



Review

Hoping for more: How cognitive science has and hasn't been helpful to the OCD clinician



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HIGHLIGHTS

- Evidence for cognitive deficits in obsessive-compulsive disorder (OCD) is equivocal.
- Beliefs about cognition appear to impact OCD symptoms.
- Many cognitive science paradigms may conflate processes with outcomes.
- Many observed cognitive deficits are better explained by belief models.
- Cognitive science research should focus on clinically-relevant treatment targets.

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ABSTRACT

Cognitive-behavioural models of obsessive-compulsive disorder (OCD) stemmed from knowledge acquired from cognitive science. Researchers continue to apply basic cognitive-affective science methods to understanding OCD, with the overarching goal of improving and refining evidence-based treatments. However, the degree to which such research has contributed to this goal is unclear. We reviewed OCD research in the general areas that comprise basic cognitive science, and evaluated the degree to which it has contributed to our understanding of the development, maintenance, and treatment of OCD. We focused on studies that either compared people with and without OCD and/or used experimental psychopathology methods with human participants, and attempted to resolve some of the conflicting theories related to the importance of cognitive deficits vs. cognitive biases. Overall, we observed equivocal findings for deficits in perception, attention, memory, and executive functioning. Moreover, many so-called deficits were moderated and/or explained by OCD-relevant beliefs, highlighting the role of confidence in cognitive processes as integral to our understanding of OCD. We discussed these findings in terms of cognitive measurement, cognitive-behavioural models, and clinical applicability, and made recommendations for future research that may offer innovation and insight helpful to clinicians working to improve the symptoms and lives of people with OCD.

1. Introduction

Obsessive-Compulsive Disorder (OCD) is characterized by obsessions—repeated, unwanted, intrusive, distressing thoughts—and compulsions—repeated overt or covert behaviours used to reduce the likelihood of perceived negative consequences—that lead to significant distress and impairment (DSM-5; [American Psychiatric Association, 2013](#)). Cognitive-behavioural models of OCD contend that people's catastrophic appraisals of their intrusive thoughts lead to increased anxiety, guilt, and shame, and to engagement in behaviours to reduce these emotions and/or the likelihood of the catastrophic consequence occurring (e.g., [Rachman, 1997](#)). These behaviours are self-reinforcing,

in that they reduce the negative emotion in the short term, but perpetuate the catastrophic appraisal in the long term (e.g., “Since I checked the door, nobody broke into the house and murdered my family”). Indeed, such models stemmed originally from cognitive science—knowledge about learning, emotion, and behaviour, as well as from behavioural science (e.g., [Mowrer, 1951](#)) and cognitive theories of emotion. Researchers continue to apply basic cognitive-affective science methods to understanding OCD, with the overarching goal of improving and refining evidence-based treatments. However, the degree to which such research has contributed to this goal is unclear.

In this paper, we review research related to OCD in the general areas that comprise basic cognitive science, and evaluate the degree to which

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it has contributed to our understanding of the development, maintenance, and treatment of OCD. We could write a book on this topic, given the wealth of research available; as such, we did not conduct an exhaustive review. Instead, we focused on the areas that have been either the most fruitful or the most equivocal, to attempt to identify not only recent advances in cognitive science, but also areas for growth, as well as those for which we don't believe growth is forthcoming. Moreover, although OCD is a heterogeneous disorder with diverse symptom manifestations (e.g., harm obsessions, contamination/washing, checking, symmetry and rituals), exploring advances in cognitive science as they apply to specific manifestations of OCD is beyond the scope of the current paper, though we acknowledge that certain manifestations of OCD may be more strongly associated with certain types of cognitive deficits or biases. For example, autogenous obsessions (e.g., the perceived threat is contained within the unwanted thought) are associated with lower response inhibition compared to reactive obsessions (e.g., the obsession is provoked by a perceived threatening trigger) (Lee, Yost, & Telch, 2009).

We explored the areas of perception, attention, memory, executive functioning, and dual-systems models of cognition¹ as they relate to OCD broadly. We focused on studies that either compared people with and without OCD (to better understand OCD phenomenology, and variables that differentiate normative thinking and feeling from clinical OCD) and/or used experimental psychopathology methods with human participants (to better elucidate causal and maintaining factors). We also endeavoured to place special consideration on how this research pertains (or fails to pertain) to psychological treatment of OCD.

This review appears following a debate that spanned four papers and two journals about the usefulness of the cognitive model of OCD. First, Calkins, Berman, and Wilhelm (2013) reviewed evidence that validated the causal role of catastrophic misinterpretations of intrusive thoughts in OCD in *Current Psychiatry Reports*. Anholt and Kalanthroff (2013) replied with a Letter to the Editor, questioning the validity of this model based on findings from studies using the Obsessive Beliefs Questionnaire (OBQ; OCCWG, 2005) and a recent meta-analysis questioning the incremental validity of cognitive therapy over exposure and response prevention (ERP) for OCD (Rosa-Alcázar, Sánchez-Meca, Gómez-Conesa, & Marín-Martínez, 2008). Anholt and Kalanthroff (2014) published a similar opinion paper in *Clinical Neuropsychiatry* that further articulated their argument that OC-related beliefs were a consequence of executive dysfunctions – particularly those related to response inhibition, and that researchers should explore new avenues for OCD treatment. Finally, Mancini and Barcaccia (2014) rebutted arguments against cognitive models of OCD, and presented evidence suggesting that goals and beliefs are both necessary and sufficient to produce OCD symptoms, whereas cognitive deficits are neither. Although we focus primarily on the role of basic cognitive science, much of this research intersects with research on maladaptive beliefs. To this end, we wrote this paper with an eye to resolving some of the findings related to cognitive deficits (i.e., dysfunction in fundamental cognitive processes such as memory and executive functioning) vs. cognitive biases (i.e., beliefs or behavioural tendencies related to cognitive processes, such as a tendency to pay attention to threat, or a belief that one's memory is faulty).

2. Perception

Researchers have investigated whether the tendency for people with

¹ Concerns about manuscript length and other considerations led us to include only five specific areas. For example, we did not include interpretation bias research, because it borders basic cognitive science and belief-related research. However, such research, particularly interpretation training is certainly related to the covered areas, especially dual-systems models. We encourage readers interested in this area to refer to related manuscripts (Beadel, Ritchey, & Teachman, 2016; Beadel, Smyth, & Teachman, 2014; Clerkin & Teachman, 2011).

OCD to question their own senses (e.g., “I may have hit someone with my car”) is attributable to perceptual difficulties. Indeed, if somebody perceives things in a faulty manner, they may check their perceptions more frequently, worry about what they may have experienced, and consider themselves a danger to others, all characteristic of people with OCD. Research in this area has focused on three main topics: perceptual deficits, perceptual biases, and beliefs about perception.

2.1. Perceptual deficits

Researchers investigating OCD-relevant perceptual deficits have focused on several potential areas of dysfunction, and compared people with OCD to those without. For example, Kim et al. (2008) found that people with OCD demonstrated significantly lower abilities in biological motion detection and discrimination, but not coherent motion detection or global form perception. Shin et al. (2013) demonstrated that people with OCD were less accurate when indicating whether static body image pairs exhibited the same or different postures. Researchers recently investigated the role of situation awareness in OCD, and found that people with OCD were less accurate and slower to respond when asked to monitor the type, location, and direction of different creatures moving on a screen (Tumkaya et al., 2013). From these data, researchers have concluded that people with OCD may exhibit deficits in integrating complex sensory information, resulting in poor perception of OCD-relevant situations.

Researchers have also focused on potential deficits in facial emotion recognition among people with OCD (e.g., Sprengelmeyer et al., 1997). The bulk of this research focuses on disgust recognition, given that people with OCD report greater disgust sensitivity (e.g., Olatunji, Lohr, Sawchuk, & Tolin, 2007); however, several studies assessed deficits in general facial emotion recognition (see Daros, Zakzanis, & Rector, 2014). Researchers typically assess facial emotion recognition by presenting participants with a series of emotional faces, and measuring their accuracy at identifying each expression (e.g., anger, sadness, disgust.). Some studies also use morphed faces (i.e., two emotions in a single face) either as filler stimuli to increase task difficulty (e.g., Corcoran, Woody, & Tolin, 2008), or to evaluate recognition accuracy for ambiguous faces (e.g., Sprengelmeyer et al., 1997). Results have been mixed, with some studies identifying significant deficits in disgust recognition (e.g., Sprengelmeyer et al., 1997), some showing no differences in disgust recognition (e.g., Bozikas et al., 2009), some demonstrating deficits, but only among certain subsets of people with OCD (Corcoran et al., 2008), and others demonstrating a perceptual bias for disgust in ambiguous faces (Jhung et al., 2010).

A recent meta-analysis (Daros et al., 2014) demonstrated that people with OCD generally show reduced recognition of facial expressions overall and negative facial expressions specifically, compared to people without OCD, with the greatest effects for disgust and anger. Further, they found that approximately 40% of people with OCD demonstrated significant disruptions in facial emotion recognition, suggesting that these deficits may be relevant only for a subset of people with OCD. They found no relationships between age, gender, OCD severity, depressed mood, or stimulus set used and recognition accuracy for overall, anger, or disgust expressions (Daros et al., 2014), and one large association between self-reported obsessional thoughts and poorer recognition accuracy for angry (but not disgust or overall) faces. However, this meta-analysis included only 10 studies, and many of these studies suffered from small sample sizes, resulting in a total sample size of 221 people with OCD and 224 people without OCD. Moreover, the authors provided separate estimates for static vs. morphed images; many of the between-groups effect sizes were significant for the static images only (4–7 studies per emotion), further reducing the sample size upon which the estimates were based, and calling into question the reliability of the quantitative analysis results.

