Response Inhibition Devalues Sexual Stimuli and Alters Their Capacity to Elicit Subjective Arousal and Behavioural Approach or Avoidance

by

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ABSTRACT

RESPONSE INHIBITION DEVALUES SEXUAL STIMULI AND ALTERS THEIR CAPACITY TO ELICIT SUBJECTIVE AROUSAL AND BEHAVIOURAL APPROACH OR AVOIDANCE

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Stimuli that are ignored or from which a motor response is withheld receive more negative affective ratings than the targets of attention or response, and are less likely to elicit behavioural approach. Inhibition is the mechanism thought to trigger such effects; however, it remains unclear whether the impact of response inhibition is due to changes in stimulus value, or to other consequences of motor suppression. Resolving this uncertainty is important because representations of stimulus value are thought to provide a universal currency on which a much wider array of thought and behaviour is based than that impacted by other more restricted effects of motor-suppression. My thesis research addresses this issue directly in Experiment 1 using sexual stimuli in a paradigm that combines a response inhibition task with a new key-pressing task that measures both behavioural approach and avoidance. Evidence that prior response inhibition leads to increases in motivation to escape views of unappealing images suggests that response inhibition alters stimulus value, and does not produce a lingering global brake on motor responses that would reduce all behavioural expression. Following from this, Experiments 2 and 3 explore the extent to which the representations of value altered by response inhibition drive fundamental forms of biologically-significant responses. The results demonstrated that prior response inhibition reduces the capacity of both sexually-explicit images (Exp. 2) and video clips

(Exp. 3) to elicit feelings of sexual arousal. These findings demonstrate that the type of stimulus-value representations altered by response inhibition are likely to support a wide range of thoughts, feelings, and behaviour, including those as biologically-significant as sexual response.

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Chapter 1

Introduction

Humans have a limited capacity to fully process and respond to all objects and events in their environment. Behaviour must be goal-directed in order to prioritize which of the stimuli in the surrounding environment are worth the limited resources. Selective attention helps prioritize information to facilitate goal-directed behaviour, whereas inhibition helps to filter out task-irrelevant information (Houghten & Tipper, 1994). One way in which the dual process of attending to relevant information and inhibiting irrelevant information may direct behaviour is through bi-directional connections between attention and emotion (Vuilleumier, Armony, & Dolan, 2003). It has long been known that emotion impacts attention. For example, pictures of angry faces capture and hold attention more than pictures of emotionally neutral or novel faces (Eastwood, Smilek, & Merikle, 2001; Vuilleumier & Schwartz, 2001); however, recently it has also been shown that the amount of attention allocated to a stimulus has emotional consequences.

While emotionally salient stimuli can capture and direct attention, stimuli that were attended to or ignored in the past may influence future attentional allocation by alterations of their emotional value. Prior research has shown that distracting stimuli (e.g., abstract visual pattern, shape, object) are subsequently rated more negatively than stimuli that were targets of attention or response (e.g., Raymond, Fenske, & Tavassoli, 2003). This devaluation of distracting stimuli is thought to be due to inhibition and this effect has been consistently found across attentional (cognitive) and response inhibition (see Fenske & Raymond, 2006; Raymond, 2009; Gollwitzer et al., 2014 for reviews) as well as in memory (Vivas, Marful, Panagiotidou, & Bajo, 2016; De Vito, Al-Aidroos & Fenske, 2017; De Vito & Fenske, 2017; De Vito Ferrey, Fenske, & Al-Aidroos, 2018).

The decrease in stimulus evaluations following inhibition has also been extended to include investigations of the impact of response inhibition on stimulus-driven behaviour. Many studies have shown that even when motivationally salient objects are inhibited, approach behaviour that would normally be elicited by such items is decreased (see Veling, Lawrence, Chen, van Koningsbruggen, & Holland, 2017 for review). Some researchers have interpreted this decrease in approach behaviour as a result of an inhibition-related decrease in stimulus value (e.g., Ferrey, Frischen, & Fenske 2012), while others suggest that response inhibition may work to decrease motivated behaviour through other mechanisms, such as through decreases in motor-related neural activity (see Chambers, Garavan, & Bellgrove, 2009, and Stinear, Coxon, & Byblow, 2009 for review).

Stimulus value is thought to represent a universal currency through which behaviour is prioritized (Levy & Glimcher, 2012); if response inhibition impacts behaviour by altering stimulus value, this could have implications for even the most fundamental biologically-significant forms of behaviour, such as reward-based seeking of motivationally-relevant stimuli (e.g., food, sexual stimuli, etc.). The objective of this thesis is to test whether response inhibition can impact such fundamental forms of behaviour by investigating the impact of response inhibition on sexual arousal. To investigate whether response inhibition has consequences for behaviour as fundamental as sexual arousal, we need to understand how response inhibition leads to a decrease in motivated behaviour. In Experiment 1, we test the devaluation-by-inhibition hypothesis against the global-brake hypothesis to gain a better understanding of *how* response inhibition leads to alteration in motivated behaviour. In Experiments 2 and 3, we extend this work further to directly investigate the impact of response inhibition on subjective sexual arousal.

Devaluation-by-inhibition

Raymond, Fenske, and Tavassoli (2003) published the first experiment showing that attending to some stimuli and ignoring others has emotional consequences. They completed a two-item visual search task in which they asked participants to locate one colorful abstract art image in the presence of another distracting colorful art image. Each visual search trial was followed by an affective evaluation task wherein participants were asked to rate how cheery/dreary the target, distractor, or novel image was on a 3-point Likert scale (Raymond et al., 2003). They found that participants devalued the distractor items compared to both the novel and target items and that there was no difference in ratings between the novel and target items. This decrease in affective evaluations following visual search was interpreted as evidence of the impact of inhibition on emotion (Raymond et al., 2003).

Researchers continued to explore the impact of attentional (cognitive) inhibition using other well-known attentional paradigms. For instance, the preview benefit, the response-time improvement that occurs in a visual search task when a subset of distractors are previewed prior to the onset of the target and remaining distractors (Watson & Humphreys, 2000) is thought to result from the inhibition of the previewed distractors. Fenske, Raymond, and Kunar (2004) found that participants who showed a preview benefit subsequently rated the previewed distractors more negatively than non-previewed distractors. The authors interpreted the devaluation of the previewed distractors as evidence of the affective consequences of attentional inhibition. Raymond, Fenske, and Westoby (2005) also followed up on this line of research by pairing traditional visual search tasks with affective stimulus evaluations. Because distractors closer to a target are thought to require more inhibition to effectively ignore, given their proximity and greater potential for task interference, the devaluation-by-inhibition hypothesis predicts that such items would also be rated more negatively than distractors further from the target that require less inhibition. This is what was found, distractors closer to targets received more negative ratings than distractors further from the targets (Raymond et al., 2005), which further increased evidence for the link between inhibition and devaluation.

