-tests found no significant differences between any of the OC subtypes and Controls.

5.3.4.5. Discriminatory sensitivity (d’)
Discrimination sensitivity (d’) was larger for remember judgements than know judgements. A 2x2 ANOVA, with the factors memory type (remember v. know) and group (Checkers, Washers, OCGs, Controls), revealed a main effect of memory type ($F(1,55)=488.6, p<0.001, \eta_p^2=0.899$). However, there was no difference in discriminatory sensitivity between the groups in the d’ scores for remember and know judgements, and no interaction between group and memory type (both $F<1$).

5.3.4.6. Response bias (C)
For the analysis of response bias among the groups, a mixed 2x4 ANOVA with the factors memory type (remember, know) and group (Checker, Washer, OCG, Control) was conducted. It revealed a significant interaction between memory type and group ($F(3,55)=2.845, p=0.046, \eta_p^2=0.134$). A
follow-up one-way ANOVA analysis for remember judgements did not find a significant difference between groups. However, a follow-up one-way ANOVA for know judgements revealed a significant main effect of group ($F(3,58)=3.129, p=0.033, \eta^2=0.15$). Post-hoc Bonferroni tests revealed that this effect was driven by a significant difference in bias between Checkers and Controls ($p=0.035, d=0.9$). Again, this was a large effect size. This finding is highlighted in Figure 5.10. The greater score recorded by Controls indicates a more conservative use of know memory than that by Checkers, who, by comparison, were more willing to make know responses.

![Figure 5.10. Response bias (C) of the groups towards different memory types (remember vs. know) when reporting that a word target had been previously presented.](image)

5.3.4.7. Summary of sub-section (3)
Checkers were more reliant on know memory than Controls in the test phase of the experiment. This was in line with Hypothesis 3. However, the same effect was not found for Washers or OCGs, contrary to expectations. There was also no effect of word type on group performance. Examination of hit rates when the two different memory types were used also revealed no differences in performance between any of the groups. However, a trend towards a difference in false alarms rates when the two different memory types were used was apparent. Washers and Checkers reported the
highest numerical number of memories based on familiarity when making false alarms, with Controls reporting the lowest. Furthermore, although no group differences in discriminatory sensitivity were found, Checkers were shown to be more biased towards making know responses than Controls.

5.3.5. (4) Confidence

5.3.5.1. Specific hypothesis and areas of exploration

In this sub-section, it was expected that Checkers and Washers would be less confident in the memory recollection than Controls (Hypothesis 4). The study further explored the possibility of group differences in confidence recollection when different memory judgements (remember vs. know) were made.

5.3.5.2. Confidence in recollection

Recollection confidence rates recorded by each group, and the ANOVA results for the confidence rates for all words, hits, misses, false alarms and correct rejections, are presented in Table 5.2. Checkers were numerically the least confident about their word recollection abilities (72.3 ± 2.5 %), while Controls were numerically the most confident (80.8 ± 2.2 %). The mean confidence score for Washers was 75.2 ± 4.2 %, while for OCGs it was 79.7 ± 2.3 %. However, these numerical differences were not significant, as demonstrated by the main effect of group found in the all words analysis ($F(3,55)=2.01, p=0.123, \eta_p^2=0.099$). There were also no significant interactions between word type and group for any of the measures, although there were trends towards significant group/word type interactions for hits and false alarms (see Table 5.2). This finding contradicts Hypothesis 4.

![Figure 5.11](image-url) **Figure 5.11.** Mean recollection confidence ratings by group for all words (old and new words combined), plus ratings for hits, misses, false alarms (FAs) and correct rejections (CRs).
Table 5.2. Summary of ANOVAs comparing the confidence ratings between the groups. Confidence ratings are presented as percentage scores (Mean ± SE; ^=borderline significant).

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Checker</th>
<th>Washer</th>
<th>OCG</th>
<th>Group effect</th>
<th>Word type effect</th>
<th>Word type x group int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>All words</td>
<td>80.8 ±</td>
<td>72.3 ±</td>
<td>75.2 ±</td>
<td>79.7 ±</td>
<td>---</td>
<td>F(3,162)=23.9,</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Hits</td>
<td>84.8 ±</td>
<td>77.6 ±</td>
<td>78.1 ±</td>
<td>84.1 ±</td>
<td>---</td>
<td>F(3,161)=15.56,</td>
<td>F(9,161)=1.75,</td>
</tr>
<tr>
<td></td>
<td>1.6</td>
<td>2.5</td>
<td>4.9</td>
<td>2.3</td>
<td></td>
<td>p&lt;0.001</td>
<td>p=0.085^</td>
</tr>
<tr>
<td>Misses</td>
<td>72.2 ±</td>
<td>61.1 ±</td>
<td>64.8 ±</td>
<td>67.6 ±</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>3.2</td>
<td>4.1</td>
<td>4.6</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>False alarms</td>
<td>66.4 ±</td>
<td>59.4 ±</td>
<td>64.2 ±</td>
<td>64.6 ±</td>
<td>---</td>
<td>---</td>
<td>F(9,153)=1.70</td>
</tr>
<tr>
<td></td>
<td>2.7</td>
<td>3.7</td>
<td>4.7</td>
<td>3.2</td>
<td></td>
<td></td>
<td>p=0.099^</td>
</tr>
<tr>
<td>Correct rejects</td>
<td>82.6 ±</td>
<td>74.1 ±</td>
<td>76.7 ±</td>
<td>82.2 ±</td>
<td>---</td>
<td>F(3,137)=13.21,</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>2.7</td>
<td>3.2</td>
<td>4.3</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Different levels of confidence were recorded for the different word types when all words ($\eta_p^2=0.3$), hits ($\eta_p^2=0.22$) and correct rejections ($\eta_p^2=0.194$) were analysed separately (all $p<0.001$). For all three measures, participants were numerically the least confident when viewing checking words (all words: 74.08 ± 1.54%, hits: 79.32 ± 1.57%, correct rejections: 74.08 ± 1.92%) and the most confident when presented with washing targets (all words: 79.97 ± 1.38%, hits: 85.23 ± 1.41%, correct rejections 80.66 ± 1.60%). Post-hoc paired samples t-tests on the effects of word type (Bonferroni-corrected at $\alpha=0.0083$) found significant differences in the lowered confidence scores for checking words in comparison to all three other word types when the all words measure was examined (all $p<0.001$ – checking vs. washing, $d=0.5$; checking vs. negative, $d=0.3$; checking vs. neutral, $d=0.3$). There were also significant differences between the heightened washing confidence scores and those for negative ($p=0.002$, $d=0.2$) and neutral words ($p=0.001$, $d=0.2$). For hits, there were significant differences between the lower confidence ratings when viewing for checking words and those when viewing negative ($p=0.002$, $d=0.2$) and washing words ($p<0.001$, $d=0.5$). There were also significant differences between the higher confidence ratings for washing words compared to both negative
words \((p<0.001, d=0.3)\) and neutral words \((p<0.001, d=0.4)\). For correct rejections, there were significant differences between the lower confidence ratings given when viewing checking words compared to those when viewing all three of the other word types (all \(p<0.001\) – checking vs. washing, \(d=0.5\); checking vs. negative, \(d=0.4\); checking vs. neutral, \(d=0.4\)).

5.3.5.3. Confidence in recollection when making remember and know judgements

Table 5.3 shows mean confidence scores recorded by each group when making remember and know judgements. As can be seen, participants were significantly less confident in their recollection when reporting familiarity with a target (know judgements) than when reporting a firm memory of a target (remember judgements). Mixed 2x4 ANOVAs, with the factors memory type (remember, know) and group (Checkers, Washers, OCGs, Controls), revealed main effects of memory type when all words (old and new words combined), hits and false alarms were examined separately. No main effects of group were found in any of the analyses, and no interactions between memory type and group were found for all words and false alarms. Analysis of hit rates revealed a borderline significant interaction between group and memory type \((F(3,55)=2.653, p=0.058, \eta^2=0.126)\). However, follow-up one-way ANOVA analysis of hit rate confidence ratings for remember judgements and know judgements revealed no further group differences.

Table 5.3. Summary of ANOVAs comparing confidence ratings by group when making remember (R) and know (K) judgements. Confidence ratings are presented as percentage scores (Mean ± SE, R/K; \(^*=\)borderline significant).

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Checker</th>
<th>Washer</th>
<th>OCG</th>
<th>Group effect</th>
<th>Memory type effect</th>
<th>Memory x group int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>All words</td>
<td>88 ± 2.1/</td>
<td>85 ± 2.3/</td>
<td>83 ± 2.6/</td>
<td>88 ± 2.1/</td>
<td>---</td>
<td>(F(1,55)=309.)</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>63.1 ± 2.9</td>
<td>58 ± 3.3</td>
<td>65 ± 3.7</td>
<td>63 ± 2.9</td>
<td>(8, p&lt;0.001)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hits</td>
<td>90 ± 1.9/</td>
<td>87 ± 2.2/</td>
<td>84 ± 2.5/</td>
<td>90 ± 2.1/</td>
<td>---</td>
<td>(F(1,55)=306.)</td>
<td>(F(3,55)=2.65)</td>
</tr>
<tr>
<td></td>
<td>66 ± 3</td>
<td>59 ± 3.4</td>
<td>67 ± 3.8</td>
<td>64 ± 3.1</td>
<td>(3, p&lt;0.001)</td>
<td></td>
<td>(3, p=0.058^*)</td>
</tr>
<tr>
<td>False alarms</td>
<td>77 ± 3.8/</td>
<td>73 ± 4.3/</td>
<td>75 ± 4.7/</td>
<td>75 ± 3.9/</td>
<td>---</td>
<td>(F(1,53)=50.4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>60 ± 3.2</td>
<td>58 ± 3.7</td>
<td>62 ± 4.0</td>
<td>60 ± 3.3</td>
<td>(, p&lt;0.001)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.3.5.4. Summary of sub-section (4)
Contrary to expectations (Hypothesis 4), there were no differences between the groups in confidence in memory recollection. Confidence was also found to vary with word type, independent of group, when all words, hits and correct rejections were analysed separately, with participants being least confident about checking words and most confident about washing words. Participants were significantly less confident in their recollection when reporting familiarity with a target (know judgement) than when reporting that they had a firm memory of a word (remember judgement). Again, however, this effect was not modulated by group.

5.3.6. Correlational analysis

No relationships were found between Checker anxiety levels and task performance where significant differences were found in the study between Checker and Control groups (e.g., hit rates for checking words, response bias towards checking words). Likewise, there was no equivalent relationship between Control anxiety levels and performance in the same tasks. Examination of depression scores and task performance was not carried out because, as stated in Section 5.2.1.4, depression scores did not differ significantly between Checkers and Controls.