Researchers have put forth a variety of hypotheses to explain why such deficits may exist, ranging from disruption of neural pathways

important for recognizing disgust (e.g., Daros et al., 2014; Husted, Shapira, & Goodman, 2006), impaired learning of links between disgust cues and facial expressions because of early onset of OCD (e.g., Sprengelmeyer et al., 1997), and increased anger expression in families where one member struggles with OCD (e.g., Daros et al., 2014). What remains unclear, however, is whether and how such deficits play a role in either the development or maintenance of OCD.

Although these findings continue to implicate disgust sensitivity as a potentially important treatment target, they offer no evidence to suggest that reducing disgust-related perceptual biases could lead to improved OCD symptoms. The lack of a theoretically-plausible rationale for the causal or perpetuating role of such deficits suggests that the observed reduced facial recognition accuracy likely represents a correlate of OCD symptoms, rather than a factor important to treatment. Indeed, these differences may reflect difficulty making decisions among people with OCD when tasked with the symptom-relevant job of deciding whether a disgust expression is present.

2.2. Perceptual biases

Although some researchers look to deficit models to explain psychopathology, many look in the opposite direction: to cognitive biases. If people with OCD perceive things differently than people without, could this tendency result from distorted beliefs, rather than from a specific dysfunction in information processing? Moritz, Alpers et al. (2011) demonstrated that people with OCD (but not those without) overestimated the size of cleaning- and checking-related items, but not neutral or general fear-related items. They also overestimated the size of items perceived as OCD-relevant, and underestimated the size of items perceived as non-OCD-relevant. In other words, it appears that their perceptual *abilities* were intact (i.e., no deficit), given that they perceived the size of many stimuli similarly to people without OCD. Rather, they demonstrated a perceptual *bias*, wherein they appeared to perceive OCD-related stimuli as more dangerous or threatening than they really were.

2.3. Perceptual uncertainty

Researchers have also investigated whether beliefs about perception contribute to OCD symptoms – particularly checking. Following up on research about memory distrust (see Memory section), Hermans et al. (2008) found evidence for reduced confidence among people with OCD in their perception for a checking task (i.e., scored low on questionnaire items such as “What I have seen, is reliable”, *p.* 103). Researchers then investigated whether prolonged staring (a compulsive behaviour similar to repeated checking) could induce perceptual uncertainty. In one study, (van den Hout, Engelhard, de Boer, du Bois, & Dek, 2008), undergraduate students stared perseveratively at either a lamp or a stove-top, and then looked at either the same stimulus (i.e., relevant condition) or the other stimulus (irrelevant condition) for 10 s. They then reported their confidence in their perception of the final stimulus. Participants in both conditions reported elevated dissociation and perceptual uncertainty; however, the effect for perceptual uncertainty was stronger for the relevant condition than for the irrelevant condition. Moreover, there may be a dose-response relationship between staring duration and degree of uncertainty (maximal effect achieved in 5-min staring condition), 50% of this effect was obtained after only 15 s of staring, and over 80% was obtained after only 30s of staring (van den Hout et al., 2009). These findings suggest that even brief perseverative visual checking may contribute to perceptual uncertainty. Although not yet tested, it is plausible that this perceptual uncertainty then contributes to increased perseverative staring with the goal of ensuring a door is locked, stove is turned off, etc. Giele et al. (2016) suggest that perseverating (e.g., repeating the same word over and over) may lead to semantic satiation, wherein the meaning of the perseverated stimulus is not properly processed, leading to feelings of fuzziness, unreality, and

uncertainty. More research is needed to test this hypothesis.

2.4. Summary

The majority of studies related to perception have been conducted with respect to perceptual deficits. Indeed, there is reason to believe that at least a subset of people with OCD demonstrate deficits in processing facial emotion cues, particularly disgust. However, it is unclear how these and other perceptual deficits cause or perpetuate OCD symptoms. Emerging research suggests that both perceptual biases and beliefs about perception (linked to a form of checking behaviour) may play an important role in maintaining OCD symptoms, but replication and investigation of these factors is warranted.

3. Attention

Anxiety researchers have emphasized the role of attention bias in the development, maintenance, and treatment of anxiety disorders over the last several decades (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). Indeed, many paradigms have been developed to measure biases across different components of attention, to different types of stimuli, at different presentation durations, and within different research designs. For example, participants completing the dot-probe paradigm (MacLeod, Mathews, & Tata, 1986) identify (or localize) a probe appearing on a computer screen on the same side as a preceding stimulus within a pair of stimuli (typically threat vs. neutral); faster reaction times to targets appearing in the previous location of threatening stimuli are inferred as bias towards that stimulus type. For the more recent Attentional Blink Paradigm, participants detect a particular target in a rapid serial visual presentation of items. Researchers infer attention bias when a task-irrelevant stimulus (e.g., dirty toilet) in the stream impairs detection of the target later in the stream – i.e., an attentional blink results in a missed target (see McHugo, Olatunji, & Zald, 2013; for a detailed review). As such, researchers can detect individual differences in duration of attentional blink by manipulating the duration between the emotional distractor and the target.

Several reviews and meta-analyses have provided evidence for the consistent finding that people with elevated trait and/or state anxiety pay greater attention to threatening stimuli in their environment (Bar-Haim et al., 2007; Cisler, Bacon, & Williams, 2009). However, findings related to OCD have been equivocal at best. A recent review of studies highlighted that 71% of studies (prior to May 2011) investigating the causal role of attention bias in people with subclinical and clinical OCD (7 OCD-related experiments were included) reported null or opposite effects to hypotheses, and 29% reported mixed or inconsistent findings (Van Bockstaele et al., 2014).

3.1. Components of attention

An important distinction within this literature pertains to the *component* of attention that evidences bias. Whereas some researchers focus on initial (facilitated) orientation to threat, others point to difficulty disengaging or looking away from threat (for reviews, see Cisler & Koster, 2010; Ouimet, Gawronski, & Dozois, 2009). According to Derryberry and Reed (2002), attentional control moderates the ability to disengage from threat-relevant stimuli, such that people with anxiety and poor attentional control have the greatest difficulty looking away from salient stimuli. Moreover, the *type* of stimuli used may impact whether or not attention biases or impaired attentional control emerge. Using a rapid serial visual presentation task, Olatunji, Ciesielski, and Zald (2011) demonstrated that compared to a non-clinical control group, people with OCD showed reduced detection of a target 800 ms following an erotic distractor, suggesting difficulty disengaging attention from the erotic material. There were no differences for fear, disgust, or neutral stimuli, nor were there differences for any stimuli

200 ms following the distractors (i.e., no facilitated orientation). The authors suggested first, that these findings were attributable to greater difficulties initiating top-down regulatory processes to control attention among people with OCD, and second, that core tenets of cognitive-behavioural models of OCD such as inflated responsibility for harm, fear of committing bad behaviour, and guilt explained the specificity of the bias to erotic stimuli (Olatunji et al., 2011).

3.2. Attention bias specificity

To account for idiosyncrasy of OCD concerns, Morein-Zamir et al. (2013; Study 1) asked participants with OCD to rate a series of OCD-relevant images according to their unpleasantness, and then individualized a visual search task for each participant. Although they demonstrated difficulties disengaging from threat, their performance did not differ from people without OCD. In Study 2, participants completed the visual search task prior to rating the stimuli; again, both groups demonstrated difficulties disengaging from the threatening stimuli (compared to disengaging from positive stimuli), suggesting first, that people with OCD may not demonstrate greater threat-relevant attentional biases than the rest of the population, and second, that increasing personal relevance of the stimuli does not increase the likelihood of detecting such a bias (Morein-Zamir et al., 2013).

Charash and McKay (2002) demonstrated, using an emotional Stroop paradigm, that undergraduate students primed with disgust stimuli displayed attentional biases for disgust, which correlated with self-reported disgust sensitivity. Similarly, difficulties in disengaging from disgust-relevant stimuli emerged only for high disgust-prone undergraduate students on a rapid serial visual presentation task (Cisler, Olatunji, Lohr, & Williams, 2009). Moreover, disgust has been associated with contamination fear in particular (e.g., Olatunji et al., 2007), leading some researchers to investigate whether attentional biases for disgust are more important than those for fear among people with contamination fear. Cisler and Olatunji (2010) demonstrated that undergraduate students with high contamination fear were slower to disengage from fear- and disgust-related stimuli on a spatial cueing task, than those with low contamination fear. Similarly, high contamination-fearful undergraduate students dwelled longer on disgusted and fearful faces than on neutral faces on an eye-tracking task—suggesting impaired disengagement—than did low contamination-fearful students (Armstrong, Olatunji, Sarawgi, & Simmons, 2010).²

However, a recent meta-analysis reported no effect of content specificity (Pergamin-Hight, Naim, Bakermans-Kranenburg, van IJzendoorn, & Bar-Haim, 2015); people with OCD do not show a greater attention bias for OCD-stimuli than for non-OCD-related stimuli. Taken together, the body of research suggests that although people with OCD at times display difficulty disengaging from threat-relevant stimuli, this finding is inconsistent, and does not relate to type of threatening stimulus. Perhaps most telling is research investigating attentional bias in a more ecologically-valid environment. Bucarelli and Purdon (2016) asked people with OCD, and anxious control participants, to complete a stove-checking task while wearing an eye-tracker. They found no differences between groups in gaze duration on the stove, and less attention to threat items (i.e., fire hazards) among people with OCD compared to people without OCD. Moreover, attention to these items was unrelated to other important variables such as responsibility for harm and memory confidence among people with OCD, calling into question the theory that attentional bias to OCD-related threat plays an important role in the development and maintenance of OCD.