Overall, it was thought that the devaluation seen after stimuli were inhibited operated through the storing of mental representations; when a distractor is encountered, a mental representation of its inhibitory status is encoded along with the perceptual details of the distractor. When the item is subsequently encountered again, this inhibitory trace is re-instantiated and—because of a link between processing fluency and perceived pleasantness (Reber, Schwarz, & Wikielman, 2004)— the resulting decrease in fluency is misattributed by the participant as a decrease in pleasantness (Fenske & Raymond, 2006). Thus far, this devaluation-by-inhibition hypothesis had only been tested with relatively meaningless stimuli (i.e. "mondrians" or abstract art images), but it was unclear whether the encoded inhibitory representations would have an impact with stimuli that may have more meaningful associations, such as human faces. Raymond et al. (2005, Experiment 3) used human faces in the same visual search task they had used previously (Experiment 1 and 2) and asked participants to evaluate how trustworthy or untrustworthy the faces were. They found that even with meaningful stimuli such as faces, distractors were evaluated as less trustworthy than targets and distractors were also rated less trustworthy when they required more inhibition (i.e. when they appeared closer to target faces than distractors that were further away).

All of these experiments (Raymond et al., 2003; Fenske et al., 2004; and Raymond et al., 2005) investigated the effect of attentional inhibition on emotional evaluation using stimulus-based paradigms. That is, inhibition was applied through ignoring the presence of the distracting stimuli in service of locating or prioritizing the target stimuli. Following these stimulus-based investigations, researchers turned to response-based paradigms that investigated how attentional inhibition, applied through withholding a response to distracting stimuli, impacted emotional evaluation. Previously, Tipper, Grison, and Kessler (2003) showed that participants had slower reaction times when asked to detect targets after they had previously been paired with a stop-action cue (i.e. an inhibited response). This slowed response was thought to be evidence of an inhibitory attentional state stored in memory (Tipper et al., 2003). Indeed, Fenske and colleagues (2005) found that faces associated with stop-action cues were rated as less trustworthy than uncued faces and attributed this finding to prior inhibition.

Affective consequences of response-based attentional inhibition have since been investigated using Go/No-go response inhibition tasks. During Go/No-go tasks, participants are asked to respond to a certain set of stimuli and to withhold from responding to another. No-go cues could be indicated by cues such as stimulus category (e.g., male vs. female faces) or colour (e.g., blue vs. yellow overlays). Kiss, Raymond, Westoby, Nobre, and Eimer (2008) asked participants to respond or withhold from responding based on the race of faces presented during a Go/No-go task (White vs. Asian faces, counterbalanced between participants). After the Go/No-go task, they asked participants to evaluate how trustworthy each face was on a 4-point scale from ‘not at all trustworthy’ to ‘very trustworthy’. They found that faces previously viewed as No-go items were rated as significantly less trustworthy than those previously viewed as Go items (Kiss et al., 2008). This finding was interpreted to be a consequence of the No-go items’ previous association with response inhibition.

Along with decreased ratings of trustworthiness, Kiss and colleagues (2008) also showed important neural evidence of the impact of response inhibition on emotion. The N2 component is a small negative peak of event related potentials (ERP) during EEGs that has been commonly associated with cognitive control, the detection of novel stimuli, and the orienting of visual attention (Folstein & Van Petten, 2008). The results of several studies indicate that the N2 is generated in the dorsal anterior cingulate cortex (dACC) and reflects the monitoring of response conflict and cognitive control as it signals the overriding of a prepotent response during these tasks (Nieuwenhuis et al., 2003; Yeung, Botvinick & Cohen, 2004; Bruin & Wijers, 2002; Falkenstein, Hoormann, & Hohnsbein, 1999; Azizian, Freitas, Parvaz, & Squires, 2006). During their Go/No-go task, Kiss and colleagues (2008) also used EEG to investigate the neural correlates of response inhibition. They found that the N2 component was linked to subsequent affective ratings for No-go, but not Go, stimuli; stimuli that were inhibited and showed larger N2 amplitudes were given a more negative value. The authors interpreted this finding as physiological evidence that stimulus devaluation is specifically linked to response inhibition.

Along with Kiss and colleagues' investigation of the N2 component, there are ample lines of evidence showing the brain systems of attention and emotion are highly interconnected (see Vuilleumier, Armony, & Dolan, 2003; Vuilleumier & Huang, 2009 for reviews). A recent fMRI study showed the unique contributions of these connected systems during Go/No-go and affective rating tasks (Doallo et al., 2012). Researchers found that there was more activation of the lateral prefrontal cortex (lPFC) during No-go (inhibited) trials compared to Go trials, which correspond to the role of this region in response inhibition. Moreover, this inhibition-related activity was found to be coupled with activity in a region of orbital frontal cortex (OFC) associated with affective evaluation, providing compelling evidence for the involvement of inhibition in the encoding of stimulus value. This pattern of OFC activation was evident again when the No-go stimuli were being rated in the affective evaluation task and became coupled with activity in the amygdala, which is consistent with the role of the amygdala in emotional response. Taken together, these results suggest that the assessment and encoding of the emotional value of a stimulus is affected by inhibition, which subsequently impacts the affective rating of the stimulus during the affective rating task (Fenske & Raymond, 2006).

Overall, the body of work outlined within this section provides support for the idea that decreases in liking seen after inhibition has been applied to a stimulus is a direct result of a decrease in stimulus value encoded at the time of inhibition that is reinstated during evaluation. Since these initial investigations, evidence for this devaluation-by-inhibition hypothesis has grown, coming from a variety of tasks and contexts. Other tasks replicate and extend the finding that distractors are devalued in both stimuli- and response-based tasks with positive and negative stimuli (Frischen, Ferrey, Burt, Pistchik, & Fenske, 2012); faces (Goolsby, Shapiro & Raymond, 2009); sexual stimuli (Ferrey et al., 2012; Driscoll et al., 2018); stimuli in memory (Vivas et al., 2016; De Vito et al., 2017; De Vito & Fenske, 2017; De Vito et al., 2018); alcohol and food (Houben, Havermans, Nederkoorn, & Jansen, 2012; Veling, Aarts, & Stroebe, 2013); nonsense words (Kihara, Yagi, Takeda, & Kawahara, 2011); Chinese characters (Martiny-Huenger, Gollwitzer, & Oettingen, 2014); letters (Veling, Holland & van Knippenberg, 2007); and geometric shapes (Wessel, O'Doherty, Berkebile, Linderman, & Aron, 2014; Wessel, Tonnesen, & Aron, 2015); however, there are other competing hypotheses that propose the consequences of inhibition are attributable to phenomena other than alterations of stimulus value. Evidence for these competing hypotheses are most evident when the behavioural consequences of inhibition are taken into account.