5.4. Discussion

In the present study, we used an extended CID-R paradigm to examine priming, accuracy, remember/know memory and confidence for symptom-salient, negative and neutral verbal stimuli in non-clinical Checker and Washer groups. Comparisons were made with the performance of participants in a generalised OC (OCG) group and non-OC Controls.

5.4.1. Hypotheses

It was predicted that repetition priming effects would be apparent in test phase reaction times for words which had been presented in the study phase – Hypothesis 1. But it was expected that Checkers and Washers would make more false alarms than Controls, particularly for checking and washing words –Hypothesis 2. It was also predicted that both Checkers and Washers would demonstrate greater reliance on know memory than Controls – Hypothesis 3. Additionally, it was thought that Checkers and Washers would be less confident than Controls – Hypothesis 4. Alongside these hypotheses, we also explored the possibility of group differences in repetition priming, hit rates, discriminatory sensitivity ($d'$) and bias ($C$), and whether these might be modulated by word type.
5.4.2. Findings, interpretations and implications

Although not a universally-agreed conclusion, a good deal of previous research has pointed to poor memory with OCD, possibly reflecting some form of executive dysfunction (see Kuelz et al., 2004; Leopold & Backenstrauss, 2015; Woods, 2002). Other research has suggested the presence of memory bias towards threat, similar to attentional bias, in OC populations. Some evidence suggests that, possibly as a consequence of particular behavioural and neurobiological functioning, such cognitive dysfunction may be more apparent in Checkers than in other subtypes of OCD (Leopold & Backenstrauss, 2015). Taken as a whole, the results of the present study suggest that, rather than being poorer than that of healthy individuals, aspects of memory accuracy for verbal information may actually be improved in Checker populations – and this may be directly related to bias towards symptom-salient stimuli. Importantly, this memory enhancement requires that the information being processed is directly relevant to the particular concerns of Checkers. What is interesting, additionally, is that this heightened memory accuracy occurs even though Checkers have apparent enhanced dependency on familiarity-based memory (know memory) over firm recollection (remember memory). Our findings, then, supportive of research suggesting that Checkers demonstrate enhanced recall of checking-relevant information (e.g., Constans et al., 1995; Hansmeier, et al., 2015; Radomsky et al., 2001) and underline the importance of emotion in boosting memory performance (Hansmeier, et al., 2015). Furthermore, they are supportive of suggestions that memory biasing may be a particular feature of checking behaviour (e.g., Woods et al, 2002). By contrast with the Checker performance, no real differences in verbal memory were found for Washers or for OCGs in the present study.

In line with predictions (Hypothesis 1), repetition priming between the study and the test phases was found to be very strong for all participants, as it has been found to be in previous studies using the CID-R paradigm (e.g., Berry et al., 2008). However, there were no group differences in priming between OC participants and Controls. As such, the findings suggest no evidence of altered implicit memory in non-clinical OC individuals. Although no predictions were made about the possibility, or otherwise, of group differences in repetition priming, this finding is supportive of results reported by Kim et al. (2006) and Foa et al. (1997). Caution must be exercised when drawing conclusions from such results, as so little research has examined implicit memory in OC populations – and, indeed, at least one study has found evidence of impaired implicit learning in OC populations (Deckersbach et al., 2002). However, it is notable that although neither Kim et al. (2006) nor Foa et al. (1997) used OC-specific symptom-salient in their designs, like that employed in the present study, the outcomes in relation to implicit memory were the same.
Contrary to predictions (Hypothesis 2), the present study found no differences between any of the OC groups and Controls in false alarm rates (inaccurately reporting in the test phase that they had previously been exposed to a word target in the study phase). This contrasts with previous research by Klumpp et al. (2009) which reported higher numbers of false memories in non-clinical Checkers and Washers than Controls. It is notable, however, that the paradigm used by Klumpp and colleagues was somewhat different from that of the present study, and involved recollection of vignettes rather than individual word presentations. By contrast, however, what was found in the present study was that Checkers scored significantly more hits (accurately reporting that they had been exposed to a target in the study phase) when presented with checking-related words than Controls. Our findings suggest that, for Checkers, hit rate performance can clearly be linked to the ideographic information of the word target being presented. We made no direct predictions relating to hit rate performance.

Additionally, it is notable that no differences in discriminatory sensitivity ($d'$) were found in the present study between the groups. However, the results reported are in line with research suggesting that Checkers demonstrate enhanced recall of checking-relevant information (e.g., Hansmeier, et al., 2015), and they are supportive of theories suggesting that Checkers are biased towards threatening stimuli (our word targets were all negatively-valenced), particularly if it is salient to personal concerns (e.g., Harkin et al. 2011; Irak & Flament, 2009; Moritz et al., 2009). They can be understood in the light of previous research suggesting that the forgetting of personally relevant material may be problematic for OC participants (Tolin et al., 2002). Furthermore, we found that Checkers demonstrated more bias (as measured by $C$) than both Controls and OCGs towards reporting that checking word targets they had viewed in the test phase had previously been presented in the previous study phase. Again, this supports theories that, for Checkers at least, the processing of personally-relevant, ideographic information can impact on consequent response behaviour. Indeed, what is notable here is that, in terms of signal detection theory, Checkers in the present study required less strength of evidence than the controls to report the presence of an ‘old’ checking target than Controls, and therefore were apparently more risky or liberal in their decision-making. But, as demonstrated by the superior hit rate performance, they got their decisions right – in contrast with our prediction of enhanced false alarm rates.

As predicted (Hypothesis 3) Checkers were more reliant than Controls on the use of memory based on familiarity (know memory) than that based on firm recollection (remember memory). This was evident in findings relating to numbers of remember and know judgements made – with Checkers recording a greater number of familiarity responses than Controls. While there were no group differences when use of memory (remember vs. know) was examined for hits, a marginally significant effect of group was recorded when false alarm rates were examined – with Washers and Checkers reporting, numerically, the highest number of memories based on familiarity when recording false alarms, and Controls reporting the lowest. At the same time, when indicating that they had previously
seen a word target (an ‘old’ judgement), Checkers were more biased (as measured by C) towards reporting that their memory was based on familiarity, as opposed to firm recollection, than Controls. Such findings are in line with previous remember/know research reporting an enhanced use of memory based on loose familiarity among OC participants (e.g., van den Hout & Kindt, 2003a, 2003b, 2004; Klumpp et al, 2009). We made no predictions about differentiated bias towards familiarity among OC subtypes, but, again, Checkers were found to be the main drivers of difference between OC participants and Controls. While clearly further research is required in this area, the findings of the present study lend further weight to arguments that patients with OCD, and non-clinical OC participants in experiments, should not be treated as a single, homogenous grouping (Leopold & Backenstrass, 2015; Mataix-Cols et al., 2004; McKay et al., 2004).

Notably, however, it was found that, when assessing remember and know memory usage, word type did not modulate group performance. This contrasts with the findings relating to both hit rates and bias, in which Checker performance was enhanced when presented with of checking-related stimuli. The findings of the present study are indicative, then, of a general, rather than stimuli-specific, alteration in the balance between remember and know memory functioning in Checker populations. However, this suggestion needs investigation with additional research. Additionally, no difference in recollection confidence between any of the OC groups and Controls was found, contrary to predictions (Hypothesis 4). This is an interesting finding, as a lack of confidence in memory is one of the more robust findings of previous research with OC populations (Hermans et al, 2003; Muller & Roberts, 2005; Tolin et al., 2001). It is possible, however, that this finding is reflective of the design of this particular section of the present study. Following identification of a word target in the test phase, participants were asked to report whether they remembered the word, whether they were familiar with it or if they thought it was new. They were then asked to give a confidence rating on this decision. It is possible, then, that this rating reflected more the confidence of the participant in their decision choice (remember vs. know vs. new) rather than in their actual memory recollection abilities. It is conceivable that, had participants been asked to make a simple statement about their confidence (e.g., ‘How confident do you feel in your memory at this stage?’), different results might have been recorded.

In the present study, then, Checkers demonstrated enhanced ability at scoring checking-related hits, the greatest bias towards reporting that checking-related words were old and the greatest bias towards the use of familiarity-based memory when making ‘old’ responses. Notably, the effect sizes for these results were generally large. This is important as it suggests that the differences recorded between Checkers and Controls (though there were also some differences between Checker and OCGs) are clinically meaningful. Furthermore, the differences between Checkers and Controls cannot be attributed to comorbid depression, as this was not significantly different between the groups, or to
anxiety, as no correlations were found between anxiety and Checker or Control performance when differences between these groups were recorded. By contrast, very few differences were found between Washers and Controls. Like with the Checkers, there was no significant difference in depression levels between Washer and Control participants. But, unlike Checkers, they did not demonstrate task performance differences in comparison to Controls. In a recent review, Leopold and Backenstrass (2015) suggest that while significant differences in verbal memory between Checkers and Washers have been found, this was not strong enough to support a claim of clinical differences in verbal memory between the two groups. The findings of the present study are perhaps in line with this suggestion given that we also found few differences in performance between our Checkers and Washers. However, Leopold and Backenstrass (2015) also report that Checkers are likely to be significantly more impaired than Washers in executive functioning, which may impact on verbal information encoding and contribute to impaired memory. While this cannot explain the enhanced hit rate performance of Checkers in the present study, this may provide some insight into why there were no real differences found between Washers and Controls. More straightforwardly, though, it could be argued that the exaggerated performance of Checkers, and the apparent non-exaggerated performance of both Washers and OCGs, in some aspects of the findings occurred because the experiment was, fundamentally, a checking task. Participants were, initially, required to identify a gradually-revealed word target, and later perform the same task, before reporting whether they had seen it previously or not. This process involves a number of assessing, confirming and rejecting requirements which may be particularly relevant, or familiar, to a Checker – in comparison to a Washer. So, while the present study may have featured a stimuli set with word targets which were considered salient to checking concerns, alongside targets relevant to washing concerns, the actual task required of the participants may have been weighted in the favour of the Checkers who took part in terms of its ecological validity. A shortcoming with this argument might be, however, that some differences in performance were found between Checkers and OCGs (Checkers scored more hits for checking-related words than OCGs, and were more biased towards reporting checking-related words as ‘old’). Indeed, it is interesting that the OCG group, which recorded a mean OCI-R checking score identical to that of the Checker group (6.8 – see Methods section, Table 5.1), did not demonstrate any task performance differences from Controls. Possible explanations might lie in the differences between the two groups highlighted in the Methods section. Notably, on the OCI-R subtype measures, the Checker group scored above diagnostic cut-off for the checking subtype only. By contrast, the OCG group was above the diagnostic cut-off for five of the six subtypes. The hoarding measure was the only exception, but for this subtype the OCG group scored a significantly higher mean score than the Checker group. As such, the concerns of the participants in the Checker group might conceivably be limited purely to matters of checking. The concerns of the participants of OCG group, on the other hand, could have been multiple and spread across the various symptom dimensions recorded by the OCI-R. This may have diluted checking effects in the OCG group when taking part in the experimental task. Indeed,
evidence suggests that the neurobiological functioning of OC individuals differs according to subtype – for example, between Checkers and Washers (van den Heuval et al., 2009). In these terms, the findings of the present study serve to highlight the importance of using OC subtypes in future studies if researchers want to access the deeper nuances of OC behaviours.