² These researchers also reported a group X stimulus type interaction for initial orientation as measured by first fixation. However, given evidence that first fixation is an unreliable indicator of attention bias (Waechter, Nelson, Wright, Hyatt, & Oakman, 2014), we did not include this finding in our review.

3.3. Moderators of attention bias

There is some evidence that factors associated with OCD may impact attention bias. Inflated responsibility for harm is a core belief that contributes to the development and maintenance of OCD (Rachman, 2002). Choi and Lee (2015) tested whether manipulating amount of responsibility via a pill sorting task would impact attentional bias in undergraduate students low and high in self-reported checking behaviour. Using eye-tracking, they found that whereas people low in checking spent similar amounts of time looking at OCD-relevant words on a viewing task under conditions of low and high responsibility, people high in checking gazed longer at OCD-relevant words under conditions of high responsibility than low responsibility. Indeed, under conditions of low responsibility, there were no differences in gaze duration between people with low and high checking behaviour. In other words, the attentional bias among people with high checking emerged only under conditions of high responsibility.

Moreover, researchers (Schneier et al., 2016) recently looked not only at attention bias (i.e., the degree to which people look at threatening vs. non-threatening stimuli), but also at attention bias variability (ABV) – the degree to which people's attention to particular types of stimuli is consistent across trials (Iacoviello et al., 2014; Price et al., 2015). They found no evidence of attention bias for angry faces among people with OCD; however, people with OCD demonstrated significantly lower ABV than healthy control participants. In other words, their tendency to attend to and/or avoid angry and neutral faces was more consistent across trials. There are two plausible explanations for this finding. First, as suggested by Schneier et al. (2016), people with OCD may work harder and more diligently on the task to both respond more quickly and make fewer errors, consistent with their tendency to exhibit higher levels of perfectionism (Pinto et al., 2017). Second, ABV may actually reflect *greater* attentional control (Iacoviello et al., 2014).

Although this latter interpretation appears to conflict with research suggesting attentional control impairments among people with OCD (e.g., Olatunji et al., 2011), Schneier et al. (2016) also found that attentional control (ABV) worsened as symptom severity increased. Given the increased reliability of ABV compared to attention bias (Price et al., 2015), more research exploring its role in OCD is warranted. Moreover, research has generally focused on different components of attention bias (e.g., orientation vs. engagement) rather than on underlying processes that may drive such biases and/or contexts that facilitate the observation of particular types of biases (Armstrong & Olatunji, 2012); research aimed in these latter directions may be more fruitful in understanding the role of attention in OCD.

3.4. Beliefs about attention

Finally, research has pointed towards beliefs about attention as relevant to checking behaviour. Hermans, Martens, De Cort, Pieters, and Eelen (2003) found that people with OCD reported less confidence in their ability to keep their attention focused during a reality monitoring task (see Executive Functioning section) than did people without an anxiety disorder. This outcome was based on two items of the *Cognitive Confidence* subscale of the Meta-Cognitions Questionnaire (Cartwright-Hatton & Wells, 1997). Hermans et al. (2008) extended these findings by demonstrating that in a regression including all the Meta-Cognitions Questionnaire subscales, only cognitive confidence predicted checking. In a second regression where they divided the cognitive confidence items into pre-determined scales of *general confidence in memory*, *reality monitoring confidence*, and *confidence in keeping attentional focus*, only the latter continued to predict checking behaviour. Further, a repeated checking manipulation led to increased mistrust in attention, which was replicated at a trend-level by Dek, van den Hout, Giele, and Engelhard (2010).

3.5. Attention bias modification

Research on attention bias in anxiety disorders has evolved naturally and steadily from describing phenomenology (e.g., Thorpe & Salkovskis, 1998), examining its causal role (Mathews & MacLeod, 2002), and testing its potential as a treatment technique (e.g., Neubauer et al., 2013). Indeed, this latter focus appears to hold the greatest potential for directly applying clinical science to OCD treatment.

The literature on cognitive bias modification for attention (CBM-A) and interpretation (CBM-I) has proliferated, resulting in multiple reviews and meta-analyses (e.g., Bar-Haim, 2010; Cristea, Kok, & Cuijpers, 2015; Hakamata et al., 2010; Mogg, Waters, & Bradley, 2017), offering variable conclusions. The more recent and rigorous meta-analyses generally contend that the effects of CBM-A on anxiety symptoms and threat-related attention are small to potentially non-existent (Cristea et al., 2015; Heeren, Mogoşă, Philippot, & McNally, 2015; Mogg et al., 2017; Mogoşă, David, & Koster, 2014), and highlight low-quality studies, file-drawer effects, and methodological variability as key limitations. MacLeod and Clarke (2015) reported, however, that most trials wherein researchers successfully modified attention resulted in decreased anxiety. There is a notable paucity of research related to CBM-A and OCD.

We identified only three studies testing the effect of CBM-A on OCD-relevant symptoms and/or behaviour (Amir, Kuckertz, Najmi, & Conley, 2015; Najmi & Amir, 2010; Riemann, Kuckertz, Rozenman, Weersing, & Amir, 2013); all from the same research group. Najmi and Amir (2010) found that, compared to participants in the control condition, undergraduate students with high contamination/cleaning concerns who completed a paradigm training attention away from contamination-related words on a dot-probe task demonstrated a significant decrease in attentional bias from baseline. There was no difference between groups on self-reported state anxiety either post-training, or during a Behavioural Approach Test. Participants in the CBM-A condition completed significantly more steps towards contaminants than did participants in the control condition. Change in attention bias mediated the relationship between experimental condition and steps on the Behavioural Approach Test, suggesting it played an important role in this finding. Riemann et al. (2013) found that adolescents receiving cognitive behavioural therapy within a residential anxiety treatment program, the majority of whom were diagnosed with primary OCD, experienced greater post-treatment decreases in self-reported anxiety and OCD symptoms when they also received CBM-A (towards neutral and away from disgusted faces). Finally, Amir et al. (2015) tested whether a series of personalized cognitive bias modification paradigms could improve the effect of self-directed Exposure and Response Prevention for OCD programs. Participants' symptoms improved following the program as a whole; however, there was no evidence that CBM-A specifically exerted an effect on symptoms or exposure outcomes.

Taken together, these findings suggest that CBM-A may be a useful adjunct to cognitive behavioural therapy. However, it would be unethical to suggest incorporating CBM-A into cognitive behavioural therapy at this time, as only one study produced effects suggesting that symptoms changed as a result of CBM-A. Moreover, they all used different stimuli, paradigms, and outcome variables. Before one might recommend that CBM-A be added to cognitive behavioural therapy, a number of experimental and trial-focused studies are required.

3.6. Summary

Researchers have conducted several studies investigating the role of attention bias in OCD. Although meta-analytic findings suggest minimal influence of attention bias on OCD symptoms, research examining potential moderators suggests that OCD-relevant beliefs (e.g., inflated responsibility for harm, low confidence in attentional focus) may increase the degree of bias an individual demonstrates. Moreover,

attentional control may play a particularly important role, though more research is warranted in this area. Although attentional bias modification paradigms have demonstrated some promise, the studies related to OCD of which we are aware have been conducted by the same research group, highlighting the need for replication by independent research groups, and have not clearly demonstrated the specific role of attention bias modification in reducing symptoms, limiting the applicability of this research to clinical practice at this time.

4. Memory

Given that one common manifestation of OCD is compulsive checking, researchers have explored extensively whether deficits in memory may explain such behaviour. For example, is it possible that the reason why individuals with OCD engage in so much checking is that they simply cannot properly remember their previous check? The research on memory and OCD is extensive and complex, and examines many different aspects of memory, using a wide array of research designs and techniques. For systematic reviews and meta-analyses, see Muller and Roberts (2005) and Harkin and Kessler (2011).

Memory can be divided into many different subtypes – semantic, episodic, procedural (Tulving, 1972), memory for various stimuli such as actions, non-verbal or verbal stimuli, as well as the ability to distinguish memories for imagined events from actual events, a process known as reality monitoring (Johnson & Raye, 1981). The components of memory that have been most extensively studied within the context of OCD include visual and verbal memory, as well as reality monitoring and memory for actions. Many studies have also explored the role of memory confidence and other meta-memory factors.

4.1. Memory for actions and reality monitoring

Given the frequent urge to repeat actions (e.g., checking, washing) in OCD, researchers have investigated whether people with OCD exhibit a deficit in memory for actions. Relatedly, the rationale for examining reality monitoring in OCD is that people with OCD may engage in repetitive behaviours because they have problems distinguishing whether they performed the action or imagined performing it. In studies investigating reality monitoring, participants typically perform a list of actions, or imagine performing the actions. After a delay, participants complete a free recall or recognition test and indicate whether they performed or imagined each action. A few early studies investigating participants reporting high levels of checking behaviour found that they recalled fewer actions compared to non-checkers and evidenced recall deficits for whether they imagined or performed an action (e.g., Rubenstein, Peynircioglu, Chambless, & Pigott, 1993).

Ecker and Engelkamp (1995) found that participants with OCD exhibited lower reality monitoring for imagined vs. performed actions compared to a low checking (but not high checking) control group. Many other studies have found no deficits in reality monitoring in individuals with OCD compared to individuals without OCD (e.g., Hermans et al., 2003; McNally & Kohlbeck, 1993; Merckelbach & Wessel, 2000; Moritz, Ruhe, Jelinek, & Naber, 2009). In most of these studies, participants with and without OCD were equivalent with regard to the total number of actions recalled or recognized (Hermans et al., 2003; McNally & Kohlbeck, 1993; Moritz, Ruhe, et al., 2009). Thus, the bulk of the evidence from clinical samples suggests that people with OCD do not exhibit deficits in memory for actions, nor in reality monitoring.