Response Inhibition and Behaviour: Alteration of Stimulus Value or Global Brake on Behaviour?

Many studies examining the impact of response inhibition use behavioural tasks that measure the ability to stop an ongoing response (e.g., stop-signal task; Logan & Cowan, 1984) or withhold from making a response to a pertinent stimulus (e.g., Go/No-go task; Donders, 1969). There are findings from many behavioural tasks supporting the hypothesis that response inhibition impacts behaviour through a decrease in stimulus value. Houben, Nederkoorn, Wiers, & Jansen (2011) first showed the impact of response inhibition on behaviour by showing participants images of beer in a Go/No-go task. No-go cues were consistently paired with either beer or non-beer stimuli. Participants in the beer No-go condition showed a decrease in implicit attitudes towards beer as expected by the devaluation-by-inhibition hypothesis, but these participants also self-reported a decrease in alcohol consumption in the week following the manipulation compared to participants in the beer Go condition (Houben et al., 2011).

Decreased responses to other motivationally salient stimuli that would otherwise promote strong behavioural approach have also been demonstrated. For instance, there are now many studies showing evidence that response inhibition in a Go/No-go task reduces evaluation of No-go food items and consequently, decreases approach-motivated behaviour and consumption (e.g., Houben et al., 2012; Veling, Aarts, & Stroebe, 2013; see Veling, Lawrence, Chen, van Koningsbruggen, & Holland, 2017 for review). Conditions evoking response inhibition within gambling tasks can also impact the size of bets and other forms of gambling-related approach behavior (Stevens et al., 2015) and recent work has even shown evidence that response inhibition may aid individuals to quit smoking (Adams et al., 2017). Indeed, recent meta-analytic work shows that repeated exposure to Go/No-go tasks, known as inhibitory control training (ICT), is being used as a treatment to alter chronic problem behaviours such as alcohol, food, drug, and gambling behaviours (Jones et al., 2016).

So far, we have examined evidence supporting the devaluation-by-inhibition hypothesis, but there are other hypotheses that explain the decrease in approach behaviour subsequent to response inhibition. In particular, one alternative leading hypothesis links the behavioural indices of response inhibition to neurophysiological suppression of motor activity (Sohn, Wiltz, & Hallet, 2002), including reductions in cortico-spinal excitability and diminished motor-evoked potentials (e.g., Hoshiyama et al., 1996; Leocani et al., 2000). Reductions in motor-related neural activity are thereby thought to underlie reductions in the propensity to execute a specific behaviour (see Chambers, Garavan, & Bellgrove, 2009, and Stinear, Coxon, & Byblow, 2009 for review; Rubia et al., 2001, Coxon, Stinear, & Byblow, 2006).

These findings of reduction in motor-related neural activity with response inhibition support the possibility that suppressing a motor response leads to decreased capacity to energize subsequent behaviour, even for motivationally-salient stimuli that otherwise strongly promote behavioural approach (Freeman et al., 2015), such as appetitive food stimuli, gambling behaviour, and alcohol consumption as mentioned previously. Indeed, neurophysiological research suggests that achieving rapid behavioural suppression is facilitated by a non-specific reduction in global neuro-motor activity across a wide range of motor systems (Coxon, Stinear, & Byblow, 2006; Aron, 2007). For example, rapid hand movement suppression, speech suppression, and eye movement suppression have all been shown to concurrently reduce cortico-spinal activity and motor-evoked potentials in task-irrelevant muscles (Badry et al., 2009; Cai, Oldenkamp, & Aron, 2012; Wessel, Reynoso, & Aron, 2013). Although a lingering global-brake on motor activity could explain the decreased capacity of motivationally-salient stimuli to energize behaviour in the immediate aftermath of the application of response inhibition, it is less clear how it would account for behavioural effects extending throughout the following week (e.g., Houben et al., 2011).

In Experiment 1, we tested competing predictions that arose from the global-brake and devaluation-by-inhibition accounts of the stimulus-linked motivational consequences of response inhibition on motivationally-relevant behaviour. In order to test these hypotheses, we extended previous work done by Ferrey and colleagues (2012), who showed ratings of attractiveness and motivation to view sexual images decreased following a response inhibition task. During a Go/No-go task, Ferrey and colleagues asked participants to respond or withhold a response based on the hair colour of sparsely dressed models. In responding to hair colour, participants were actually responding to the sex of the model in the image, with all male models having dark hair and all female models having light hair (counterbalanced). Ferrey and colleagues found that, within categories of preferred and non-preferred images, participants rated images previously seen as No-go images as being less attractive than those previously seen as Go images. They followed this response inhibition task with a progressive-ratio key-press task that required participants to press a key to obtain views of different categories of images – attractive-male images, attractive-female images, or scrambled versions of the male and female images. Initially, it took only one key press to view an image from a certain category, but the number of key presses required to view the next image from this category doubled each time the category was selected. It was found that participants pressed the key significantly fewer times to obtain views of their preferred-image category when this category of images had been inhibited previously during the Go/No-go task (Ferrey et al., 2012). The same impact was not seen with non-preferred images, but the researchers concluded that this was due to a floor effect; that is, participants could not press a key significantly fewer times to obtain images of their non-preferred sex in the non-preferred No-go condition compared to the non-preferred Go condition because participants barely pressed the key to obtain these views even in the non-preferred Go condition. Therefore, Ferrey et al. concluded that participants rated images as less attractive and were less willing to invest time and effort seeking views of sexually-appealing images when such images had been associated with response inhibition (Ferrey et al., 2012).

Importantly, Ferrey and colleagues attributed the observed reductions in hedonic value and decreased approach behaviour to inhibition-altered stimulus value. If this stimulus value represents a universal currency guiding goal-directed behaviour (Levy & Glimcher, 2012), many forms of behaviour could be impacted, including biologically-significant forms of reward-based behaviour such as food consumption or sex. In order to test the reaches of the impact of response inhibition, it is important to first determine *how* response inhibition impacts behaviour. The aim of Experiment 1 is to rule out the leading competing alternative account of response inhibition, the global-brake hypothesis. Equipped with this knowledge, we will then be able to explore the role response inhibition may play in behaviour as fundamental as sexual response.

Response Inhibition and Sexual Arousal?