The results of the present study provide behavioural support for biological models of OCD which have consistently found evidence of dysfunction in the DLPFC circuitry of the brain, which is linked to affective processing (Menzies et al., 2008). Importantly, the results provide clear evidence of the modulating role of emotion in OC verbal memory. This in line with the findings of Studies 2 and 3 reported in this thesis, both of which highlighted the role of emotion in OC selective attention. Studies 1, 2 and 3 found new, nuanced evidence of attentional bias in OC and checking populations. But it was unclear from Studies 2 and 3 whether attentional bias was specific-to or more enhanced among Checkers, as additional subtypes were not tested. However, the findings of the present study suggest that altered long-term memory functioning and bias towards symptom-specific stimuli may, indeed, be more particular to the mechanics and maintenance of checking than washing. They are in line with cognitive-behavioural models of accounts of OCD that point to inflated personal responsibility with the condition (Salkovskis, 1985). Heightened responsibility, it is argued, may lead Checkers to be overly-vigilant towards the presence of threatening and/or symptom-specific stimuli. Consequently, a memory bias for such stimuli may be more likely to occur (Muller & Roberts, 2005). The excessive reliance on know memory demonstrated by Checkers in the present study also may have a role in underpinning the exaggerated levels of doubting commonly reported by people with OCD (OCCWG, 2005).

5.4.3. Limitations

The present study has a number of limitations within which its findings need to be considered. Although we used tailored, symptom-salient stimuli, the pre-study (see Appendix 7) which established this stimuli set was not without its limitations. Nine people in total took part in the study, and data relating to the particular saliency of checking and washing word targets was collected from four OC participants. These participants only provided saliency and valence ratings for candidate checking and washing word targets. They did not provide ratings for candidate negative words, which were rated for valence, concreteness and imageability by non-OC Control participants. Thus, it may be that some of the negative word targets used in the present study could have had saliency to our Checker and Washer participants without us knowing.

Additionally, the washing words used in the study were given higher ratings of concreteness and imageability in the pre-study than the other word types, and differed in terms of frequency scores (see
Appendix 7). However, despite these differences, the presence of washing words had little impact on performance in the study, other than the repetition priming effect reported in Section 5.3.2.3. Importantly, no group differences were recorded in this analysis.

Like the previous studies in this thesis, an a priori analysis was not carried out in advance to assess the amount of participants needed to obtain appropriate power. Again, the total sample size (N=59) was small, and the number of participants recruited for each subtype was uneven (Checkers, N=14; Washers, N=11; OCGs, N=16; and Controls, N=18). A post-hoc G*power analysis revealed that Study 4 appeared to have enough power to achieve large between-groups effects, in which the performances of the four groups in two measures were compared, at the recommended statistical power of 0.8 (Cohen, 1988). It also had enough power for the large effects recorded when Checkers and Controls were compared on a single measure (e.g. hit rates for checking words, bias towards checking words). However, for small and medium effects it was underpowered. The G*power analysis revealed that, when comparing the four groups, a small between-groups effect (ηp² = 0.01) would require a sample of N=1084, a medium effect (ηp² = 0.09) would require N=116 and a large effect (ηp² = 0.25) would need N=40. For two-group comparisons on a single measure, small effect (d = 0.2) necessitated a sample of N=620, a medium effect (d = 0.5) needed a sample of N=102, while a large effect (d = 0.8) required N=42. Like the studies in Chapter 4 and 5, the present study had explicit inclusion and exclusion criteria relating to the presence or non-presence of checking and washing symptoms. However, although the findings in relation to the performance of the Checker group are extremely interesting (along with the comparable non-performance of the Washer and OCG groups), this issue of sample size means the overall results need to be considered with a degree of caution.

5.4.4. Future research

Future research would be aided by the development of a more rigorously-tested stimuli set for use in the assessment of verbal memory. It also would be interesting to develop remember/know paradigms in which both OC verbal and visual memory could assessed concurrently, so that the performance of Checkers, and other subtypes, could be compared across memory types. Larger sample sizes than the ones in the present study would be useful to aid statistical power.

5.4.5. Conclusions

In conclusion, the present, and final, study of this thesis found new evidence of altered memory for verbal information in Checker populations. Crucially, this occurs when information is directly relevant to their particular concerns. Checkers demonstrated both enhanced bias towards checking-related words and enhanced ability at scoring checking-related hits. Additionally, Checkers have a
heightened dependency on familiarity-based memory (know memory) over firm recollection (remember memory). These results highlight a key function of emotion – that of boosting memory performance (Hansmeier, et al., 2015). The findings tally with the evidence of attentional bias found in Studies 1, 2 and 3 in this thesis. They provide a deep account of cognitive functioning in OC populations. Notably, no real differences in verbal memory were found for Washers or for OCGs in the present study when compared with Controls. This may be reflective of the nature of the experimental task, and/or differences in neurobiological functioning between OC subtypes.
Chapter 6

General discussion
6.1. General discussion

6.1.1. Thesis aims

Key characteristics of OCD, such as repetition, ritual and doubt, may reflect alterations, or dysfunction, in cognitive processing – specifically in the operation of selective attention and memory. The operation of bias in both attention and memory towards threatening, symptom-salient stimuli may be mutually-reinforcing, and serve to strengthen an individual’s OC symptomology. However, inconsistent findings have been provided by neuropsychological tests which have assessed selective attention and memory with OCD. This thesis has argued that the mixed pattern of results to-date is likely, at least partly, to reflect methodological issues. The experimental paradigms which have been used in previous research have had overly-contrasting task requirements, and are likely to have lacked the necessary sensitivity to gain deep access to the complex nuances of OC cognitive processing.

The thesis aimed to provide novel evidence that altered processing in selective attention and long-term memory are both underpinned by biases and emotional functioning which are specific to OC populations. It looked to demonstrate this through the use of nuanced, participant-focussed and tightly-controlled experimental designs, with the aim of enabling a more fine-tuned account of how key components of cognition operate in OCD. Additionally, the use of non-clinical participants was in line with the wealth of evidence that OCD is a dimensional condition, and which needs to be understood more broadly than just in terms of those who have received a clinical diagnosis.

The possibility of altered selective attention in OC populations has been assessed by only a small number of studies. These have used either Stroop, dot-probe paradigms, inhibition of return or negative priming paradigms. The requirements of these tasks vary considerably and it is questionable how far some of these paradigms measure selective attention processes. Curiously, little, if any, research appears to have investigated selective attention deficits in people with OCD using visual search paradigms. This is despite the advantages of visual search as a measure of selective attention, which have been repeatedly demonstrated in healthy populations. This thesis looked to address this gap in the literature. The studies reported in Chapters 2-4 used variants of the PoP inter-trial paradigm, which is an established measure of selective attention. Meanwhile, the functioning of verbal long-term memory in OC populations remains unclear. Some studies report impairments with the condition, others do not. Furthermore, other research has demonstrated enhanced verbal memory in people with OCD for symptom-salient stimuli. There remains limited research examining verbal memory in OCD using designs which can access more subtle aspects of OC cognition, such as those based on remember/know theory. Additionally, there has been limited research examining OC
subtype populations which uses verbal stimuli which has been selected because of its saliency to the particular concerns of those subtypes. The majority of research into memory with OCD has focused on the operation of non-verbal memory. However, there is a gap in the literature for an in-depth study of multiple aspects of long-term verbal memory in OC populations which can help clarify the relationship between the condition and this area of cognition. This thesis looked to address this issue.

6.1 1.1. Research question of thesis

In attempting to address some of the issues in previous research via the use of alternative experimental paradigms, to what extent can selective attention and long-term memory said to be similarly altered in non-clinical OC populations, and what are the roles played by bias and emotion in any such alterations?

6.1.2. Summary of studies

All four studies reported in this thesis examined non-clinical OC populations. Inclusion and exclusion criteria were strict, and sampling was tightly controlled. Assessments of obsessive-compulsiveness among participants were made using the OCI-R (Foa et al, 2002). Non-diagnosed depression and anxiety levels were also monitored in all the studies using the HADS questionnaire. Broadly, all participants were of a similar age (18-30-years-old) and social demographic – they were all students at the University of Surrey. The first study of the thesis, Study 1, featured a general OC participant group (with hoarders excluded) and non-OC Controls. Having established the presence of effects, the remaining studies looked to further examine the results of Study 1 and tighten the focus of examination to Checker populations. Thus, Studies 2 and 3 both involved Checker and Non-Checker groups in selective attention tasks. Finally, Study 4 included Washer and general OC populations, alongside Checkers and non-OC Controls, allowing for a deeper assessment of how far altered cognition and bias towards symptom-salient stimuli, assessed via a verbal memory paradigm, could be understood as a particular feature of checking behaviour. In all studies, the presence of clinically-diagnosed comorbid conditions was controlled-for via strict exclusion criteria. The use of non-clinical participants who were free of comorbid conditions also served to control possible confounding effects of medication-use associated with diagnosed neuropsychiatric disorder. Differences in anxiety between OC and non-OC participants, as measured by the HADS, were apparent in the studies. However, anxiety only correlated with Checker performance in Study 3, in an analysis relating to the effect of pictures presented in trial sequences. This is an interesting finding, and needs further examination (see Section 6.1.5). However, mean depression scores recorded by all groups in all four studies all fell within the ‘normal’ range of the HADS measure. Importantly, there were no correlations between depression and the findings from any of the four studies presented in this thesis.
**Study 1:** The first study of the thesis involved a classic three-colour PoP visual search task. This study had two aims. Firstly, it looked to examine whether people with OC behaviour have visual search PoP performance deficits. Secondly, it aimed to examine whether target activation and distractor inhibition processes were altered in a non-clinical OC population. Similar PoP effects (faster reaction times with target colour repetition) were recorded for the OC and Control groups. However, OC participants were slower overall compared to Controls – suggesting altered selective attention processes. Furthermore, they were particularly slow in specific inter-trial sequences – when the distractor colour was exchanged between trials and the target colour stayed the same. This was in comparison with their performance in sequences in which distractor colour stayed the same, but target colour changed. This suggests a biasing of selection attention towards, and a difficulty inhibiting, distractor information in the OC group.