4.2. Nonverbal memory

Nonverbal memory refers to the ability to recall or recognize non-verbal, often visual, information. Researchers often use standardized neuropsychological tests, such as the Rey-Osterrieth Complex Figure Test (Osterrieth, 1944) to assess for nonverbal memory. For example,

the Rey-Osterrieth Complex Figure Test consists of an abstract figure that participants must first learn and copy. After a short and long delay, participants recreate the image from memory.

Since one of the symptoms of OCD involves repetitive behaviour, most research examining nonverbal memory has focused on immediate memory. Several studies have found that individuals with OCD exhibit lower nonverbal immediate recall (e.g., Aronowitz et al., 1994a; Penadés, Catalán, Andrés, Salamero, & Gastó, 2005; Savage et al., 1999; Tallis, Pratt, & Jamani, 1999) and nonverbal working memory performance (Jaafari et al., 2013) compared to healthy and anxious control participants; though some studies have failed to find such a difference for immediate nonverbal recall (e.g., Bohne et al., 2005; Christensen, Kim, Dysken, & Maxwell Hoover, 1992). Some studies have found evidence of delayed nonverbal memory deficits (e.g., Christensen et al., 1992; Savage et al., 1999; Tallis et al., 1999), however, others have not (e.g., Moritz, Kloss, von Eckstaedt, & Jelinek, 2009).

4.3. Verbal memory

Verbal memory refers to the ability to recall or recognize verbally presented material such as words or sentences. Researchers have studied verbal memory in OCD using a range of tasks including standardized tests of verbal memory such as the California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1987), simple word lists, and word lists containing threat-relevant material (e.g., germs). Most studies examining verbal memory have failed to find deficits in individuals with OCD (e.g., Christensen et al., 1992; Macdonald, Antony, Macleod, & Richter, 1997), though some have found such evidence (e.g., Jaafari et al., 2013; Savage et al., 2000). For example, Savage et al. (2000) found that participants with OCD demonstrated lower overall learning on the California Verbal Learning Test but no deficits in retention compared to non-anxious control participants. Thus, research assessing general memory provides evidence for nonverbal memory deficits, and some evidence for verbal memory deficits, though findings are inconsistent. However, several studies using ecologically-relevant threat stimuli rather than standardized neuropsychological tests found no deficits in memory (e.g., Radomsky, Rachman, & Hammond, 2001), and some have even found evidence for enhanced memory in OCD (e.g., Radomsky & Rachman, 1999). These findings call into question the general memory deficit hypothesis.

One prevailing theory for the observed memory deficits is that they are due to poor organizational strategies used by people with OCD. Indeed, deficits in performance on the Rey-Osterrieth Complex Figure Test have been explained by poor organization strategies used during the copy portion of the task where encoding takes place (Savage et al., 1999, 2000). Additionally, researchers demonstrated that people with OCD use fewer semantic clustering strategies—potentially more effective than serial clustering—on the California Verbal Learning Test than people without OCD (Savage et al., 2000). The authors found that use of these less efficient strategies mediated the relationship between OCD and visual and verbal memory (Savage et al., 2000). However, not all researchers have found organizational strategy deficits in OCD (e.g., Bohne et al., 2005).

Researchers have demonstrated that cognitive training aimed at improving organizational strategies not only improves use of such strategies, but also improves memory in participants with OCD (e.g., Park et al., 2006). In one study, this training also improved self-reported OCD symptoms compared to a no-training control group (Park et al., 2006). However, to the best of our knowledge, this training has not been compared to existing evidence-based treatments.

Another recent hypothesis is that people with OCD are not impaired in their memory performance, but rather some of the symptoms—specifically thought monitoring—may cause these impairments. Participants with and without OCD monitored either OCD-relevant or neutral thoughts while completing a verbal test; participants in the control condition completed the test without thought monitoring (Fink

et al., 2017). Regardless of OCD status, performance on the verbal task declined when attention was divided (i.e., when completing the thought monitoring task). Among participants with OCD, performance was particularly affected during the OCD relevant thought monitoring task. Thus, memory deficits in OCD, if they exist, may be secondary to some of the core symptoms of OCD rather than a causal factor.

4.4. Memory research using ecologically relevant materials

Some researchers have also argued that inconsistency in research findings on memory and OCD are due primarily to the type of stimuli used. Radomsky and Rachman (2004) argued that to really understand memory functioning in OCD, researchers must use material that is personally significant for individuals with OCD. Indeed, cognitive behavioural models (Rachman, 1997; Salkovskis, 1985) focus on beliefs that are important in the context of OCD, rather than cognitive functioning, per se.

4.5. Visual and verbal memory for threat-relevant material

Cognitive behavioural models of some subtypes of OCD (Rachman, 2004) have suggested that people with OCD will evidence enhanced memory, but only for material perceived as threatening or dangerous (i.e., memory bias). Researchers investigating this hypothesis present participants with stimuli that are threatening, neutral, and also sometimes non-threatening, and then ask participants to recall or recognize the objects.

In one of the first studies to examine memory bias in OCD, participants with contamination OCD and healthy control participants heard sentences that either did or did not contain OCD-related content (Foa, Amir, Gershuny, Molnar, & Kozak, 1997). Participants later completed a recognition task to assess explicit memory. Both people with and without OCD recognized more neutral than threat sentences; there were no differences in ratings of confidence in their recognition memory. Although this study failed to find evidence of a memory bias for threat, it also failed to find evidence for memory deficits.

Several subsequent studies have explored memory bias for threat in OCD, several of which have found at least some evidence for a threat-relevant memory bias (Ceschi, Van der Linden, Dunker, Perroud, & Brédart, 2003; Radomsky et al., 2001; Radomsky & Rachman, 1999; Tolin, Hamlin, & Foa, 2002). Tolin et al. (2002) found that participants with OCD were more accurate in recalling OCD-relevant words than non-anxious and anxious control participants. Radomsky and Rachman (1999) asked participants with OCD, anxious, and non-anxious participants to view clean or dirty objects. After a delay, participants with OCD remembered more dirty than clean objects. Ceschi et al. (2003) failed to replicate this enhanced explicit memory bias for threat in OCD, though in their study, participants with OCD were more accurate in recalling which objects were dirty. At least one other study failed to find enhanced memory for threat in OCD (Tolin et al., 2001) and one study found lower free recall and recognition in participants with OCD for both neutral and threat words compared to participants without OCD or another anxiety disorder (Tuna, Tekcan, & Topçuoğlu, 2005). In summary, the evidence supporting a memory bias for threat in OCD is also equivocal; however, most of these studies suggest that when the material to be remembered is relevant to OCD, there is very little evidence of a memory deficit.

4.6. Beliefs about memory

In many of the studies mentioned above, participants with OCD were less confident in their memory, even when memory performance was intact (Hermans et al., 2003; Merckelbach & Wessel, 2000), though this was not the case universally (Tallis et al., 1999). van den Hout and Kindt (2003) hypothesized that repeated checking may explain this low confidence by increasing the familiarity of the specific situation,

resulting in decreased perceptual processing and consequently less vivid and detailed memory. This reduced detailed memory leads to decrements in memory confidence. To test this hypothesis, they examined the effects of repeated checking on memory confidence, vividness, and detail in a non-clinical sample. Using a virtual stove and faucet, participants first completed a single check of 6 stove knobs. They then reported the vividness and detail of their memory for the check. Participants then engaged either in repeated relevant checking (i.e., 20 trials of checking the stove knobs) or irrelevant checking (i.e., 20 trials of checking a faucet). Participants once again completed a single check of the stove knob. The researchers found that though accuracy for the check did not change, participants in the relevant checking condition reported decreased confidence, vividness, and detail in their memory for that last check, whereas these memory features were unaffected in the irrelevant checking condition. Numerous studies using a similar paradigm have replicated these results following repeated checking in both undergraduate students and in participants with OCD (e.g., Ashbaugh & Radomsky, 2007; Boschen & Vuksanovic, 2007; Dek et al., 2010; Radomsky, Dugas, Alcolado, & Lavoie, 2014). A few studies have found small declines in memory accuracy as well as confidence (Dek et al., 2010; Radomsky et al., 2014), though most studies have found memory accuracy to be unaffected (e.g., Boschen & Vuksanovic, 2007; van den Hout & Kindt, 2003). Consistent with the hypothesis that the act of checking, and not the threat relevance of the item being checked leads to reduced memory confidence, declines in memory confidence have been observed not only for checking potentially dangerous items (e.g., stove knobs) but also more benign items (e.g., faucets) (Dek et al., 2010).

4.7. Impact of beliefs on memory confidence

Beliefs associated with OCD, specifically inflated responsibility for harm, also appear to impact memory confidence. Boschen and Vuksanovic (2007) asked participants with and without OCD to complete the stove checking experiment under conditions of high or low responsibility. Repeated relevant checking resulted in decreased memory confidence but not accuracy. Additionally, participants with OCD in the high responsibility condition showed further declines in memory confidence. Conditions of high responsibility, however, do not always result in declines in memory confidence; memory confidence may be affected not only by the act of repeated checking, but also by beliefs. Moritz et al. (2007) asked participants to learn a shopping list under conditions of high (i.e., items for a town in need) or low (i.e., shopping list) responsibility. They later asked participants to recognize items on the list. The responsibility manipulation on its own did not affect memory accuracy for the list in participants with or without OCD. However, under conditions of high responsibility, participants with OCD expressed more doubt in their answers. Moritz and Jaeger (2017), however, found no memory confidence decline with high levels of responsibility; rather, participants with OCD expressed lower memory confidence regardless of responsibility level.