Sexual arousal is a state that is composed of physiological and subjective components (de Jong, 2009). In fact, Everaerd (1988) argued that sexual arousal should be thought of as an emotion. Specifically, subjective arousal can be thought of as “the emotional experience of sexual arousal including the awareness of autonomic arousal, expectation of reward, and motivated desire” (Everaerd, 1988 as cited in de Jong, 2009, p. 237). Unsurprisingly then, given the evidence of the reciprocal links between emotion and attention (e.g., Vuillemier et al., 2003), sexual arousal has also been linked to attention (see de Jong, 2009 for review).

There are various models that combine cognitive and affective factors to explain sexual response (e.g., Janssen et al., 2000; Toates, 2009; Stoleru et al., 2012). These models contend that evaluation or appraisal of sexual stimuli happens relatively automatically and unconsciously (for review see Chivers, 2017). Both implicit and explicit processing occurs at various stages of these models (de Jong, 2009). Sexual-information processing theory (Janssen et al., 2000) is a well-cited theory of sexual response that splits sexual arousal into two phases: an appraisal phase and a response generation phase. Janssen and colleagues claim that if sexual meaning is present during the appraisal phase, this will lead to genital response; however, this model also requires the absence of non-sexual or emotionally negative meanings at the appraisal stage. If a sexual stimulus is evaluated as sexual and positive, more attention is paid to the stimulus and to internal cues of arousal starting a positive feedback loop that increases sexual response. If the sexual stimulus is evaluated as nonsexual or as negative in some way, this disrupts the loop and lessens sexual response or stops it altogether. Janssen and colleagues contend that if negative affect is present during the appraisal stage, this could lead instead to lower levels of response. The type of negative affect that sexual-information processing theory cites is negative affect pertaining to "threat- or worry-related meanings"(Janssen et al., 2000). That is, concerns "regarding one's own (sexual) performance rather than to the mere evaluation of a stimulus event" (Janssen et al., 2000, p. 10).

Moreover, Stoleru and colleagues (2012) have created a "four-component neurophenomenological model of visually induced sexual arousal", which includes cognitive, motivational, emotional, and autonomic/neuroendocrine components. Much like Janssen and colleagues (2000), they propose that appraisal is the earliest phase of sexual arousal and that all other phases depend on it; however, they specifically implicate the OFC in the appraisal of sexual stimuli and propose that inhibitory processes may decrease the appraisal of sexual relevance of stimuli through changes in OFC activation (Stoleru et al., 2012). This converges strongly with Doallo et al.'s (2012) evidence of a link between coupled activity in inhibition-related regions and OFC and subsequent stimulus evaluations. In addition, Stoleru and colleagues cite that the OFC is thought to help predict future rewards through an internal representation of incentive value (Roesach & Olsen, 2007). Indeed, multiple studies using fMRI have provided support for the idea that the OFC is involved in the appraisal of sexual stimuli (e.g., Ishai, 2007; Paul, Schiffer, & Zwarg, 2008). These findings of OFC activation representing the value of sexual stimuli support the notion that stimulus value may be representative of a universal currency for the prioritization of goal-directed behaviour (Levy & Glimcher, 2012). Given Doallo and colleagues' (2012) conclusions that the OFC is involved in devaluation-by-inhibition through representation of stimulus value, and Stoleru and colleagues' model citing the OFC's involvement in stimulus appraisal and value, it stands to reason that response inhibition may also impact sexual response through the alteration of stimulus value. My thesis research is designed to explore whether response inhibition decreases sexual arousal via decreased stimulus value. If this decrease in sexual arousal were observed, this would provide further evidence for the notion that stimulus value represents a universal currency (Levy & Glimcher, 2012) that flexibly impacts a wider range of behaviour than initially realized in previous investigations of the affective and behavioural consequences of response inhibition.

Of note is that Stoleru and colleagues (2012) model, as well as many of the theories investigating the interconnections of cognitive and affective processing in sexual arousal, also include discussion of inhibition (Janssen et al., 2000; Toates, 2009; Stoleru et al., 2012); however, this conceptualization of inhibition is not the same as defined herein. When discussing inhibition, these researchers are referring to the suppression of sexual response itself. For instance, Janssen and Bancroft (2007) proposed the dual-control model of sexual response. In proposing the dual-control model, the researchers discussed the interplay between sexual excitation and inhibition. Within this theory, they identified two types of sexual inhibition: inhibition due to threat of performance failure and inhibition due to the threat of performance consequences. These types of inhibition are similar to the types of negative affect cited in the sexual-information processing theory, whereby negative affect that lessened a sexual response is likely to be threat- or worry-related (Janssen et al., 2000). In contrast, inhibition discussed within this thesis refers to inhibition of the neurocognitive representations of a stimulus or its associated motor-response to achieve goal-directed behaviour. It is thus far unknown whether the previously observed decreases in liking and approach behaviour attributed to response inhibition will translate into decreases in sexual arousal in the same way that negative affect associated with threat- or worry-related affect is purported to. Additionally, some work has been done to investigate how the presence of self-reported negative affect impacts subjective sexual arousal with mixed results (e.g., Peterson & Janssen, 2007), and it remains unclear how stimulus-based negative affect might impact subjective sexual arousal, as opposed to these more global measures of affect or mood.

Even though the type of inhibition being considered here differs from that involved in the dual-control model of sexual response (Janssen & Bancroft, 2007), there may be similar implications for sexual arousal. Here, we predict that inhibiting a sexual stimulus will decrease the stimulus value associated with it, which will in turn decrease motivated behaviour to approach it, and sexual arousal in response to it. Similarly, inhibition of sexual response leads to decreased expression of subjective sexual arousal, behavioural response, and progression to ejaculation or orgasm (Janssen & Bancroft, 2007; Toates, 2009); however, if response inhibition decreases sexual response, this may broaden the scope of understanding of different cognitive-affective mechanisms that impact sexual arousal. The outcomes of sexual inhibition as well as the predicted outcome of response inhibition are both problematic for individuals who experience sexual dysfunction, such as erectile difficulties or problems with sexual desire. If it is found that attentional mechanisms such as response inhibition are impacting the very processing of sexual stimuli early on in the sexual response process (i.e., the appraisal phase of sexual response), this can be identified as a potential site for clinical intervention.