**Study 2:** This study looked to further investigate the findings of Study 1 by introducing emotional and checking-related pictures into the task. It investigated the impact of presenting a neutral, a negative or a checking-related picture before each visual search array on the performance of the classic PoP task. For this task, we compared the performance of non-clinical Checkers and Non-Checkers. In contrast to the results of Study 1, the findings showed no performance differences between Checkers and Non-Checkers in the visual search task (the same reaction times were recorded). PoP effects were similar for both groups and there was no group-specific impact of emotional pictures on the task performance. It is possible that the presence of emotional pictures in the task acted to boost the attentional performance of the Checker group, eliminating the group differences evident in Study 1.

**Study 3:** This study further investigated possible attentional bias effects recorded in in Study 1, using a visual search derived from the PoP design. Like Study 2, it used non-clinical Checkers and Non-Checkers and emotional and checking-related pictures. However, it presented these targets and distractors in the visual search array. The emotional content of the pictures was manipulated in two conditions. In the first (Target Neutral condition), target pictures remained neutral, but distractors changed picture categories. In the second (Target Change condition), distractor pictures remained neutral, but targets changed category. The results revealed that Checkers and Non-Checkers recorded similar reaction times. Emotional pictures influenced the visual search by speeding up performances in the Target Change trials and slowing down performances in the Target Neutral trials, though this was not different between groups. However, when inter-trial effects were examined, it was evident that the emotion of the picture in the previous trial influenced performances in Checkers, but not Non-Checkers. The findings suggest that altered target and distractor processing among Checkers in visual search will be particularly highlighted with use of symptom-salient stimuli.
**Study 4:** This final study investigated whether OC attentional biases and altered cognition, evident in Studies 1, 2 and 3, might also be reflected in memory biasing and altered memory performance. Multiple aspects of verbal memory in non-clinical Checkers, Washers and a general OC group (OCGs), along with Controls, were assessed. In a further difference with Studies 1, 2 and 3, this study featured checking, negative and neutral printed word stimuli. A CID-R paradigm was used, an extended to incorporate measures allowing analysis of both remember/know memory and confidence ratings. This enabled assessment of several memory-related measures, including priming (reaction times), accuracy (discriminatory sensitivity, hits and false alarms), response bias and confidence ratings. Key findings were that Checkers made more correct responses (hits) than Controls (particularly for checking words), Checkers were more reliant on know memory than Controls (particularly for checking words), and Checkers demonstrated an enhanced response bias towards checking words. The results suggest that while Checkers may have exaggerated dependency on know memory, their memory may be more accurate (when measured by hit rate), particularly when stimuli are salient to their concerns.

### 6.1.3. Assessment of thesis findings

This thesis provides new evidence that altered selective attention and long-term verbal memory processes are likely to be a feature of the OCD – and, specifically, OC checking. Previous research has produced a lack of clarity concerning the presence of dysfunction in these areas of cognition. However, the findings reported here point to four overall outcomes. Firstly, the studies provide novel evidence suggesting that bias towards emotional, particularly symptom-salient, information plays an active role in the operation of both selective attention and long-term verbal memory, particularly in checking populations. Secondly, they show that altered cognition and biasing is a demonstrable feature of non-clinical OCD. Thirdly, they suggest that visual search paradigms, and in particular inter-trial paradigms, could play a role in generating better understandings of selective attention in OCD. The results of Studies 1, 2 and 3 further emphasise the utility of visual search and, in particular, the PoP paradigm as a measure of selective attention. But they also highlight how the study of inter-trial effects and the use of symptom-salient can reveal features of OC cognition that might remain hidden with the use more traditionally-deployed paradigms, such as the Stroop. Fourthly, the findings of Study 4 demonstrate the value of the comprehensive and novel approach to the examination of long-term verbal memory in OCD which was taken in its design. Previous research had suggested differences between OC populations and controls in non-verbal memory, but less firm findings relating to verbal memory. The results of Study 4, however, provide clear and strong evidence of altered verbal memory and bias towards symptom-salient stimuli in Checkers.
6.1.3.1. Meaningfulness of findings

While previous studies examining cognitive processes with OCD have pointed to the presence of deficits with the condition, the magnitude of difference between OC participants and controls in such research has been questioned. For example, the meta-analysis by Abramovitch et al. (2013) reported reduced performance by OC participants in all six cognitive domains (attention, memory, executive function, visuospatial ability, processing speed and working memory) and 10 of the sub-domains (e.g., verbal and non-verbal memory, planning) – details in Table 1.1, Section 1.6. However, the majority of effect sizes were medium (though some were small). Consequently, the authors questioned whether it could be concluded that clinically-meaningful group differences could be said to exist between OC and non-OC populations in the majority of these cognitive areas. The meta-analysis did not cover selective attention, only sustained attention. The average effect size here was medium. However, verbal memory studies were assessed by Abramovitch and colleagues. The average effect size for these was small-to-medium, and stood in contrast with the large average effect size for non-verbal memory. The authors suggested that inconsistent experimental design, notably in relation to the use of symptom-salient, and confounding issues relating to symptom heterogeneity and the presence of comorbid conditions are likely to have affected findings. In the studies in this thesis, the experiments were designed with such criticisms in mind. The aim was to see whether, once this had been attempted, more meaningful findings in relation to selective attention and verbal memory would emerge from the data.

The p values and effect sizes of key findings from all the studies in this thesis are provided in two tables in Appendix 8. Specific details of findings which are discussed in the following section can be found in these tables. One of the main findings from Study 1 was that OC participants were consistently slower than Controls throughout the PoP task – indicating a general deficit in selective attention. Importantly, the effect size for this group difference was large. The group/task interaction when reaction times for specific target activation and distractor inhibition inter-trial sequences (PRnewD vs. PRnewT) was of similar large size. In Study 2, reaction time differences between the groups were not found, a result which could be attributable to the insertion of an emotional component to the standard PoP task in its design. However, group differences were found in error rates in this study. Checkers made fewer overall errors than Non-Checkers. The effect size here was medium. However, the effect size was large for the lower rate of errors recorded by Checkers in comparison with Controls in the Swap condition of Study 2. In Study 3, reaction time differences were not found between the groups when sequential effects were examined. Like Study 2, this experiment also used emotional and symptom-salient. By comparison, where differential performance by OC participants in inter-trial tasks was found in the selection attention studies, the effect sizes were generally smaller. Thus, in Study 1, OC participants were slower in PRnewD sequences than PRnewT sequences. The effect size of this finding was very small. In Study 3, Checkers were slower in Target
Neutral trials than in Target Change trials when both checking pictures and negative pictures had featured in the previous search array. The effect for checking pictures was small-to-medium and for negative pictures was small. Meanwhile, in Study 4, performance differences were found between Checkers and Controls in a number of areas of assessment. Thus, a greater number of hits for checking words were recorded by Checkers than Controls, while an enhanced bias towards checking words demonstrated by Checkers was of a large magnitude. Checkers showed an increased use of know memory compared to Controls, and a heightened bias towards the use of know memory. Importantly, the effect sizes of these findings were uniformly large.

Two observations can be made about this data. Firstly, where differences between an OC population and a non-OC population were found in this thesis (Study 1, Study 2 and Study 4), the large effect sizes recorded indicate that these differences were meaningful. This is important, as it implies clinical differences between the groups. As stated, Abramovitch et al. (2013) had raised concerns over the clinical meaning of previous research pointing to cognitive deficits with OCD because of the low average effect sizes across these studies. In the studies reported in this thesis, we attempted alternative methods of examining the selective attention and long-term memory. Additionally, we controlled-for diagnosed comorbid conditions (all studies) and the presence of hoarders (Study 1), recorded levels of anxiety and depression (all studies), we used emotional and symptom-salient and examined OC subtype populations (Studies 2, 3 and 4), and we examined bias towards distracting stimuli (all studies). It is possible that the findings we recorded were as a consequence of taking this approach. This is not to say that previous researchers have also not looked to design their studies along these lines. However, to our knowledge, no studies have been reported which have examined selective attention in OCD using the PoP visual search paradigm, and, likewise, no studies have examined long-term verbal memory using the CID-R paradigm. The second observation is that, where differential performance by an OC population was found within a task (Study 1 and Study 3), the effect sizes were recorded were smaller in comparison to those found for group differences. The reaction time difference between PRnewD and PRnewT sequences in Study 1, for example, was a very small effect. One the aims of Study 3 was assess whether this finding reflected an attentional bias towards distractor stimuli, and if this type of effect would become more significant with the use of emotional and symptom-salient. This did appear to happen (see the findings relating to checking and negative stimuli inter-trial sequences) but, although the effect sizes were numerically larger than in Study 1, they were still small or small-to-medium. This suggests that clinically-establishing the precise mechanics underpinning OC visual search performance is a more difficult task. The evidence from the selective attention studies in this thesis points to differentiated OC performance when certain task types are manipulated. However, the findings are not as strong as others relating to group differences.
6.1.3.2. The relationship between bias, emotion and cognition

The studies in this thesis provide new evidence demonstrating the active role of emotion in modulating and biasing OC cognitive performance. This applies both in selective attention visual search and in long-term memory – performance in both these areas of cognition can altered with the introduction of symptom-salient stimuli. When long-term memory was examined in Study 4, the effect of emotional and symptom-salient stimuli on OC populations – specifically, Checkers – was very clear. Strong, differentiated performance was found for Checkers compared to Controls in various measures of assessment. Checkers demonstrated more bias towards checking words and a greater use of familiarity memory than Controls, but also recorded a greater hit rate for checking words. Thus, their memories of word targets were less clear, and they were riskier in their assessments of whether or not a checking word had been previously presented in the study phase of the task. But, despite this, they were more accurate (as measured by hit rate) when identifying whether a checking word was old or new. As such, this study demonstrates that emotion can actively modulate long-term verbal memory in Checkers, and that the differences between their performance and that of Controls can be shown to be clinically-meaningful. Differences in verbal memory were not found between Washers and Controls, and general OC participants (OCGs) and Controls, in Study 4. There may have been reasons why the CID-R task was particularly suited to Checkers (these are discussed in Section 5.4.2). However, the findings are supportive of previous research suggesting that the behavioural expressions and neurological correlates of OCD differ among subtypes of the condition (e.g., Bragdon et al., 2018; Mataix-Cols et al., 2004).