Even without engaging in repeated checking, beliefs about one's memory may influence repeated checking. In one study (Alcolado & Radomsky, 2011), undergraduate participants completed the Wechsler Memory Scale Revised. The researchers then provided false feedback, such that participants were told their memory scores fell within either the 35th–40th percentile (low memory confidence condition) or in the 85th–90th percentile (high memory confidence condition). Participants then completed two memory tasks. For both tasks, participants in the low memory confidence condition reported greater urges to check their answers compared to participants in the high memory confidence condition, suggesting that beliefs about memory contribute to repeated checking. Consistent with this notion, researchers recently developed a measure of trait beliefs related to cognitive performance, the Memory and Cognitive Confidence Scale (Nedeljkovic & Kyrios, 2007). Scores on this scale differentiate between those with and without OCD, correlate

with OCD symptom severity, and predict OCD symptomatology incrementally to self-reported anxiety, depression, and beliefs commonly associated with OCD, such as inflated responsibility.

4.8. Summary

Research on the various domains of memory suggests that deficits in the ability to remember information is at best inconsistent in individuals with OCD. However, reduced confidence in memory and doubts about memory appear to be robust. It is therefore surprising that little research has examined whether modifying beliefs about memory confidence could be a potential target for treatment in OCD. One study did find that psychoeducation and behavioural experiments targeting beliefs in memory did improve checking symptoms (Alcolado & Radomsky, 2016). Further systematic research on this method as a potential intervention is warranted.

5. Executive Functioning

Executive functioning is a set of cognitive processes that allow a person to engage in goal-directed, future-oriented behaviour, and involves various parts of the prefrontal cortex, as well as networks linking subcortical areas, such as the basal ganglia to cortical areas (Suchy, 2009). Given research suggesting that OCD is characterized by problems in these brain regions (Saxena, Bota, & Brody, 2001; but see Whiteside, Port, & Abramowitz, 2004), research has focused on executive functioning in OCD. Such studies tend to rely upon basic neuropsychological tests to isolate specific executive functions and explore the impact of executive dysfunction (i.e., deficits) on complex cognitive processes, such as problem-solving and decision making.

Researchers have studied executive functioning within the context of OCD using a wide variety of neuropsychological tests purporting to measure specific components of executive functioning (see Suchy, 2009 for reviews of assessment procedures). Processes that have traditionally been studied within the context of OCD include fluency, set-shifting, response inhibition, working memory, and decision making. We first explore research that examines basic executive functioning process in OCD and then discuss the impact that any deficits may have on more complex cognitive operations in OCD.

5.1. Fluency

Fluency refers to the ability to generate multiple exemplars from a given category. Verbal fluency tasks include generating words for a given category (e.g., animals). Non-verbal fluency tasks ask participants to generate spatial designs. Most studies in OCD have found no performance deficits relative to anxious (Bannon, Gonsalvez, Croft, & Boyce, 2006) or healthy control participants (e.g., Whitney, Fastenau, Evans, & Lysaker, 2004). Christensen et al. (1992) found verbal fluency deficits, and Moritz et al. (2002) found creative verbal fluency deficits, relative to participants without a psychological disorder. Performance by OCD participants in Moritz et al. (2002) was similar to those with depression or schizophrenia, suggesting a lack of specificity.

5.2. Set-shifting

Set-shifting refers to the ability to shift attention towards different features of a stimulus set. Examples of tasks designed to measure set-shifting ability include the Wisconsin Card Sorting Task (WCST; Loong, 1990) and Trail Making B (Reitan, 1992). Given that one symptom of OCD is perseveration of a behaviour (e.g., repeated checking, washing), researchers have explored whether OCD is characterized by deficits in set-shifting.

On the Trail Making Test B, participants with OCD responded more slowly, though not necessarily less accurately compared to healthy control participants, though psychomotor speed may account for these

differences as participants with OCD were also found to be slower on the Trail Making Test A, a measure of psychomotor speed (e.g., Aronowitz et al., 1994a; Moritz et al., 2002; Moritz, Kloss, et al., 2009). Here again, it is plausible that people with OCD invest greater effort and have a higher need for accuracy, resulting in slower responses, likely representing increased perfectionism rather than an executive functioning deficit.

On the Wisconsin Card Sorting Task, participants with OCD exhibited more perseverative errors and completed fewer categories compared to healthy and anxious control participants (Bannon et al., 2006), though several other studies have failed to find such deficits in set-shifting using this task (e.g., Christensen et al., 1992; Moritz et al., 2002). Further complicating this issue, Bohne et al. (2005) found no deficits in errors/perseverative errors on the Wisconsin Card Sorting Task among participants with OCD relative to participants without OCD, but did find that participants with OCD showed less improvement in learning efficiency across categories. Furthermore, they observed no deficits in performance among OCD participants on a different measure of set-shifting, the Object Alternation Task. Thus, any potential deficits in this area are small and inconsistent.

5.3. Response inhibition

Response inhibition is measured in tasks in which an automatic response needs to be inhibited. Examples of tasks that assess response inhibition include the Stroop task (Golden & Freshwater, 2002) and the Go/No-Go task (Fox, Michie, Wynne, & Maybery, 2000). Most studies have found evidence for deficits in response inhibition both on the Stroop task (e.g., Bannon et al., 2006; Penadés et al., 2005), a measure of cognitive inhibition, and the Go/No Go task (e.g., Bannon et al., 2006; Bannon, Gonsalvez, Croft, & Boyce, 2002), a measure of motor inhibition, though a few studies have failed to find a difference in performance of OCD participants relative to control participants on the Stroop task (Aronowitz et al., 1994; Moritz et al., 2002).

One study attempted to tease apart whether deficits observed on the Go/No Go and the Stroop tasks are a result of reduced ability to inhibit an automatic response or enhanced facilitation of an automatic response (Bannon, Gonsalvez, & Croft, 2008). These researchers included neutral, generally threatening, panic-related, or OCD-related stimuli to examine whether stimulus threat-relevance affects inhibition and/or facilitation in OCD. They asked participants to respond to the location of a target word. On facilitation trials participants respond to the same target word as the preceding trial; on inhibition trials, participants respond to a different target word than the preceding trial, though the same target word is present for both trials. Participants with OCD exhibited reduced response inhibition and enhanced facilitation compared to anxious and healthy control participants. The threat-relevance of the trials did not affect results, suggesting that the effects were unrelated to the schema or belief system of OCD participants.

5.4. Working memory

Working memory refers to the process of holding and manipulating information in memory to complete a task. For example, in the digit span task, people recite back, and at times reorganize according to a specific rule, an increasingly longer list of numbers. Once again, attempting to explain repetitive behaviours forms the rationale for studying a component of executive functioning – working memory. Several researchers have included measures of working memory in their test battery comparing performance of people with OCD to that of healthy and anxious participants (e.g., Bannon et al., 2006; Bohne et al., 2005). Findings are mixed, with about half the studies finding evidence for working memory deficits, most notably in nonverbal working memory (e.g., Aronowitz et al., 1994; Jaafari et al., 2013), and the others failing to find such deficits (e.g., Bannon et al., 2008). A recent study demonstrated that compared to participants without OCD, people

with OCD performed worse on a reading span and backwards location span task (Jaafari et al., 2013). Both tasks involved not only holding information in mind for a short period of time, but also manipulating that information. Performance on these tasks correlated significantly with performance on a drawing comparison task designed to elicit checking behaviour. People with OCD who exhibited slower comparisons and a larger number of gazes on the comparison task also evidenced poorer verbal and nonverbal working memory. These results suggest there may be a relationship between working memory ability and checking behaviour. However, as with most studies exploring executive functioning in OCD, results are correlational. Similar to general memory performance, divided attention as a result of thought monitoring may cause the observed decrements in working memory.

5.5. Decision making

Decision making refers to the ability to weigh evidence and select a response to maximize a goal. Though arguably a more complex task involving other executive functions (e.g., response inhibition, working memory), decision making is often categorized as an executive function. In the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994), participants select cards from four decks with the goal of winning as much money as possible. In two decks, winnings are large, but losses are even larger, whereas in the other deck winnings are small, but losses are even smaller. Thus, in the Iowa Gambling Task, the correct solution to achieve the goal of winning is to select cards from the decks where losses are small.

People with OCD often express doubt or distrust in their decision making as to whether a compulsive action was properly completed. Consistent with this tendency, people with OCD have reported elevated intolerance of uncertainty (OCCWG, 2005). Perhaps then, OCD is characterized by deficits in decision making processes. Surprisingly fewer studies have examined decision making in OCD. One study found that individuals with OCD and their first-degree relatives performed more poorly on the Iowa Gambling Task than individuals without OCD and their relatives, suggesting that deficits in decision making may be a heritable risk factor for OCD (Cavedini, Zorzi, Piccinni, Cavallini, & Bellodi, 2010). However, other studies, using a different gambling task have failed to find evidence of such deficits (Whitney et al., 2004).