The Present Research

In my thesis, we extend prior investigations of inhibition-related stimulus devaluation by exploring the impact of response inhibition on hedonic value, motivated behaviour, and subjective sexual arousal. The objective of this thesis is to provide converging evidence about whether the affective consequences of response inhibition are due to alterations in stimulus value and the extent to which it can impact behaviour as fundamental and biologically-significant as sexual response. To do so, we first needed to rule out a compelling alternative hypothesis regarding the impact of response inhibition on behaviour. The global-brake hypothesis states that motivated behaviour is decreased due to a lingering global brake on motor-response following response inhibition. In Experiment 1, we created methods to directly test the devaluation-by-inhibition and global-brake hypotheses. We found support for the devaluation-by-inhibition hypothesis and proceeded to extend the investigation of the impact of response inhibition from ratings of sexual attractiveness in prior research (Ferrey et al., 2012; Experiment 1: Driscoll et al., 2018) to the investigation of the impact of response inhibition on subjective sexual arousal in Experiments 2 and 3. In Experiment 2, we used sexual images Go/No-go and evaluation tasks to assess subjective sexual arousal and in Experiment 3, we used a Go/No-go task and explicit video. Together, the findings support the devaluation-by-inhibition hypothesis and suggest that stimulus value is a universal currency through which even fundamental reward-based behaviour, such as sexual arousal, can be impacted.

Chapter 2

Response Inhibition, Ratings of Attractiveness, and Motivation

Information presented in this chapter has been published. Some information from the published manuscript is also present in other chapters. While minor alterations have been made to the published version, the original manuscript can be found here:

Driscoll, R. L., Quinn de Launay, K., & Fenske, M.J. (2018). Less approach, more avoidance: Response inhibition has motivational consequences for sexual stimuli that reflect changes in affective value not a lingering global brake on behavior. *Psychonomic bulletin & review, 25*(1), 463-471.

Ignoring a stimulus or withholding a response from it decreases the value associated with it; this is the premise of the devaluation-by-inhibition hypothesis. Much work has been done to support his hypothesis, showing that the reciprocal links between attention and emotion mean that not only do emotional stimuli direct attention, but the amount of attention allocated to a stimulus impacts the emotion associated with it (Fenske & Raymond, 2006). Recent work has extended the devaluation-by-inhibition hypothesis from response inhibition having affective impact to response inhibition having behavioural impact. Indeed, it has been shown that when individuals inhibit even very motivationally salient stimuli, such as alcohol (e.g., Houben et al., 2011), food (e.g., Veling, Aarts & Stroebe, 2013), or sexual images (Ferrey et al., 2012), they are less likely to subsequently approach or consume these stimuli. The devaluation-by-inhibition hypothesis would infer that this decrease in approach behaviour is due to a decrease in value of these stimuli; however, the lack of subsequent engagement with these appetitive stimuli have also been suggested to derive from a global-brake of motor responses following response inhibition (see Chambers, Garavan, & Bellgrove, 2009, and Stinear, Coxon, & Byblow, 2009 for review; Rubia et al., 2001; Coxon, Stinear, & Byblow, 2006).

In Experiment 1, we tested competing predictions that arise from the global-brake and devaluation-by-inhibition accounts of the stimulus-linked motivational consequences of response inhibition on motivationally-relevant behaviour. We used the same Go/No-go task that Ferrey, Frischen, & Fenske (2012) used to associate response inhibition with erotic images of participants' preferred and non-preferred sex. In a subsequent Affective-evaluation task, they found that previously inhibited (No-go) items were subsequently rated as less attractive than non-inhibited (Go) items, and that the magnitude of this effect was similar for both preferred-sex and non-preferred images. Furthermore, in a Motivated-viewing task, Ferrey et al. observed that prior response inhibition of preferred-sex images reduced participants' willingness to expend time and key-pressing effort to view such motivationally-relevant stimuli. While this decrease in approach behaviour toward otherwise-appealing stimuli is predicted by both the global-brake and devaluation-by-inhibition hypotheses, we modified the Motivated-viewing task to provide a measure of stimulus-driven motivated behaviour about which these competing hypotheses make opposite predictions. Specifically, rather than using a task that only assesses an inhibition-related change in stimulus approach, we developed a task with which we could also assess possible inhibition-related changes in participants' willingness to expend time and key-pressing effort to escape views of unwanted stimuli. This is important because an inhibition-related global brake on motor activity and lingering decrease in the ability to energize subsequent behaviour predicts a reduction in all key-pressing behaviour regardless of whether keys are being pressed to view appealing images or to avoid viewing unappealing images. In contrast, an inhibition-related reduction of stimulus value predicts a decrease in key-presses to view otherwise-appealing images, but an *increase* in key-presses to avoid viewing images that have become even more unappealing through stimulus devaluation.

The inclusion of a measure of stimulus avoidance also underscores the importance of the present experiment for addressing the void in the literature concerning how response inhibition impacts processing linked to behavioural avoidance of motivationally-relevant stimuli. Whereas a growing number of studies have examined the impact of appetitive and aversive stimuli on mechanisms of response inhibition (e.g., Albert, López-Martín, & Carretié, 2010; Yuan, Meng, Yang, Yao, Hu, & Yuan, 2012) and several studies have now examined the impact of response inhibition on behavioural approach elicited by appetitive stimuli (e.g., Ferrey et al., 2012; Houben et al., 2011; 2012; Veling et al., 2013), nothing is known yet about the corresponding impact of response inhibition on behavioural avoidance elicited by aversive stimuli.

Methods

The methods used in our experiment were a modified version of those used by Ferrey et al. (2012) and were approved by the University of Guelph Research Ethics Board (REB#15MY034).

Participants

160 undergraduate students aged 18-35 (M = 18.56 years, SD = 2.45 years) with normal or corrected-to-normal vision were recruited from the University of Guelph undergraduate research participant pool in exchange for course credit. The appropriateness of our sample size was determined using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007), which indicated that 80 participants would be required to detect the same-sized effect of response inhibition on behavioural approach as in Ferrey et al.'s (2012) Experiment 2 (d = .82) with a power of 0.95 at

an alpha of .05. However, we were primarily interested in an effect of response inhibition on behavioural avoidance. The existence and size of such an effect is not yet known, however, and there is some affective-rating evidence that the consequences of response inhibition may be greater for appetitive stimuli than for affectively neutral or aversive stimuli (e.g., Veling, Holland, & van Knippenberg, 2008; Chen, Veling, Dijksterhuis, & Holland, 2016). This supports our decision to use a sample that was twice the size determined by our formal calculation to ensure that we could detect an effect of response inhibition on behavioural avoidance, even if it were more moderate in magnitude than that for behavioural approach. One participant left the experiment shortly after it began without further explanation. Data from five participants were excluded because of low accuracy on the Go/No-Go task (> 2.5 *SDs* below average). Data from an additional seven participants were excluded because they indicated equal attraction to males and females. Only individuals strongly attracted to males or females were included because our hypotheses specifically related to the impact of response inhibition on sexually-relevant stimuli. These exclusion criteria were determined *a priori* based on previous work (i.e. Veling et al., 2008; Frischen et al., 2012; Ferrey et al., 2012). Results are reported for the remaining 147 participants. Thirty-nine of the 41 males within this sample reported being strongly attracted to females; 105 of the 106 females reported being strongly attracted to males.