When considering the findings of this thesis in relation to selective attention, the exact nature of this active role of emotion becomes more complex. Indeed, Studies 2 and 3 suggest that it may appear to act in the elimination of differences between OC participants and controls, if non-sequential effects only are examined. Both of these studies were follow-ups to Study 1, which used non-emotional stimuli and examined a general OC population – and in which group differences in reaction times were found. Both used emotional and symptom-salient stimuli and examined a Checker population. The reports of Studies 2 and 3 (Chapters 3 and 4) suggest that it is conceivable that the presence of emotional and symptom-salient in these studies could have acted to eliminate differences between the groups – possibly by boosting the attentional faculties of the Checker participants. This is somewhat speculative and, considering the lack of research in this area, needs further investigation. However, it is in line with the findings of previous research which has examined the influence of emotion on cognitive performance (e.g., Becker, 2009 – see Chapter 3). Furthermore, while the populations used in Studies 1 and 2 were different, it is notable that the key difference in the PoP tasks assessed in the two studies was the addition of the picture stimuli presentations in advance of search arrays in Study 2. Of course, other factors may have played a part, but this does support the suggestion that the presence of emotion served to actively eliminate group differences.
However, the thesis also provides evidence that the presence of emotional and symptom-salient stimuli can induce biased OC performance when sequential effects (the impact of the content of the immediate previous trial) are analysed. Thus, in Study 3 the impact on checking and negative pictures on the performance of Checkers became clearly apparent, with the group recording slowed reaction times in the Target Neutral condition (when distractor information was swapped) and speeded reaction times in the Target Change condition (when target information was swapped) when such pictures were presented in the immediate preceding trial. This particular aspect of the thesis was following up a specific finding using non-emotional stimuli in Study 1, in which OC participants were found to have impaired performance in particular inter-trial sequences in which search array distractor colours were swapped between trials but target colour stayed the same. The findings of Study 1 suggested a biasing of selection attention in the OC group towards distractor information. Importantly, when this was further examined in Study 3, the introduction of emotional and symptom-salient stimuli and the specific focus on a Checker population resulted in similar, but stronger (see Section 6.1.3.1) inter-trial sequential effects. As stated in Chapter 4, what this perhaps demonstrates is the importance of looking beyond ‘headline’ reaction times in experimental research examining OC populations. While more research is needed, it is evident that nuanced and subtle designs – like those which can assess sequential effects – may be highly useful in establishing more robust and consistent accounts of OC cognition.

6.1.3.3. Theoretical implications

This thesis provides novel evidence which supports theories of cognitive dysfunction in OC and Checker populations (e.g., Clayton et al., 1999; Bradley et al., 2016; Enright & Beech 1990, 1993; Woods et al, 2002). Importantly, the findings provide strong evidence that alterations in selective attention and long-term memory are likely to be underpinned by the same mechanism – bias towards stimuli which offers a specific, symptom-salient threat. Much of the findings in this thesis, then, are in line with the cognitive-behavioural account of OCD. As stated in Section 1.4.1, Salkovskis (1985) argues that bias towards threat is a key feature of OCD, and fundamental to the maintenance of the condition. Notably, the cognitive-behavioural model argues that bias emerges from an enhanced sense of personal responsibility, and that this may be particularly apparent among Checkers – and it is among Checkers that the strongest effects were recorded in this thesis. Indeed, the findings of Study 4 are supportive of theories that altered memory, in the form of biasing towards symptom-specific stimuli, may be a particular feature of being a Checker (e.g., Woods et al., 2002). According to the cognitive-behavioural model, repetitive rituals may occur because of a heightened sense of responsibility felt by an individual (Salkovskis, 1985). But while this may lead a Checker to be on the hunt for potential threat, a Washer may be more focussed on threat-elimination and avoidance (Jones & Krochmalik, 2002; Rachman, 2002). Conceivably then, enhanced vigilance towards the symptom-salient word stimuli used in Study 4 could have resulted in the differentiated performance by Checker
participants – but also the comparable lack of altered performance by Washer participants. Additionally, doubt is a more common behavioural manifestation among Checkers than Washers (Rachman, 2002). It is notable that Study 4, although differences in memory confidence were not found, Checkers were reliant on familiarity with stimuli (know memory) than firm recollection (remember memory). It possible that the manifestation of doubting could occur because Checker memory is more weighted towards a looser sense of the familiar, rather than definite recollection. The thesis findings also suggest that, where relevant selective attention effects were found (e.g., Study 1 and Study 3), neither of the theorised delayed disengagement nor hyper-vigilance mechanisms (see Section 1.5.1.1) which are believed to underpin altered OC attentional behaviour were solely at the root of observed biasing. For example, in Study 3, it is unclear whether reaction time differences among Checkers when sequential effects were examined were more driven by slowed Target Neutral performance than speedier Target Change performance. From the results reported here, it is possible to conclude that both mechanisms are likely to contribute to attentional bias. Further research should examine this in more detail.

Importantly, the findings of the studies reported in this thesis emerge from the use of non-clinical populations. This is significant for two reasons. Firstly, the findings serve to further demonstrate that OCD and OC behaviours are dimensional rather than categorical. Secondly, they highlight how, if further progress is to be made in understanding the neuropsychological mechanics of OCD, research should encompass populations other than those which have been a clinical diagnosis of the condition. OC behaviours are broad and varied, but also on a continuum. There is much to be gained from the study of non-clinical OC groupings which can inform both more severe manifestations of OCD and wider theoretical accounts of the condition. Additionally, the findings of the thesis, and particularly those of the final study (Study 4) in which three OC populations were compared, highlight the importance of using OC subtype participant groupings in research. They are supportive of theories that differing subtypes are likely to display differing cognitive profiles (e.g., Mataix-Cols et al., 2004). In Study 4, the key group differences were between Checkers and the Controls. Checkers performed differently to both Washers and the homogenous OC group (OCGs). Furthermore, it is notable that the OCG group performed at a similar level to that of the Control participants. Possible reasons for this have been discussed in Chapter 5. However, this strengthens the argument that bias towards threat is most evident in Checkers, but also that this may be particularly apparent among those who are relatively free of other OC tendencies.

Finally, the findings of the studies also provide some support for biological models of OCD pointing to fronto-striatal and DLPFC circuitry dysfunction with the condition (Menzies et al, 2008). Although we did not test this directly (e.g., with the use of EEG or fMRI methodology) the paradigms used in these studies draw on these particular brain areas.
6.1.4. Limitations

A priori assessments of sample sizes for each of the studies presented in this thesis were not carried out. As reported in the study chapters, post hoc analysis revealed that the sample sizes for each of the studies were big enough to record appropriately-powered large effects, but that medium and small effects could be considered to be under-powered. While some of the findings presented had corresponding large effect sizes, particularly those in Study 4, it is evident that all of the studies would have benefitted from the use of a greater number of participants. The assessment procedures used for recruitment of participants for the studies in this thesis could have been more comprehensive. In all four studies, we used only the OCI-R (Foa et al., 2002) to assess levels of checking, washing and overall obsessive-compulsiveness. The criteria we used to assess the presence of possible OC tendencies had been established in previous research. However, the use of a single questionnaire might not have been enough to definitively provide evidence of OC behaviours in participants.

The thesis would have benefitted from the use of multiple OC subtype groups in Studies 2 and 3, as well as in Study 4. This would have helped establish how far the selective attention findings of these two studies could be understood as being particular to the checking subtype. It would have aided comparisons with the assessments of bias and dysfunction in long-term memory in Study 4, which found strong effects for Checkers, but little altered performance among Washers and generalised OC participants. Additionally, inclusion of non-OC anxious control groups in the studies might have helped establish whether differentiated OC performance could be specifically attributed to OC cognition, and not broader anxiety per se. This might have been particularly relevant for Study 3, in which a correlation was found between anxiety among Checkers and their reaction time performance in trial sequences involving checking and negative picture stimuli.

6.1.5. Future research

A number of questions arise from findings of this thesis. It remains unclear how far OC attentional and memory biasing operate in a mutually reinforcing way. Studies examining both processes with the same sample populations could contribute to greater understandings of this relationship. Furthermore, would intervention in one of these areas of cognition have consequential effects on biasing in the other? Indeed, the findings from this thesis might be informative for some clinical applications. There is some suggestion that interventions which target bias and emotional dysregulation with OCD may support frontline treatments (Allen & Barlow, 2009; Mogg & Bradley, 2016). For example, attentional bias modification (ABM; MacLeod & Mathews, 2012) programmes look to decrease bias towards threat. However, they do not provide consistent results. It is conceivable that adaptations of visual search paradigms might aid such interventions, given their effectiveness at tapping into
selective attention processes. The same could possibly be applied to the CID-R paradigm, given that biasing towards checking stimuli among Checkers was clearly demonstrated in Study 4. However, this would need considerable assessment by research, particularly given that ABM-type treatments that currently exist are lacking in empirical support.

The notion that emotion may serve to boost performance in visual search tasks among OC participants needs deeper examination. This is a somewhat tentative explanation for some of the findings in Studies 2 and 3. Indeed, when sequential effects were examined in Study 3, reaction times were modulated by the emotional content of stimuli – speeding up in one task condition, but slowing down in the other. One way this could be further investigated could be through the incorporation of EEG methodology into these visual search designs. Eimer et al. (2010) used EEG in their PoP study to assess the activity of the N2pc event-related potential (ERP) component in healthy participants. The N2pc is considered to be a neurological marker for the operation of selective attention. The use of such approach could help provide insights into the brain-based mechanics of attentional processing in OCD. Additionally, it is notable that, in the main, OC anxiety did not correlate with altered performance throughout the thesis. The exception was in Study 3, in which a relationship was found between Checker anxiety levels and performance in inter-trials sequences in which the immediately preceding picture contained checking or negative stimuli. It is possible that exaggerated stress response triggered by such images may play a role in delayed disengagement processes in these sequences. Further examination of the relationship between stress (for review, see Furtado & Katzman, 2015) and OC bias and cognition would aid insights into the mechanics of the condition.

With specific reference to the study of long-term verbal memory, efforts should be made to produce a bank of validated word stimuli that could be used in such studies. As far as can be ascertained, no such resource exists. However, the use of more rigorously-tested verbal stimuli would be highly beneficial in future research.

Additionally, how the findings might vary with symptom severity ought to be assessed. Ultimately, the studies which are detailed in this thesis should be carried out with patient groups to better assess the clinical relevance of the reported findings. Finally, understanding the development and maintenance of OCD is important for how it is treated. Single studies can be hugely informative in this regard. However, longitudinal research assessing selective attention and long-term memory could give additional insights into the interactions between cognition and the phenomenology of the condition over time.
6.1.6. Conclusions

This thesis provides novel evidence that bias and emotion are drivers of dysfunction in OC cognition. The operation of both underpins altered performance in selective attention and long-term memory tasks. This is likely, also, to be a particular feature of the Checker cognitive profile. The findings of previous research in these areas have been mixed. However, with the use of tightly-controlled experimental paradigms incorporating symptom-salient and which assess subtypes of OCD, clinically-meaningful differences between OC and non-OC populations can be observed. Importantly, the results reported here were recorded with non-clinical participants. The further adoption of such nuanced approaches to the study of OCD and OC behaviours should help throw clear light on the broader dimensions and mechanics of the condition.
References


Freud, S. (1909). *Notes on a case of obsessional neurosis*. Last retrieved on 02.11.18. from https://archive.org/stream/SigmundFreud/Sigmund%20Freud%20%5B1909%5D%20Notes%20Upon%20A%20Case%20Of%20Obsessional%20Neurosis%20%28The%20Rat%20Man%20Case%20History%29%28James%20Strachey%20Translation%201955%29_djvu.txt


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Appendices
Appendix 1

Brendan Richards  
Department of Psychology  
FAHS  

19 January 2012  

Dear Mr Richards  

A study of selective attention and obsessive-compulsive disorder (EC/2011/08/FAHS)  

I am writing to inform you that the Chairman, on behalf of the Ethics Committee, has considered the Amendments requested to the above protocol and has approved them on the understanding that the Ethical Guidelines for Teaching and Research are observed. Please be advised that the Ethics Committee is able to audit research to ensure that researchers are abiding by the University requirements and guidelines.  