Several recent models propose that doubt and difficulties in the decision making process are important to OCD (Lazarov, Dar, Oded, & Liberman, 2010; Nestadt et al., 2016; O'Connor, Aardema, & Pélissier, 2005; Wahl, Salkovskis, & Cotter, 2008). Each of these models highlights factors with regards to the type or amount of information required to make a decision, resulting in pervasive doubt and slowed response time in decision making across a range of tasks, including those relevant to OCD (e.g., “are my hands contaminated?”) and general neuropsychological tasks. They differ, however, in the source of the doubt. Nestadt et al. (2016) suggests that the threshold of required information in OCD is greater than the threshold of required information in people without OCD. Similarly, Wahl et al.'s (2008) elevated evidence requirement model posits that individuals with OCD, particularly under conditions of high responsibility, require more evidence, often including subjective judgements, to terminate repetitive behaviour compared to people without OCD. According to this model, all people can enter a state where more evidence is required, but the threshold of reaching that state is lower in people with OCD. Lazarov et al.'s (2010) seeking proxies for internal states model suggests that the type of information used to derive a decision is faulty. He contends that people with OCD have difficulty using internal states (e.g., perceptual, cognitive, affective, bodily state information) to derive a decision due to the inherent ambiguity of this information. As a result, they use external proxies, such as excessive hand washing or checking, to infer internal states that most individuals would use to terminate a behaviour. Finally, O'Connor's inferential confusion model suggests that individuals with OCD use faulty inductive reasoning strategies,

characterized by distrust of the senses and over-reliance on hypothetical possibilities (O'Connor, Aardema, & Pélissier, 2005). Though each model differs slightly in emphasis and are contradictory to some extent, all suggest that there is a deficiency in the decision-making process in people with OCD.

There is a body of research just emerging that seeks to test these theories. Consistent with Nestadt et al. (2016) model and the elevated evidence model (Wahl et al., 2008), individuals with OCD have higher decision thresholds than people without OCD, particularly under conditions of high uncertainty (Banca et al., 2015; Wahl et al., 2008). Under conditions of high (but not low) perceptual uncertainty, participants with OCD completing a perceptual discrimination task had a higher decision boundary and took more time to make decisions than non-clinical control participants (Banca et al., 2015). When participants were rewarded for faster response times and penalized for slower response times, differences between participants with and without OCD in the time taken to reach a decision were reduced without affecting performance accuracy in the OCD participants. These results suggest that decision making difficulties in people with OCD appear only when the information required to make the decision is unclear.

People with OCD may use different reasoning strategies than those without OCD. For example, compared to individuals with generalized anxiety disorder and non-anxious control participants, individuals with OCD demonstrated differences on some inductive and probabilistic reasoning tasks, but not deductive reasoning tasks (Pélissier & O'Connor, 2002). However, results may reflect slowed response and a need for certainty, as opposed to maladaptive reasoning strategies (Simpson, Cove, Fineberg, Msetfi, & Ball, 2007). Indeed, other researchers failed to find inductive reasoning deficits in OCD, and found differences in deductive reasoning strategies but only for neutral rather than emotional content (Simpson et al., 2007).

The type and amount of information necessary to make a decision may differentiate people with OCD from those without. Aardema, O'Connor, Pélissier, and Lavoie (2009) asked participants with and without OCD to estimate the probability of a negative outcome in either an OCD relevant or irrelevant situation. After estimating the probability, participants were then provided with additional information, some of which was reality-based (e.g., You look in the rear-view mirror and see a pothole on the road) and some of which was possibility-based (e.g., The pothole *may not* have been deep enough to cause the bump). They found that the possibility-based information had larger effects on outcome estimates in people with OCD compared to people without OCD. In a recent follow-up study, researchers disentangled the reality- and possibility-based information from the negative outcome, such that the reality-based information reflected safety instead of danger (e.g., You look in the rear-view mirror and do not see a pothole on the road) and the possibility-based information reflected danger instead of safety (e.g., The pothole may not be visible from the rear-view) (Gangemi, Mancini, & Dar, 2015). Using this paradigm, they found that individuals with and without OCD were influenced by the content of the information (e.g., safety or danger) rather than the type of information (e.g., reality- or possibility-based). It is unclear whether OCD is characterized by reasoning deficits. However, in non-clinical participants, if inductive reasoning is manipulated such that participants are asked to generate multiple explanations for an unlikely catastrophic outcome to a benign situation, the believability of the unlikely outcome increases compared to not generating multiple explanations (Giele, van den Hout, Engelhard, Dek, & Hofmeijer, 2011). Reasoning strategies may not be deficient per se, but under conditions of high threat, people with OCD may generate more explanations for the occurrence of their feared outcome, thereby enhancing their conviction that it will occur.

Several studies have examined whether the source of information available influences decision-making. Researchers explored the relative impact of internal versus external perceptual information in decision making in OCD. Woody and Szechtman (2005) demonstrated that non-clinical participants for whom the sense of satisfaction from washing

after being contaminated was eliminated exhibited more hand washing. Individuals with OCD report relying more on internal information (e.g., a feeling of just rightness) and less on external perceptual information (e.g., "is there still dirt on my hands?") compared to people without OCD (Wahl et al., 2008).

There is also evidence to suggest that individuals with OCD rely on external information as a proxy for their internal state (e.g., Lazarov, Dar, Liberman, & Oded, 2012). For example, participants were asked to tense their muscles to a certain level (Lazarov, Liberman, Hermesh, & Dar, 2014), under conditions of subjective feedback (e.g., physiological response) and external feedback related to their internal state (e.g., EMG biofeedback or false biofeedback). Participants with OCD were less accurate in producing the required muscle tension when they were not given feedback, were more likely to ask for the biofeedback, and were more influenced by the false feedback compared to healthy and anxious control participants. These results support the seeking proxies for internal states model; however, more research is needed to determine whether reliance on external proxies is specific to subjective internal states, as proposed by the model, and whether it extends to domains that are relevant to OCD (e.g., "are my hands contaminated?").

Here again, confidence in cognition may influence this maladaptive information selection strategy. Zhang et al. (2017) manipulated confidence in participants' ability to read their internal states using the same muscle tension experimental design described previously. They found that undergraduate student participants for whom confidence was undermined were more likely to use the external biofeedback information than those in a control condition.

To date, research findings suggest that individuals with OCD require more information in making decisions, want to use internal states of reference to reach a decision, however distrust their internal states and rely instead on idiosyncratic external stop rules. The findings, however, are at times contradictory. For example, some findings emphasize overreliance on external information (e.g., Lazarov et al., 2012), whereas others emphasize overreliance on internal information (e.g., Wahl et al., 2008). Furthermore, the degree of threat inherent in the problem appears to influence differences in decision making (e.g., Gangemi et al., 2015). Despite its complexity, this research is promising. Future studies should focus on exploring whether different decision making strategies are used in different states –the decision-making strategy used to conclude that danger is likely and prompts the compulsion may be different from the decision-making strategy used to determine when to stop the compulsion in OCD.

5.6. Summary

Research on lower-level executive functioning processes is inconsistent with regards to whether deficits are observed in people with OCD. Though early research was equivocal with regards to whether OCD is characterized by working memory deficits, recent correlational research suggests that such deficits may be related to checking behaviour specifically (Jaafari et al., 2013). Furthermore, there is mounting evidence that higher level executive functioning (e.g., decision making), which likely involves many lower order processes, may be deficient in OCD. It is not yet clear whether difficulties in decision making are a cause, consequence, or a cause *and* consequence of OCD; however, there appears to be some evidence that treatments targeting decision making strategies in OCD may be of benefit (e.g., O'Connor et al., 2005).

6. Dual-systems models of cognition and behaviour

Dual-systems models focus on the distinction and interplay between implicit and explicit systems (Strack & Deutsch, 2004). Researchers contend that implicit systems comprise concepts in memory that are activated relatively automatically, unconsciously, and rapidly via spreading activation. Explicit systems, however, function via relatively

controlled, conscious, and slower endorsement or invalidation of specific propositions. These systems operate in a feedback loop, such that automatically activated associations impact explicitly endorsed beliefs, and repeated explicit endorsement of beliefs strengthen associations. Researchers contend that identifying, measuring, and potentially targeting implicit beliefs directly may lead to improved treatment outcomes, given that current evidence-based treatments focus primarily on explicit processes and beliefs (Ouimet, Bahl, & Radomsky, 2016; Roefs et al., 2011).

Researchers also distinguish between implicit *cognition*, which refers to automatic associations between concepts (e.g., toilet-dangerous; Teachman & Woody, 2004) and automatic behavioural tendencies, which refer to rapid and likely uncontrollable approach or avoidance of various stimuli (e.g., Heuer, Rinck, & Becker, 2007), though they are both used as indicators of automatic associations. The most common tool used to assess implicit cognition is the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998), for which participants categorize stimuli quickly and accurately, but in different condition blocks. In consistent blocks, participants categorize stimulus type (e.g., contaminant vs. non-contaminant) and attributes (e.g., dangerous vs. safe) according to labels at the top of the screen. The labels for stimulus type and attribute are grouped together on the left and right sides of the screen depending on block. For consistent blocks, pairs are those that we expect to be stronger (e.g., germ-dirty); for inconsistent blocks, pairs are those that we expect to be weaker (e.g., germ-clean). Standardized calculation procedures (Greenwald, Nosek, & Banaji, 2003) compare response times on consistent and inconsistent blocks, resulting in an overall effect size for the degree to which participants associate, for example, germs, with dirtiness vs. cleanliness. For the Approach-Avoidance Task (Rinck & Becker, 2007), participants use a joystick to push and pull pictures away and towards them, based on a particular characteristic (e.g., colour of the picture frame). In reality, researchers measure the speed with which they approach (pull) or avoid (push) different types of stimuli (e.g., contamination-relevant vs. neutral) to assess their automatic behavioural tendencies. Recently, research using each of these paradigms has produced evidence that people with OCD may differ in some of their implicit and explicit beliefs from those without OCD.