Stimuli and Apparatus

The stimulus set included 288 digital color photographs of light-skinned attractive males and females. No nudity was shown, but images were selected for their explicit sexual appeal. Half of the images were males, half were females; both sets contained an equal number of light-haired and dark-haired individuals. Each image appeared at display center on a white background, subtending approximately 10.6° × 16.3° visual angle at a viewing distance of approximately

60cm. A black '+' symbol that subtended approximately 0.90° x 0.90° visual angle was used as a central fixation cross. Stimulus presentation and behavioral response collection were controlled by E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA, USA) running on an Intel Core 2 Duo computer with a 50.8 cm LCD monitor (resolution: 1680 × 1050 pixels).

Design and Procedure

Response Inhibition and Affective-evaluation Phase. The first phase combined alternating sequences of Go/No-go trials and Affective-evaluation trials to assess the impact of response inhibition on perceived attractiveness of preferred-sex and non-preferred-sex images. This phase consisted of 16 blocks, each comprised of 12 Go/No-go trials followed by 12 Affective-evaluation trials (see Fig. 1). The Go/No-go trials required participants to press the spacebar with both index fingers as quickly as possible whenever the person depicted in the image had dark hair (or light hair; this Go cue switched once halfway through the session, its order counterbalanced across participants) and to otherwise refrain from responding. Images—each presented for 250 ms followed by a 1000 ms fixation display—were randomly selected with the constraint that each set of 12 trials comprised equiprobable factorial combinations of sex and hair color. In the Affective-evaluation trials, participants rated the attractiveness of the same 12 images on a four-point scale ranging from 1 ("Not at all attractive") to 4 ("Very attractive"). Participants were encouraged to use the full range of responses. Images were presented in the same order for 250 ms each, followed by a 1000 ms blank display. Participants were instructed to indicate the attractiveness of the person in each image based on their immediate personal reaction, rather than an estimate of objective attractiveness.

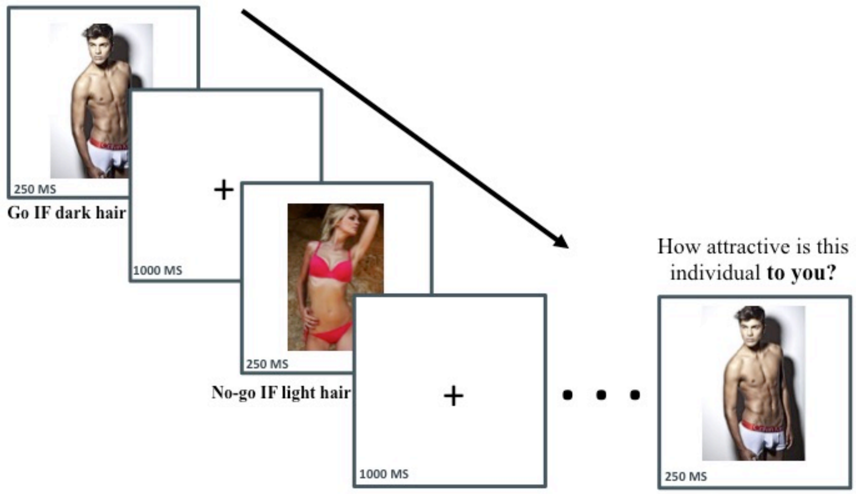

Figure 1. Example of the stimulus sequence in the Go/No-go and evaluation tasks used in all three studies. In this example, attractive male images are “Go” stimuli that require a speeded key-press response, and attractive female images are “No-go” stimuli that require the response to be withheld. In Experiment 1 and 2, after every 12 Go/No-go trials, the same stimuli are affectively evaluated.

Motivated-viewing Phase. The second phase of the study used a progressive-ratio key-press task to assess the impact of prior response inhibition on the capacity of preferred-sex and non-preferred images to elicit behavioural approach or avoidance (see Figure 2). This phase consisted of 8 blocks of 12 image-viewing trials. Each image of an attractive male or female initially appeared partially-obscured by a moderate amount of random coloured noise applied with a uniform distribution. Participants were told that they could press a key labeled ‘clear’ to see more of an image or a different key labeled ‘blurry’ to see less of an image. The keys were on a progressive-ratio schedule such that each time an image within a given category (e.g., male images) was made completely clear or completely obscured, twice as many key presses were needed to make the next image from that category completely clear or completely obscured. Participants were instructed that any key-press response was acceptable, but that they eventually needed to reach one of the extremes (i.e. fully-clear or -obscured) in order to progress to the next image. Individuals could make up to 32 key-presses to see a certain type of image (male or female); however, if at any point they changed their mind, they could make the opposite response.

Levels of approach motivation for preferred-sex and non-preferred images were operationalized as the number of key-presses a participant made to completely enhance the visibility of the images from that category. Levels of avoidance motivation for preferred-sex and non-preferred images were operationalized as the number of key-presses a participant made to completely obscure the visibility of images from that category.

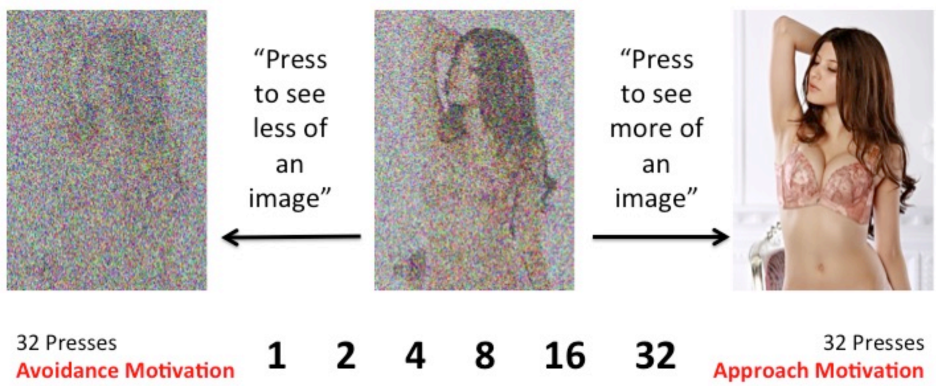

Figure 2. Example of the possible stimulus transitions in each trial of the Motivated-viewing Phase in Experiment 1. Each attractive female and attractive male image initially appeared partially-obscured by visual noise. Participants could choose to either make the image more visible (stimulus approach) or less visible (stimulus avoidance) by pressing different keys. The keys were on a progressive-ratio schedule: twice as many presses were needed to achieve a completely clear or a complete obscured view for each successive image of a given type.