If the project includes distribution of a survey or questionnaire to members of the University community, researchers are asked to include a statement advising that the project has been reviewed by the University’s Ethics Committee.  

Date of confirmation of ethical opinion: 9 June 2011 (FAHS Committee).  
Date of favourable ethical opinion of amendment to protocol: 19 January 2012  

The list of amended documents reviewed and approved by the Chairman is as follows:-  

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Yours sincerely  

Glenn Moulton  
Secretary, University Ethics Committee  
Academic Registry  

cc: Professor S Williamson, Chairman, Ethics Committee
Appendix 2

08 June 2016

Dear Mr Richards,

UEC ref: UEC/2016/030/FHMS
Study Title: Investigating the influence of emotional pictures on selective attention, distraction and inhibition in sub-clinical obsessive compulsive checkers

On behalf of the Ethics Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the submitted protocol and supporting documentation.

Date of confirmation of ethical opinion: 08 June 2016

The final list of documents reviewed by the Committee is as follows:

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This opinion is given on the understanding that you will comply with the University’s Ethical Principles & Procedures for Teaching and Research.

If the project includes distribution of a survey or questionnaire to members of the University community, researchers are asked to include a statement advising that the project has been reviewed by the University’s Ethics Committee.

If you wish to make any amendments to your protocol please address your request to the Secretary of the Ethics Committee and attach any revised documentation.
The Committee will need to be notified of adverse reactions suffered by research participants, and if
the study is terminated earlier than expected with reasons. Please be advised that the Ethics
Committee is able to audit research to ensure that researchers are abiding by the University
requirements and guidelines.

You are asked to note that a further submission to the Ethics Committee will be required in the event
that the study is not completed within five years of the above date.

Please inform me when the research has been completed.

Yours sincerely

[Signature]

Miss Rebecca Green
Assistant Research Integrity and Governance Officer, Research & Enterprise Support

Copy to:
Professor Annette Sterr, Dr Laura Simonds
Appendix 3

Study 2: Valence and arousal ratings for picture stimuli

The checking pictures used in Study 2 were part of a broader set of stimuli specifically developed for the experimental assessment of aspects of obsessive-compulsive disorder and its subtypes (Simon et al., 2012). The negative and neutral pictures were taken from the International Affective Picture System database (Lang et al., 2008).

All the picture images used in the study, along with additional exemplars of each category, had previously been rated for valence and arousal by Checker and Non-Checker participants (N=11 per group) in a validation study by Gomes-Victorino (2017). The specific pictures used in the present study were selected from this larger stimuli set following further analysis of the data collected by Gomes-Victorino (2017) – see Figures 1 and 2.

Valence

Analysis revealed that the checking pictures selected for the present study had been rated as significantly more negatively by Checker participants than by Non-Checkers in Gomes-Victorino (2017) – see Figure 1. A mixed 3x2 ANOVA, with the factors picture category (checking, negative, neutral) and group (Checkers, Non-Checkers), found a significant main effect of picture type \( (F(1.899,56.978)=133.4, \ p<0.001, \ \eta^2_p=0.816) \), a significant main effect of group \( (F(1,30)=11.6, \ p=0.002, \ \eta^2_p=0.286) \) and a significant interaction between group and picture type \( (F(1.899,56.978)=4.2, \ p=0.022, \ \eta^2_p=0.123) \). Post-hoc independent \( t \) tests showed that the interaction was driven by a significant difference in higher valence scores given for checking pictures by Checkers than those by Non-Checkers \( (t(30)=3.243, \ p=0.003, \ d=1.1) \). There were no differences in valence ratings between Checkers and Non-Checkers for the selected negative and neutral pictures. As can be seen in Figure 1, negative pictures were rated by both groups as the most negatively-valenced, with neutral pictures considered the least negatively-valenced.
Figure 1. Mean valence ratings (1-9, low-high) for the checking, negative and neutral pictures used in Study 2. As can be seen, Checker participants rated the checking pictures to be more negatively-valenced than non-checkers. There were no group differences in valence ratings for the selected negative and neutral pictures.

### Arousal

Checkers in Gomes-Victorino (2017) gave significantly higher arousal ratings for the checking pictures selected for the present study than Non-Checkers – see Figure 2 (note, lower scores equate to greater arousal). A mixed 3x2 ANOVA, with the factors picture category (checking, negative, neutral) and group (Checkers, Non-Checkers), found a significant main effect of picture type ($F(2,60)=88.947, p<0.001, \eta^2_p=0.748$), a significant main effect of group ($F(1,30)=29.74, p<0.001, \eta^2_p=0.498$) and a significant interaction between group and picture type ($F(2,60)=4.247, p=0.019, \eta^2_p=0.124$). Post-hoc independent t tests revealed a significant difference in the greater ratings for arousal (lower scores) given for checking pictures by Checkers than those given by Non-Checkers ($t(30)=4.984, p_c<0.001, d=1.8$). Checkers also reported greater ratings of arousal for the selected negative pictures than Non-Checkers ($t(30)=3.531, p_c=0.001, d=1.2$). There were no differences in arousal ratings between Checkers and Controls for the selected neutral pictures.

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</table>

![Arousal Graph]
As can be seen, checkers gave higher arousal ratings than Non-Checkers for the checking and negative pictures used in the present study. There were no differences in arousal ratings given by Checkers and Non-Checkers for the selected neutral pictures.

*Figure 2. Mean arousal ratings (1-9, high-low) for the checking, negative and neutral pictures used in Study 2.*
Appendix 4

Study 2 and 3 – checklist of possible task-based explanations for high rates of omissions

Note, assessments apply to both studies – which were run concurrently using the same equipment. Similar rates of omissions were recorded in both studies.

<table>
<thead>
<tr>
<th>Potential cause</th>
<th>Assessment</th>
</tr>
</thead>
</table>
| On-screen task instructions in Studies 2 & 3 | 1. Same for all participants.  
2. Instructions clearly stated that the task was to respond to the cut of the odd-one-out in every trial.  
3. Instructions clearly stated that aim of the task was to be as fast and accurate as possible.  
4. In the case of Study 2, it was clearly stated that the aim was to respond to the search array and NOT the picture image which appeared in advance of each search array.  
5. Experimenter also verbally went through the task instructions with each participant to ensure they understood the task.  
6. Verbal instructions were further supported by paper print-outs of example trials search arrays.  
7. Participants only began the task when they confirmed to the experimenter that they understood and were happy with its requirements. |
| Verbal cues given by researcher in Studies 2 & 3 | 1. In both studies, verbal instructions were the same for each participant.  
2. The experimenter verbally detailed the requirements of the tasks in addition to the instructions being presented on-screen.  
3. Verbal instructions were further supported by paper print-outs of example trials search arrays.  
4. Participants only began the tasks when they confirmed to the experimenter that they understood and were happy with its requirements.  
5. Participants were told that, if they believed they had made an error in a trial, they should not dwell on it and should instead concentrate on upcoming trials. |
| Global failure to understand tasks | 1. Omissions rate range was very large, but it was not consistently high. This applied to both groups and both studies.  
2. Mean RTs for correct responses/choice error responses were around 700-900ms. Admissible RTs DID NOT cluster near the end of the response time window (1,500ms). This applied to both groups and both experiments.  
3. Most participants scored below 50% omission rate.  
4. No evidence that participants were guessing their responses |
– choice error rate was 4-6%, as was expected. This was the same for both studies.

5. Two participants in Study 3 were removed because of likely failure to understand the task – exceptionally high omission rate. Four participants in Study 2 were removed for same reason.

6. With the exclusion of participants detailed in (4), points 1-3 indicate that the task was understood on a global level.

<table>
<thead>
<tr>
<th>Individual failure to understand tasks</th>
<th>1. Two participants in Study 3 were removed because of likely failure to understand the task – exceptionally high omission rate. Four participants in Study 3 were removed for same reason.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. One of these participants removed in Study 3 was also removed in Study 2 – this person had the largest omission rate (approx. 98%).</td>
</tr>
<tr>
<td></td>
<td>3. Difficult to know why these people did not perform the task appropriately. However, the evidence is that (despite a high and varying omissions rate), the majority of participants understood the requirements of the task.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Difficulty/design of tasks</th>
<th>1. Designs of the experiments were based on classic PoP studies. Additional elements (the use of emotional pictures) were informed by previous studies.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Study 2:</td>
</tr>
<tr>
<td></td>
<td>• A classic PoP paradigm, with the addition of a picture before each search array presentation.</td>
</tr>
<tr>
<td></td>
<td>• Search arrays on screen for 150ms. Response window of 0-1,500ms.</td>
</tr>
<tr>
<td></td>
<td>• Design of the emotional component of experiment was similar to that of Kristjanssen et al. (2013).</td>
</tr>
<tr>
<td></td>
<td>• Data analysed includes responses from 100-1,500ms in order to incorporate all possible later responses.</td>
</tr>
<tr>
<td></td>
<td>• Exclusion of responses &lt;100ms acted to exclude responses to previous trials that overlapped into current trials. Very few responses were recorded &gt;1,200ms.</td>
</tr>
<tr>
<td></td>
<td>Study 3:</td>
</tr>
<tr>
<td></td>
<td>• Visual search arrays were presented for 1,000ms. This is longer than classic colour/shape PoP experiments, which usually present search arrays for 150ms. The increased presentation time was in order than the more complex content of picture images could be processed by participants.</td>
</tr>
<tr>
<td></td>
<td>• Response window of 0-1,500ms.</td>
</tr>
<tr>
<td></td>
<td>• The 1,000ms picture presentation window was longer than that used by Moritz et al. (2009) in their IOR study (pictures were on-screen for</td>
</tr>
</tbody>
</table>
400ms), but shorter than that used by Lamy et al. (2008) in their emotional faces PoP study (on-screen until participant response).