6.1. Implicit beliefs in OCD

In two clever studies, Teachman and colleagues (Teachman & Clerkin, 2007; Teachman, Woody, & Magee, 2006) investigated the effects of manipulating undergraduate student participants' beliefs about their own intrusive thoughts on their implicit and explicit cognition. Teachman et al. (2006) asked participants to think about intrusive thoughts they had experienced, and then informed them either that their intrusive thoughts were meaningful and important, or meaningless and unimportant. The manipulation led to changes in people's implicit, but not explicit beliefs about the importance of thoughts. Moreover, people in the meaningful condition also showed greater implicit associations between themselves and dangerousness, but only if they also reported high baseline levels of obsessive-compulsive thoughts. Teachman and Clerkin (2007) found similar results when they manipulated the perceived morality of intrusive thoughts. Together, these findings suggest that people's explicit beliefs may make them more vulnerable to activation of problematic automatic associations.

Pirutinsky, Siev, and Rosmarin (2015) examined how implicit and explicit attitudes about God (e.g., as gracious vs. punishing) related to self-reported (i.e., explicit) scrupulosity—OCD-linked religious or moral fears—among a community sample of Jewish people who reported at least a moderate belief in God. They found that implicit and explicit attitudes each correlated uniquely with scrupulosity, suggesting that they exert differential effects. Moreover, they contributed additional variance in scrupulosity to each other, and also interacted, such that

people with the highest self-reported scrupulosity were those that exhibited strong negative attitudes about God, both implicitly and explicitly. Nicholson and Barnes-Holmes (2012) demonstrated that implicit disgust sensitivity and disgust propensity differentially predicted various outcomes, including avoidance on a Behavioural Approach Test, and self-reported washing, cleaning, and OC concerns. People with OCD showed stronger implicit shame associations with intrusive thoughts than did people with Body Dysmorphic Disorder or Social Anxiety Disorder, or no psychological disorder (Clerkin, Teachman, Smith, & Buhlmann, 2014). Finally, Najmi, Kuckertz, and Amir (2010) found that people with high contamination fear were slower to pull contamination-relevant stimuli than neutral stimuli on an Approach-Avoidance Task; no such difference emerged among people with low contamination fear, or for speed of pushing other types of stimuli in either group. Degree of pulling bias was related to self-reported OCD symptoms, suggesting that automatic behavioural tendencies may differ only when people need to inhibit their avoid response.

6.2. Differential predictive ability of implicit vs. explicit cognition

Measuring implicit attitudes is resource- and time-intensive. Although such measurement may give us important information regarding the phenomenology of OCD, these paradigms are clinically useful only to the degree that they provide information incremental to self-report questionnaires or clinical interviews. Implicit beliefs may be important to clinical practice if they predict cognitive, behavioural, or symptomatic outcomes differentially to explicit beliefs. Green and Teachman (2013) investigated the relationships between implicit and explicit contamination threat (i.e., threat overestimation) and diverse outcomes. They demonstrated that whereas explicit (but not implicit) measures predicted contamination symptoms and OC-related distress and thoughts during a Behavioural Approach Test, implicit (but not explicit) measures predicted behavioural avoidance.

Furthermore, researchers have investigated the effects of manipulating automatic associations and/or behavioural tendencies on diverse outcomes. Green and Teachman (2012) tried to manipulate associations among undergraduate participants with self-reported clinical levels of contamination fear by showing the participant's own smiling face or an approach-related word when they clicked on a picture of a contaminant (active condition). They observed no effect of this manipulation (compared to a control condition) on implicit associations, performance on a Behavioural Approach Test, or emotional vulnerability.

Amir, Kuckertz, and Najmi (2013), however, reported success at modifying an Approach-Avoidance Task to manipulate OCD-related automatic behavioural tendencies. At post-training, undergraduate students with high self-reported cleaning concerns in the active condition demonstrated reduced push and pull biases (for contamination pictures) compared to those in the control condition. Moreover, they completed significantly more steps on a Behavioural Approach Test, suggesting that the automatic approach may have made real-life approach easier. In a crucial test of this assertion, Amir et al. demonstrated that condition differences on the Behavioural Approach Test were mediated by post-manipulation pull bias. Weil, Feist, Moritz, and Wittekind (2017) extended these findings within a community sample of people with self-reported clinical levels of OCD symptoms who completed similar training at home, after completing baseline measures. People in the active condition (compared to wait-list control) evidenced reduced self-reported OCD symptoms and compulsions 4 weeks following the beginning of the online protocol. Symptom reduction was unrelated to the frequency with which participants reported completing the training. Moreover, the authors were unable to assess whether their automatic behavioural tendencies changed, and reported significant attrition prior to post-test, resulting in underpowered analyses.

6.3. Summary

Together, these findings suggest that people with OCD likely hold different implicit and explicit beliefs than those without, and that the two types of beliefs exert differential influences on cognitive, behavioural, and subjective outcomes. However, the research is limited, needs replication, and is not always consistent. Moreover, it's unclear whether changes in implicit associations lead to symptom reduction, nor what is the best way to achieve such changes should they prove to be an important treatment target. Indeed, cognitive behavioural therapy for OCD may accomplish such changes secondary to explicit belief change, particularly if interventions include behavioural experiments that allow clients to approach feared stimuli/thoughts and feel safe.

7. Discussion

We reviewed the literature related to recent advances in cognitive science in OCD. We focused on known-groups and experimental psychopathology methods in the areas of perception, attention, memory, executive functioning, and dual-systems models. Although an exhaustive review was beyond the scope of this paper, we endeavoured to present a balanced review of the extant data. We were careful to present research supporting both cognitive deficit and cognitive bias viewpoints, when such findings were available. Nonetheless, our interpretations of the literature must be viewed within the context of a selective review. By taking a broad lens to cognitive science, we were able to observe cross-cutting issues. Most notably, we observed that: 1) Cognitive science methods are rarely process-pure and often conflate cognitive processes with measure outcomes; 2) Many findings related to potential cognitive deficits are moderated by beliefs about cognition, suggesting cognitive confidence as an important potential explanatory factor of observed deficits; and 3) Although cognitive science has led to many important discoveries about the OCD phenomenology, its contributions to treatment have been limited both in terms of innovation and applicability.

When is a duck not a duck? Cognitive science methods as process-impure. Throughout this article, we describe several different paradigms as “measures of...”, as if the outcome and the underlying cognitive process are one and the same. Rather, such outcomes are inferences that offer a proxy of a particular cognitive function. For example, we measure unconscious automatic associations between concepts by comparing stimulus categorization response times to logically associated vs. illogically associated label pairs on the IAT. The speed with which people respond to different trial types is believed to represent the strength of the automatic association between those concepts. However, [Gawronski \(2009\)](#) concluded that these outcomes are often context-specific and amenable to change, and represent associations that are often available to conscious awareness. In other words, the IAT effect, for example, is relatively far-removed from the actual process of rapid activation of associations. Similarly, computerized attention tasks do not always correlate with eye-tracking (e.g., [Mogg, Millar, & Bradley, 2000](#)), tests of different executive functions often recruit similar cognitive processes or brain regions (e.g., [Duncan & Owen, 2000](#)), and many tasks purporting to measure a particular construct may actually be measuring other constructs as well.

For example, we described the Stroop task – wherein participants must ignore the meaning of a word to name the colour in which the word is printed as accurately as possible – as both a measure of attention bias and of response inhibition. In the first interpretation, people who are slower to name OCD-related words than neutral words are demonstrating a bias towards OCD stimuli. In the second interpretation, this same effect provides evidence of difficulty (i.e., a deficit) inhibiting a learned response. We could also interpret this finding as evidence of automatic behavioural tendencies (i.e., implicit cognition). We are not arguing that the Stroop measures none of these processes,

but rather, that determining which process is most responsible for the outcome is difficult, if not impossible given our extant paradigms. There are also clear similarities between measures of reality monitoring, perceptual uncertainty, and decision-making using internal vs. external cues. Consider fluency, described earlier as the ability to generate multiple exemplars of a category. What cognitive processes might contribute to, for example, naming as many foods as possible that begin with the letter “S”? Attention is required to stay on task; working memory is required to keep in mind those exemplars already said while actively searching for others; response inhibition is required to inhibit verbalizing non-food and non-S items; verbal and nonverbal memory serve as the “bank” of possible exemplars; and people may generate their exemplars automatically via the implicit system, or more intentionally via purposeful memory search. What does it mean, then, if somebody with OCD produces fewer exemplars than somebody without? Many of these tasks and outcomes conflate diverse cognitive processes, serving to potentially muddy the waters, rather than clarify them.

To add to this process-impurity, many interpretations of these measures fail to take into account other “non-cognitive science” characteristics of people with OCD that may explain the observed outcomes. For example, [Schneier et al. \(2016\)](#) found that people with OCD were both slower and more accurate on an attention task than others, suggesting they may have been more meticulous and exerted more effort on each trial. Similarly, findings on the Trail-Making Tests show that people with OCD are slower on both A and B tests, but make fewer errors on the B test (e.g., [Moritz, Kloss, et al., 2009](#)). Moreover, several studies highlighted the role of intolerance of uncertainty, harm overestimation, and responsibility for harm in OCD behaviour. So-called cognitive deficits may better represent the tendency for participants with OCD to take tasks more seriously, feel more responsible to perform them correctly, exert more effort, and require more certainty before submitting their response, thereby reducing the speed with which they respond, the number of items they complete, etc. In that scenario, timed responses will produce deficient outcomes on a particular test without actually belying a dysfunctional process. Indeed, on decision making tasks, if the rewards of giving a speeded response are increased, individuals with OCD increase their response rate without a cost to their accuracy ([Banca et al., 2015](#)). How might a true deficit explain this finding?