Questionnaires and Debriefing. Following both phases, participants filled out a demographic questionnaire, which included a modified Kinsey scale to assess self-reported sexual attraction (Kinsey Institute, Indiana University). This seven-point scale asked participants to mark the description that best described their sexuality, from "exclusively attracted to females" to "exclusively attracted to males" and included an option to indicate "no socio-sexual contacts or reactions". All participants were then debriefed before leaving the experiment.

Results

Because each participant experienced only one particular combination of Response-status and Sexual-relevance conditions (i.e., Preferred-sex images on No-go trials and Non-preferred images on Go trials, or vice versa), the impact of response inhibition on each of our dependent measures (hedonic ratings and approach- and avoidance-motivated key-presses to erotic images) had to be assessed between groups. We did this using two-way ANOVAs that treated both Response-status (Go vs. No-go) and Sexual-relevance (Preferred vs. Non-preferred sex) as between-subjects factors. Independent-samples t-tests (two-tailed) were used for planned comparisons involving simple effects. Ratings from Go/No-go trials in which an error was made (M = 4.6%, SD = 3.7) were excluded from analysis.

Hedonic ratings Participants rated Preferred-sex images (M=2.94) as significantly more attractive than Non-preferred images (M=1.97), $F(1, 290)=223.94$, $p<.001$, $\eta^2=.44$, confirming their sexually appealing nature. Furthermore, participants rated No-go images as significantly less attractive than Go images, $F(1, 290)=10.54$, p=.001, $\eta^2=.04$; this was the case for both the Preferred-sex [$t(145)=2.40$, p=.018, d=.50] and the Non-preferred conditions [$t(145)=2.20$, p=.029, d=.40; see Figure 3]. There was no significant interaction between these effects (F<1). This pattern of results showing that both sexually appealing and non-appealing stimuli become hedonically devalued after being associated with response inhibition closely replicates the same findings by Ferrey et al (2012).

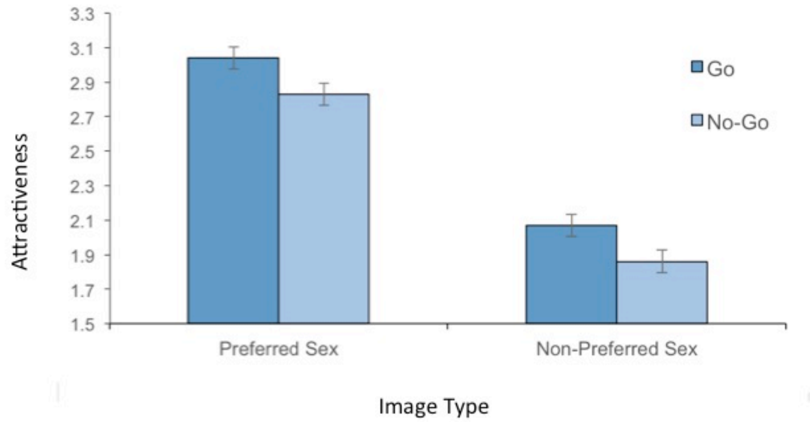

Figure 3. Experiment 1, Phase 1 results. Average ratings of attractiveness for preferred and non-preferred stimuli according to trial type (Go/No-Go). Error bars represent standard errors of the means.

Motivated-viewing key presses

Stimulus-approach motivation. The number of times participants pressed the 'Clear' key to obtain better views of Preferred-sex images (*M*=17.68) was significantly greater than that for Non-preferred images (*M*=3.60), F (1, 290) = 290.30, p<.001 η^2 = .50, confirming their motivational capacity to elicit behavioural approach. Furthermore, the number of times participants pressed the 'Clear' key to obtain better views decreased significantly when such images had previously appeared as No-go items (*M*=9.18) than as Go items (*M*=12.18), F(1, 290)=12.48, p<.001, η^2 =.04; this was the case for the Preferred-sex [t(145)=3.09, p=.002, d=.51] but only marginally so for the Non-preferred condition [t(145)=1.72, p=.087, d=.30; see Figure 4]. The interaction between these effects was also only marginally significant, F(1, 290)=3.11, p=.079, η^2 =.01. Finding that the motivational capacity of sexually-appealing images to elicit behavioral approach is diminished after being associated with response inhibition also closely replicates the same findings by Ferrey et al. (2012).

Stimulus-avoidance motivation. The number of times participants pressed the 'Blurry' key to escape views of Non-preferred sex images (*M*=14.91) was significantly greater than that for Preferred-sex images (*M*=1.89), F (1, 290)=255.72, p <.001, η^2 =.50, confirming their motivational capacity to elicit behavioural avoidance. Furthermore, the number of times participants pressed the 'Blurry' key to escape views increased significantly when such images had previously appeared as No-go items (*M*=9.18) than as Go items (*M*=7.07), F(1, 290)=10.70, p =.001, η^2 =.04; this was the case for the Non-preferred sex [t(145)=2.95, p =0.004, d=.50] but not the Preferred-sex condition [t(145)=1.64, p=.103, d=.30; see Figure 4]. The interaction between these effects was significant, F(1, 290)=6.00, p=.015, η^2 =.02. Finding that the motivational capacity of sexually-unappealing images to elicit behavioral avoidance is enhanced after being associated with response inhibition is a novel and important discovery.

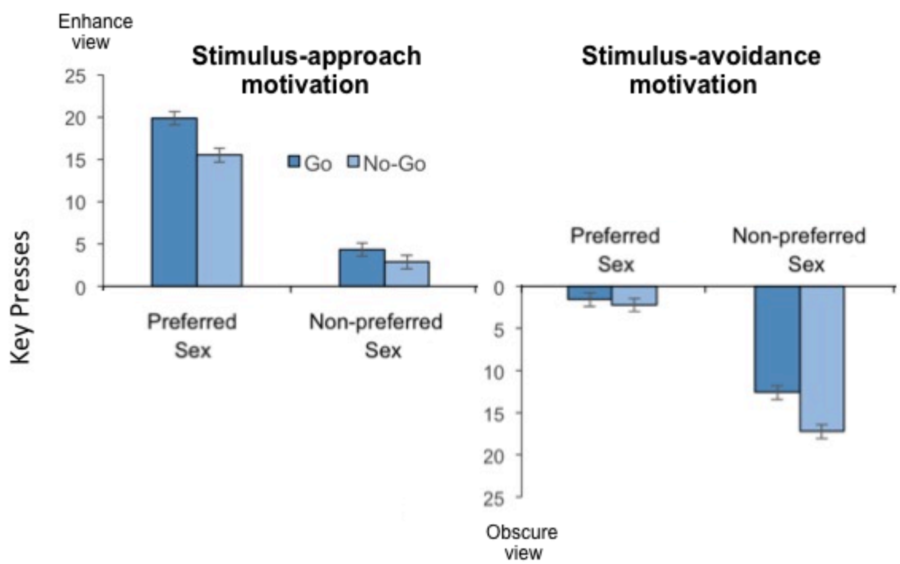

Figure 4. Experiment 1, Phase 2 results. Number of key-presses made to view preferred stimuli or to avoid non-preferred stimuli according to trial type (Go/No-Go). Error bars represent standard errors of the means.