- Data analysed includes responses from 100-1,500ms in order to incorporate all possible later responses.
- Exclusion of responses <100ms acts to exclude responses to previous trials that overlap into current trials. Very few responses were recorded >1,200ms.

3. In both Study 2 and Study 3, participants completed two practice blocks before the main experiment began. All condition combinations featured in practice blocks. Experimenter stayed with the participant while practice blocks were performed in order to check task was being carried out correctly. Participants who were not happy with the task after the practice blocks were able to repeat them until they were comfortable with the.

<table>
<thead>
<tr>
<th>Emotional content of pictures interfering with difficulty of tasks</th>
<th>1. Data analysis revealed no differences in omissions rates between picture types.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical/equipment error</td>
<td>1. Both experiments were piloted, and ran and recorded successfully.</td>
</tr>
<tr>
<td></td>
<td>2. The functioning of response boxes were checked ahead of each participant’s recording session. In practise blocks, the researcher actively listened for mouse ‘clicks’ when participants were making their responses.</td>
</tr>
<tr>
<td></td>
<td>3. No evidence in the output of failure of response boxes to record participant button presses – for example, no long passages of consistent non-responses.</td>
</tr>
<tr>
<td></td>
<td>4. The exception to (3) was in the participants who were later excluded for likely failure to understand the task.</td>
</tr>
<tr>
<td></td>
<td>5. Further to (4), one excluded participant performed in this manner in BOTH experiments. If response box failure was a problem, it would be highly unlikely to have affected this participant both times in such an equal manner.</td>
</tr>
</tbody>
</table>
Appendix 5

Study 3: Valence and arousal ratings for picture stimuli

As in Study 2, the checking pictures used in Study 3 were part of a broader set of stimuli specifically developed for the examination of obsessive-compulsive disorder and its subtypes by Simon et al. (2012). The negative and neutral pictures were taken from the International Affective Picture System database (Lang et al., 2008).

Again, like in Study 2, all the picture images used in Study 3, had previously been rated for valence and arousal by Checker and Non-Checker participants (N=11 per group) in a validation study by Gomes-Victorino (2017). The specific pictures used Study 3 were chosen from this stimuli set following further analysis of the data collected by Gomes-Victorino (2017) – see Figures 1 and 2.

Valence

Analysis revealed that the checking pictures selected for the present study had been rated in the validation study as significantly more negatively-valenced by Checker participants than by Non-Checkers – see Figure 1. A mixed 3x2 ANOVA, with the factors picture type (checking, negative, neutral) and group (Checkers, Non-Checkers), found a significant main effect of picture type ($F(1.761,38.75)=108.77, p<0.001, \eta_p^2=0.832$), a significant main effect of group ($F(1,22)=8.804, p=0.007, \eta_p^2=0.286$) and a significant interaction between group and picture type ($F(1.761,38.75)=6.018, p=0.007, \eta_p^2=0.215$). Post-hoc independent $t$-tests showed that the interaction was driven by a significant difference in higher valence scores given for checking pictures by Checkers than those by Non-Checkers ($t(22)=3.572, p_c=0.002$). There were no differences in valence ratings between Checkers and Non-Checkers for the negative and neutral pictures selected. As can be seen in Figure 1, negative pictures were rated by both groups as the most negatively-valenced, with neutral pictures given the lowest negative-valence ratings.
Figure 1. Mean valence ratings (1-9, low-high) for the checking, negative and neutral pictures used in the Study 3. Checker participants rated the checking pictures to be more negatively-valenced than Non-Checkers. There were no group differences in valence ratings for the selected negative and neutral pictures.

Arousal

Checkers in Gomes-Victorino (2017) gave significantly higher arousal ratings for all pictures selected for the present study than Non-Checkers – see Figure 2 (note, lower scores equate to greater arousal). A mixed 3x2 ANOVA, with the factors picture type (checking, negative, neutral) and group (Checkers, Non-Checkers), found a significant main effect of picture type ($F(2,44)=68.448, p<0.001, \eta^2_p=0.757$) and a significant main effect of group ($F(1,22)=16.208, p=0.001, \eta^2_p=0.424$). However, there was no interaction between group and picture type ($F(2,44)=1.724, p=0.19, \eta^2_p=0.073$).
Secondary neutral pictures
A separate group of secondary neutral picture images was also created to act as targets in the Target Neutral condition and distractors in the Target Change condition. This group also contained 12 picture exemplars, all of which were unique to the secondary neutral group. All stimuli, and their associated ratings, were from Gomes-Victorino (2017). They were originally taken from the International Affective Picture System database (Lang et al., 2008).

As can be seen in Figure 3, there were no group differences in valence ratings for the secondary neutral set of pictures ($t(22)=1.753$, $p=0.094$). Checkers in the validation study gave the selected pictures higher ratings of arousal than Non-Checkers ($t(22)=3.001$, $p=0.007$). However, the mean scores recorded by both groups were very similar (Checker: $5.2 \pm 0.12$; Non-Checker: $5.7 \pm 0.11$). Both scores were indicative of neutral ratings of arousal (scores of 5 indicating arousal levels were neither high nor low).
Figure 3. Mean valence and arousal ratings (1-9) for the secondary neutral pictures used in the present study. Ratings made in a validation study by Gomes-Victorino (2017). (Note, valence ratings are low-high. Arousal ratings are high-low).
Brendan Richards  
School of Psychology  
FAHS  

06 August 2012

A study of priming, remember/know memory and memory confidence in sub-clinical obsessive-compulsive checkers and washers EC/2012/82/FAHS

Dear Mr Richards,

On behalf of the Ethics Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the submitted protocol and supporting documentation.

Date of confirmation of ethical opinion: 6 August 2012.

The list of documents reviewed by the Committee is as follows:

<table>
<thead>
<tr>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary of the project</td>
</tr>
<tr>
<td>Detailed protocol – pre-study</td>
</tr>
<tr>
<td>Detailed protocol – main study</td>
</tr>
<tr>
<td>Participant Information Sheet – pre-study</td>
</tr>
<tr>
<td>Participant Information Sheet – main study</td>
</tr>
<tr>
<td>Consent form – pre-study</td>
</tr>
<tr>
<td>Consent form – main study</td>
</tr>
<tr>
<td>Word list documentation</td>
</tr>
<tr>
<td>Participant debriefing sheet – pre-study</td>
</tr>
<tr>
<td>Participant debriefing sheet – main study</td>
</tr>
<tr>
<td>Recruitment adverts</td>
</tr>
<tr>
<td>Risk assessment</td>
</tr>
<tr>
<td>Protocol Submission Proforma: Insurance</td>
</tr>
<tr>
<td>Confirmation of collaboration letters</td>
</tr>
<tr>
<td>Appendices</td>
</tr>
</tbody>
</table>

This opinion is given on the understanding that you will comply with the University’s Ethical Guidelines for Teaching and Research, and with the conditions set out as follows:

- Participant Information Sheet: Pre-Study, on page 2 – What are the risks and disadvantages of taking part – there seems to be a mistake on the final line i.e. “will be advised DISTRESS to seek help from trained professional. There are several typos/missing words throughout the documentation and advise that you have one more read through, need to make sure it reads correctly. Some of the words in Section 2e are repeated, eg dirty, germs & maims.

I would be grateful if you would confirm, in writing, your acceptance of the conditions above.
If the project includes distribution of a survey or questionnaire to members of the University community, researchers are asked to include a statement advising that the project has been reviewed by the University's Ethics Committee.

If you wish to make any amendments to your protocol please address your request to the Secretary of the Ethics Committee and attach any revised documentation.

The Committee will need to be notified of any adverse reactions suffered by research participants, and if the study is terminated earlier than expected, with reasons. Please be advised that the Ethics Committee is able to audit research to ensure that researchers are abiding by the University requirements and guidelines.

You are asked to note that a further submission to the Ethics Committee will be required in the event that the study is not completed within five years of the above date.

Please inform me when the research has been completed.

Yours sincerely

Glenn Moulton
Secretary, University Ethics Committee
Academic Registry
Brendan Richards  
PhD student  
Room 03AC04  
Department of Psychology  
University of Surrey

Gienn Moulton  
Secretary  
University of Surrey Ethics Committee  
University of Surrey  
Guildford  
Surrey

August 8 2012

Dear Mr Moulton

Re: A study of priming, remember/know memory and memory confidence in sub-clinical obsessive-compulsive checkers and washers (EC/2012/82/FAHS)

I writing to confirm that I accept the conditions stated in your letter dated August 6 2012 regarding the study detailed above.

Thank you for your help.

Yours sincerely

Brendan Richards
Appendix 7

Creation of word stimuli set for Study 4

Introduction
Few previous studies examining verbal recollection in obsessive-compulsive behaviour have tailored their word stimuli to specific obsessive-compulsive concerns (e.g., checking and washing). Those that have tended to use a small number of stimuli items. Consequently, we carried out a pre-study in advance of the main experiment (see Chapter 5) with the aim of formulating a bespoke word stimuli data set specifically relevant to obsessive-compulsive washing and checking concerns, along with negative and neutral targets, that would be large enough for use in the main study. The design of the pre-study was similar to that carried out by Lavy et al. (1994) prior to their study of emotional stimuli processing in obsessive-compulsive disorder.

The pre-study consisted of two parts. In Part 1, we aimed to establish a bank of possible checking and washing words which could be used as targets in the main study. For this, we recruited an obsessive-compulsive group, comprising non-clinical participants with elevated checking and washing tendencies (the OC group). Participants were asked to rate a series of words for their relevance to checking and washing concerns. They were also asked to give valence scores for each word. In Part 2, we looked to refine this list and to collect possible negative and neutral word targets for use in the main study. For this, we recruited a non-obsessive-compulsive control group of participants (the Control group). This group was asked to give valence scores for both negative and neutral word candidates, as well as the potential checking and washing word targets which had been rated by the OC group in Part 1. The aim of this was to establish normed valence scores for all possible word targets in order to control for valence effects. In addition, Control participants were asked to give concreteness and imageability scores for all potential negative, neutral, checking and washing word targets. Concreteness was defined as the extent to which a word target represented an item, items or concept that could be sensually experienced, as opposed to being more abstract. Imageability was defined as the extent to which a word could conjure up an image in the participant’s mind (Richardson, 1974). The aim was to establish normed concreteness and imageability scores for all word candidates.

Following the completion of Parts 1 and 2, data scores were analysed before the final stimuli set was selected.
Participants

Participants were screened in advance of taking part in the study using the OCI-R (Foa et al., 2002 – for details see Chapter 1, Section 1.14.1.2). The OC group comprised four non-clinical participants. All four reported total OCI-R scores of >21, checking subscale scores of ≥5 and washing subscale scores of ≥4. The Control group comprised five participants. All five reported total OCI-R scores of <21 and checking and washing subscale scores of 0. All participants spoke English as their first language. Participants were given an information sheet and provided informed consent ahead of taking part in the study. They were debriefed on completion.