The bulk of the research examining cognitive deficits in people with OCD has been correlational (e.g., [Moritz et al., 2002](#); [Olatunji et al., 2011](#)), as have the many studies exploring beliefs related to cognitive performance (e.g., [Hermans et al., 2003](#); [Nedeljkovic & Kyrios, 2007](#)). Such correlational approaches cannot definitively inform us as to the causal impact of either cognitive deficits or biases/beliefs in the development of OCD. Maladaptive beliefs about uncertainty, perfectionism, and low cognitive confidence, may represent a consequence of cognitive deficits (e.g., I have a poor memory therefore I am uncertain about what just transpired) or a cause of OCD symptoms. Experimental research, particularly within the domain of belief-based models of OCD, is starting to emerge (e.g., [Alcolado & Radomsky, 2011](#)). Though our interpretation of the research findings is that observed cognitive deficits are likely a consequence of OCD symptoms, rather than a causal (or even maintaining) factor, there is a need for experimental research in which researchers manipulate cognitive deficits and/or beliefs to investigate their impact on OCD related behaviours.

Another notable limitation of many of the studies cited here is the relative lack of research examining how individual differences and demographic characteristics (e.g., gender, age) may influence cognitive performance and/or beliefs in OCD, despite documented differences in OCD presentation across some demographic characteristics (e.g., [Bogetto, Venturello, Albert, Maina, & Ravizza, 1999](#)). Despite such differences, most studies cited do not examine whether individual differences exert an effect on cognitive functioning or beliefs in relation to OCD. The few studies that have examined gender or age differences

generally fail to find an effect of age (e.g., Henin et al., 2001) or gender (e.g., Christensen et al., 1992). Furthermore, many studies that take an experimental psychopathology approach to investigate purported mechanisms do so in undergraduate populations, resulting in high percentages of women and a lack of older participants (e.g., Ashbaugh & Radomsky, 2007). This may inadvertently obfuscate any impact that such factors have. We encourage researchers to examine or report on the impact of basic demographic characteristics in the future and to attempt to make samples as representative as possible.

I think therefore I act: The importance of beliefs in explaining so-called cognitive deficits. In virtually every cognitive science domain we reviewed, we found evidence for the moderating (if not explanatory) role of beliefs on task outcomes. For example, in the cases of attention to OCD-related stimuli (e.g., Choi & Lee, 2015) and memory confidence (e.g., Boschen & Vuksanovic, 2007), task outcome depended on level of responsibility; in the case of decision-making thresholds (e.g., Banca et al., 2015) task outcome depended on degree of uncertainty. Most notably, beliefs about cognition emerged as particularly important. Consistent with suggestions by Hermans et al. (2008) and Nedeljkovic, Moulding, Kyrios, and Doron (2009), we propose that many of the observed deficits likely represent reduced cognitive confidence, or perhaps more aptly, cognitive distrust. Indeed, studies have reported lack of confidence in one's own senses (e.g., van den Hout et al., 2009; Lazarov et al., 2014), one's ability to control attentional focus (Hermans et al., 2008), one's ability to make decisions (Zhang et al., 2017), and one's memory (van den Hout & Kindt, 2003). Although many of these findings stem from research on checking behaviour, it is highly plausible that such constructs impact other forms of OCD as well. Some of the earliest models of OCD highlight distrust of self (e.g., "I may be a dangerous person") as integral to our understanding of obsessionality (e.g., Rachman, 1997).

This general distrust may extend to other areas; for example, recent research from one of us (AR) demonstrated that fear of losing control leads to increased checking behaviour, highlighting a new potential cognitive treatment target (Gagné & Radomsky, 2017). Here again, we could interpret the findings as potentially indicating difficulties with working memory or decision-making, but the more cohesive story may be to look simply at maladaptive beliefs, consistent with cognitive models of OCD. We contend that focusing on such beliefs may be more fruitful from a clinical perspective, in terms of assessment, case conceptualization, and treatment planning. Cognitive distrust is likely to be more amenable to change via behavioural experiments than are perceptual or working memory deficits. Indeed, attempts to reduce OCD symptoms via potential executive functioning deficits have been largely ineffective (see Moritz, Wess, et al., 2011; for an example).

The scientist-only model: Have we forgotten about practice? The original tenets of Beck (1970) were derived from cognitive theory, and focused on the causal and maintaining role of a person's belief systems and expectancies, offering multiple testable personal hypotheses to target via cognitive therapy. To this end, turning to cognitive science to provide us with more nuanced information about how cognition impacts symptoms makes perfect sense. Indeed, in Salkovskis' (1985) landmark application of cognitive-behavioural theory to OCD, he suggested that "...obsessional thinking is the archetypal example of a cognitive disorder in the neuroses" (p. 571). Moreover, cognitive science paradigms have demonstrated that many cognitive processes that characterize OCD represent exaggerations of those present among healthy samples. Cognitive science has provided a wealth of information about the way that people with OCD think. Yet, with the exception of ERP, a cognitive behavioural therapy derived from learning research, few recent effective treatment innovations have emerged from basic cognitive science. In fact, novel cognitive behavioural therapy for OCD advances that could be attributed to cognitive science, actually stem from work rebutting its findings.

For example, one of us (AR) recently reported findings from a novel intervention for compulsive checking targeting negative beliefs about

memory (Alcolado & Radomsky, 2016). Participants diagnosed with OCD who completed two sessions of this intervention that focused on psychoeducation and behavioural experiments to test their maladaptive beliefs about checking reported decreased time spent checking, checking symptoms, and maladaptive beliefs about memory, as well as improved visuospatial memory, compared to a wait-list control group. Moreover, changes in beliefs about memory actually predicted decreased checking symptoms, suggesting they were a key mechanism of symptom improvement. The studies that originally focused on the role of memory confidence in compulsive checking came about largely as a reaction to research suggesting that people with OCD checked compulsively because of memory deficits (e.g., van den Hout & Kindt, 2003), for which the evidence is equivocal.

There are, however, some recent clinical innovations based in cognitive science that bear mentioning. From our review, attention bias modification seems to show some potential as an adjunctive treatment to cognitive behavioural therapy, particularly if it makes in vivo exposure more acceptable to clients. However, the evidence is limited and needs replication with long-term data. Moreover, the mechanism is likely more related to those typical of ERP (e.g., belief disconfirmation) rather than to change in attention bias, per se, given that research findings do not support the existence of such a bias among people with OCD. Also, because we focused primarily on research conducted with humans, reviewing the data on d-cycloserine and inhibitory learning as they relate to ERP was beyond the scope of this paper. Briefly, there is some evidence that adding d-cycloserine to ERP for OCD leads to faster response earlier in treatment and potentially reduced drop-out (e.g., Chasson et al., 2010; but see Storch et al., 2007). However, a recent Cochrane Review of double-blind placebo-controlled trials of d-cycloserine + ERP for anxiety disorders found no evidence that d-cycloserine leads to improved post-treatment or follow-up outcomes, and cited low quality of heterogeneous studies as a main limitation (Ori et al., 2015). Similarly, Craske and colleagues (Craske et al., 2008, Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014) described an inhibitory learning approach to ERP, which highlights the main mechanism of exposure as expectancy violation and development of new cognitive associations. Recent findings have provided support for this model in improving ERP outcomes (e.g., Deacon et al., 2013). To our knowledge, however, only one article has been specific to OCD, and it was a theoretical rather than empirical paper (Arch & Abramowitz, 2015).

We must highlight that our conclusions are not that cognitive science has nothing to offer to treatment of OCD. Indeed, two of us (AA & AO) focus our research primarily on applying basic cognitive science methodology to understanding anxiety and related disorders, and using that knowledge to refine their treatment. Rather, we argue that recent advances in cognitive science and OCD have not readily translated to recent advances in clinical practice for OCD. Meiser (2011, p. 184) contends that experimental paradigms are both "essential" and "dangerous" in basic psychological research. Specifically, he argues that the type of methods we have described herein often suffer from paradigm specificity, such that researchers become more interested in the outcomes of a particular task, than in the process underlying such an outcome. Indeed, those of us interested in basic cognitive underpinnings of psychopathology may engage in creating a similar limitation: do we at times focus on measuring an outcome without necessarily considering first how the process driving that outcome could be targeted in therapy to improve the symptoms and lives of people suffering from OCD? If so, we hope this review will serve as a call not just for clinically-applicable cognitive science, but also for research geared towards improving existing evidence-based treatment, and with the client in mind. Although many studies highlight factors that could be exported to clinical settings, in our view, the best candidates for implementation are those that clients would readily agree are relevant to their own clinical problems. In other words, we suggest focusing cognitive science on novel domains and aspects of cognition that people struggling with OCD complain of during assessment and therapy

sessions. Many of these factors have related very closely to cognitive science (e.g., “I feel like I can't remember important things clearly”; “I know everything is okay, but I don't trust myself”). These should be examined by cognitive scientists, and then if experimental work shows that symptom reduction is likely, should be further explored as novel intervention techniques. Simply explaining the cognitive phenomenology of OCD without a direct view towards enhancing its clinical relevance, although interesting, is unlikely to be helpful.

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Allison Ouimet, Andrea Ashbaugh, and Adam Radomsky collaborated to generate the idea for the review, define review parameters, and plan overall manuscript preparation. Allison Ouimet and Andrea Ashbaugh conducted literature reviews and drafted the initial manuscript (with input from Adam Radomsky). Adam Radomsky reviewed and revised the initial draft, and wrote portions of the final draft. All authors contributed to and have approved the final manuscript.

Conflict of interest

All authors declare they have no conflict of interest.

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