Pre-study design and procedure

The pre-study consisted of two parts. In Part 1, we aimed to establish a bank of checking and washing word targets. Part 1 was carried out by the OC group. In Part 2, we looked to refine this list and to formulate matched negative neutral and neutral targets. Part 2 was carried out by the Control group. Flowchart representations of the pre-study procedures for Parts 1 and 2 are in Figure 1.

Part 1:

OC group participants were presented with a list of 264 printed words, formulated into a table. They were asked to rate each of the words for their relevance to checking behaviours and washing behaviours, and also give a rating for the valence of each word. Rating for word relevance was on a scale from 1-10, where one indicated ‘no relevance’, five indicated ‘medium relevance’ and 10 indicated ‘very high relevance’. Ratings for valence were on a scale of 1-10, where 1 indicated ‘very negative’, five indicated ‘neutral’ and 10 indicated ‘very positive’.

The words selected for Part 1 were all four to six-letters-long. They were chosen following a literature search of previous OCD experiments using word stimuli, consultation with Dr Laura Simonds and Dr Clara Strauss (lecturers in clinical psychology specialising in OCD at the University of Surrey), and detailed word searches using the English Lexicon Project (Balota et al., 2007) database.

Part 2:

Following analysis of Part 1 data, 33 washing-relevant words and 58 checking-relevant words were selected as possible OC-salient word stimuli candidates. All these words had been given high negative valence ratings (scores between one and three) and had been rated as having high relevance to checking and washing (scores between seven and 10) by at least two participants. In order to compile sets of negative and neutral words, and to refine the OC word list, the potential checking and washing targets were included in an extended list of possible negative and neutral targets (total words=334). The potential negative and neutral targets were sourced via the English Lexicon Project (Balota et al., 2007) database. Control group participants were presented with the list of 334 printed words, formulated into a table. They were asked to give valance ratings for the words using the same 1-10 scale used in Part 1. In addition, participants were also asked to rate all the words (including OC-
salient candidates) for concreteness and imageability – this was on a scale of 1-10, where one indicated low concreteness/imageability and 10 indicated high concreteness/imageability.

**Part 1**

**Participants**
- OC group  
  \(N=4\)

**Pre-task**
- Information sheet
- Informed consent

**Task**
- Provide ratings for 264 potential checking and washing words:
  1. OC relevance
  2. Valence

**Post-task**
- Debriefing

**Part 2**

**Participants**
- Control group  
  \(N=5\)

**Pre-task**
- Information sheet
- Informed consent

**Task**
- Provide ratings for 334 potential checking, washing, negative and neutral words:
  1. Valence
  2. **Concreteness**
  3. **Imageability**

**Post-task**
- Debriefing

*Figure 1. Schematic representations of the procedures of Part 1 and Part 2 of the pre-study.*

**Creation of final stimuli lists**

Following the analysis of data from Part 2, 156 word targets were selected for use in the experiment. Fifty-two of these words were salient to checking and washing concerns (26 were checking-relevant and 26 were washing-relevant). A further 52 words were classed as negative, and another 52 words classed as neutral. Checking and washing words had all been rated by Control participants in Part 2 as having negative valence (scores between one and three). The selected negative words had all been scored by Control participants as having negative valence. Neutral word targets had a mean valence score of five.
In addition, a further 20 neutral words were used as filler trials in the main experiment study phase to control for primacy and recency effects.

**Word lists A and B**
The word stimuli were divided into two lists – List A and List B. Each contained 78 words, comprising of 13 checking, 13 washing, 26 negative and 26 neutral words. For each participant, one of these lists was to be used in the study phase of the main experiment, with the other being used in the test phase.

The final Lists A and B were carefully balanced (see Tables 1, 2 and 3). Analysis revealed no significant differences between the overall mean valence of List A and B ($p=0.58$); the overall mean valence of List A without neutral words and List B without neutral words ($p=0.767$); the overall mean concreteness of words in List A and in List B ($p=0.439$); the overall mean imageability of words in List A and in List B ($p=0.605$); the overall Hal frequency (Lund & Burgess, 1996) ratings for List A and B ($p=0.707$); the overall checking and washing word relevance scores for List A and List B ($p=0.868$); and the overall checking and washing word valence scores for List A and List B ($p=0.513$).

**Table 1.** Mean and median ratings for List A word stimuli reported by Controls taking part in Part 2 of the pre-study.

<table>
<thead>
<tr>
<th>Word type</th>
<th>Valence (m/med)</th>
<th>Concreteness (m/med)</th>
<th>Imageability (m/med)</th>
<th>No. of letters (m)</th>
<th>Hal frequency (m/med)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checking</td>
<td>3.2/3</td>
<td>4/3</td>
<td>4.8/5</td>
<td>5.15</td>
<td>18655.15/12379</td>
</tr>
<tr>
<td>Washing</td>
<td>2.9/2</td>
<td>6.6/7</td>
<td>7.3/7</td>
<td>5.15</td>
<td>4471.15/3351</td>
</tr>
<tr>
<td>Negative</td>
<td>2.8/3</td>
<td>4.5/4</td>
<td>5.7/6</td>
<td>5.23</td>
<td>10134.732001.5</td>
</tr>
<tr>
<td>Neutral</td>
<td>5.7/5</td>
<td>5.4/5</td>
<td>6.6.5</td>
<td>5.26</td>
<td>10419.07/2524.5</td>
</tr>
<tr>
<td>Overall</td>
<td>3.8/3</td>
<td>5/4</td>
<td>5.9/6</td>
<td>5.21</td>
<td>10705.65/3420</td>
</tr>
<tr>
<td>Overall-Neut</td>
<td>2.9/3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Mean and median ratings for List B word reported by Controls taking part in Part 2 of the pre-study.

<table>
<thead>
<tr>
<th>Word type</th>
<th>Valence (m/med)</th>
<th>Concreteness (m/med)</th>
<th>Imageability (m/med)</th>
<th>No. of letters (m)</th>
<th>Hal freq (m/med)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checking</td>
<td>3.1/3</td>
<td>4.4/2</td>
<td>5.3/4</td>
<td>5.15</td>
<td>16990.53/9581</td>
</tr>
<tr>
<td>Washing</td>
<td>2.7/2</td>
<td>6.1/6</td>
<td>7/7</td>
<td>5.15</td>
<td>5620.61/1002</td>
</tr>
<tr>
<td>Negative</td>
<td>2.8/3</td>
<td>5.2/5</td>
<td>6.4/7</td>
<td>5.03</td>
<td>10436.26/3685.5</td>
</tr>
<tr>
<td>Neutral</td>
<td>5.6/5</td>
<td>5.6/5</td>
<td>5.7/5.5</td>
<td>5.42</td>
<td>10871.5/2699.5</td>
</tr>
<tr>
<td>Overall</td>
<td>3.78/3</td>
<td>5.3/5</td>
<td>6.1/6</td>
<td>5.2</td>
<td>10871.11/3476</td>
</tr>
<tr>
<td>Overall-Neut</td>
<td>2.88/3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Mean and median ratings for the relevance and valence of List A and B checking and washing words, as reported by OC participants taking part in Part 1 of the pre-study.

<table>
<thead>
<tr>
<th>Word type</th>
<th>List A</th>
<th>List B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OC relevance (m/med)</td>
<td>Valence (m/med)</td>
</tr>
<tr>
<td>Checking</td>
<td>9.2/9.3</td>
<td>1.9/1.7</td>
</tr>
<tr>
<td>Washing</td>
<td>8.7/8.5</td>
<td>2.4/2.5</td>
</tr>
<tr>
<td>Overall</td>
<td>9/9.1</td>
<td>2.2/2</td>
</tr>
</tbody>
</table>
### Experimental stimuli – List A

<table>
<thead>
<tr>
<th>Word</th>
<th>Word type</th>
<th>Word</th>
<th>Word type</th>
</tr>
</thead>
<tbody>
<tr>
<td>peril</td>
<td>Checking</td>
<td>dismay</td>
<td>Negative</td>
</tr>
<tr>
<td>fire</td>
<td>Checking</td>
<td>cruel</td>
<td>Negative</td>
</tr>
<tr>
<td>risk</td>
<td>Checking</td>
<td>gunman</td>
<td>Negative</td>
</tr>
<tr>
<td>fault</td>
<td>Checking</td>
<td>dismal</td>
<td>Negative</td>
</tr>
<tr>
<td>blamed</td>
<td>Checking</td>
<td>doomed</td>
<td>Negative</td>
</tr>
<tr>
<td>forget</td>
<td>Checking</td>
<td>sadly</td>
<td>Negative</td>
</tr>
<tr>
<td>harm</td>
<td>Checking</td>
<td>junkie</td>
<td>Negative</td>
</tr>
<tr>
<td>unsafe</td>
<td>Checking</td>
<td>devoid</td>
<td>Negative</td>
</tr>
<tr>
<td>ruin</td>
<td>Checking</td>
<td>bleak</td>
<td>Negative</td>
</tr>
<tr>
<td>murder</td>
<td>Checking</td>
<td>dunce</td>
<td>Negative</td>
</tr>
<tr>
<td>infect</td>
<td>Checking</td>
<td>crisis</td>
<td>Negative</td>
</tr>
<tr>
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## Experimental stimuli – List B

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### Primacy and recency trial words

#### Primacy
- yule
- works
- rarest
- viable
- means
- unites
- wearer
- raises
- within
- affix

#### Recency
- adorn
- means
- week
- afoot
- teak
- raked
- venues
- amends
- origin
- works
Table 1. Summary of p values and effect sizes ($\eta_p^2$ and Cohen’s $d$) for key findings from the selective attention studies in this thesis. Effect size values for $\eta_p^2$ are reported following ANOVA analysis. Effect size values for Cohen’s $d$ are reported following Bonferroni post-hoc $t$-test analysis. Following Cohen (1988), the magnitude of effect sizes were considered to be the following – $\eta_p^2$: small=0.01, medium=0.09, large=0.25; $d$: small=0.2, medium=0.5, large=0.8.

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<td>PRnewD vs. PRnewT RTs:&lt;br&gt; i. Group/task interaction</td>
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Table 2. Summary of $p$ values and effect sizes ($\eta_p^2$ and Cohen’s $d$) for key findings from the long-term memory study carried out as part of this thesis. Effect size values for $\eta_p^2$ are reported following ANOVA analysis. Effect size values for Cohen’s $d$ are reported following Bonferroni post-hoc $t$-test analysis. Following Cohen (1988), the magnitude of effect sizes were considered to be the following – $\eta_p^2$: small=0.01, medium=0.09, large=0.25; $d$: small=0.2, medium=0.5, large=0.8.

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