Discussion

Response inhibition reduces the capacity of visual stimuli to elicit approach-motivated behaviour (e.g., Houben et al., 2012; Ferrey et al., 2012; Veling et al., 2013; Jones & Field, 2013; Freeman et al., 2015, Wessel et al., 2015), but it remains unclear exactly how this occurs: through a modulation of stimulus value as predicted by devaluation-by-inhibition, or through a lingering brake on behaviour as predicted by global-brake. We directly compared and contrasted the global-brake and devaluation-by-inhibition accounts of the motivational consequences of response inhibition by modifying Ferrey et al.'s (2012) procedure to not only provide a measure of inhibition-related change in hedonic value and motivated stimulus approach, but to also include a measure of inhibition-related change in motivated stimulus avoidance. Our results provide strong support for the devaluation-by-inhibition hypothesis.

The global-brake hypothesis predicts a reduction in all key-pressing behaviour regardless of whether keys are being pressed to obtain views of appealing images or to avoid viewing unappealing images. In contrast, the devaluation-by-inhibition hypothesis predicts a decrease in key-presses to obtain views of otherwise-appealing images, but an *increase* in key-presses to avoid viewing images that have become even more unappealing through devaluation. This is precisely what we found: participants were less willing to repeatedly press a key to obtain better views of sexually-appealing images after being associated with response inhibition but they worked harder to escape views of sexually unappealing images after being associated with response inhibition. Such inhibition-related increases in behavioural expression are inconsistent with a lingering global brake on action.

Our findings closely replicate those reported by Ferrey et al. (2012) concerning the impact of response inhibition on the hedonic value and motivational salience of sexual stimuli. This includes the finding that both sexually appealing and non-appealing images received more negative hedonic evaluations after being associated with response inhibition on No-go trials than with response on Go trials. These hedonic-evaluation findings converge nicely with prior evidence that both positively valenced and negatively valenced stimuli receive more negative affective ratings after being associated with response inhibition on No-go trials than with response on Go trials (e.g., Frischen et al., 2012). This evidence is consistent with the interpretation that response inhibition does not merely attenuate the intensity of stimulus-evoked emotion linked to an item's existing affective status, but has a distinctly negative impact on stimulus value, per se. Our close replication of Ferrey et al.'s (2012) results also includes the finding that the motivational incentive to seek and obtain views of otherwise-appealing sexual images is significantly reduced in individuals who have recently inhibited images of that type. This finding is noteworthy for showing that a reduction in motivational incentive carries over to different instances of the inhibited stimulus category, and extends prior observations that inhibition-related reductions in hedonic value can generalize to influence evaluations of other stimuli, as long as they are from the same category or otherwise share the same features as previously inhibited items (e.g., Raymond et al., 2003; Goolsby et al., 2009).

While the replication of key experimental findings is important, the novel and theoretically meaningful finding from our experiment is that such generalized effects of response inhibition are not limited to reductions in motivated approach of appetitive stimuli, but also include increases in motivated avoidance of aversive stimuli. This finding helps to address a void in the literature concerning how response inhibition impacts processing linked to behavioural avoidance of motivationally-relevant stimuli. Whereas a growing number of studies have examined the impact of appetitive and aversive stimuli on mechanisms of response inhibition (e.g., Albert et al., 2010; Yuan et al., 2012) and several studies have examined the impact of response inhibition on behavioural approach elicited by appetitive stimuli (e.g., Ferrey et al., 2012; Houben et al., 2011; 2012; Veling et al., 2013), the results from our motivated-viewing task with sexually-unappealing images represent the first advance in knowledge about the corresponding impact of response inhibition on the motivational capacity of stimuli to elicit behavioural avoidance. The convergence in findings that stimulus-associated response inhibition can negatively impact hedonic ratings of such items, reduce their capacity to elicit behavioural approach and increase their capacity to elicit behavioural avoidance suggests that changes in both subjective evaluations and motivated behaviour may be linked to changes in representation of stimulus value common to both processes.

There is growing evidence that the changes in stimulus value observed following tasks that involve attentional (e.g., Raymond et al., 2003; 2005; Fenske et al., 2004; 2005; Kiss et al., 2007; Martiny-Huenger et al., 2014), response- (e.g., Frischen et al., 2012; Ferrey et al., 2012; Kiss et al., 2008), and memory-related inhibition (e.g., De Vito & Fenske, 2017; Vivas et al., 2016) may be due to the negative affective consequences of inhibition *per se.* However, it is important to emphasize that our combination of Go/No-go plus Hedonic-rating and Motivated-viewing tasks did not include a novel control condition against which the potential negative effects of response inhibition on the value of stimuli associated with No-go trials could be distinguished from any positive effects of active responding on the value of stimuli associated with Go trials. Evidence of the enhancement of stimulus value through active responding has so-far been limited (e.g., Schonberg et al., 2014; but cf. Veling et al., 2008), and possibly restricted to certain conditions that encourage rapid responses on Go trials (Chen et al., 2016). Our experimental procedure did not include such conditions.

Nevertheless, Veling et al.'s (2008) Behaviour-Stimulus Interaction theory and related findings by Chen et al. (2016) raise the question of whether the processes linked to response inhibition on No-go trials and those linked to responding on Go trials have the same affective consequences for positively-valenced stimuli associated with behavioural approach as they do for negatively-valenced stimuli associated with behavioural avoidance. The inhibition of behavioural-approach on No-go trials, according to this view, specifically reduces motivational value for appetitive stimuli, but not for aversive or affectively neutral items. Our finding of a significant decrease in key-presses to increase visibility of preferred-sex images, but only a marginal decrease for non-preferred images (Figure 4) is consistent with this perspective. Caution is needed when interpreting this apparent interaction, however, given that it was only marginally significant and given the likelihood of it arising via a floor effect (i.e., it's hard to reduce a participant's willingness to press a key to see more of an aversive image if they already lack any motivation to press a key to view it).

Although some questions still remain unanswered, the findings of this experiment provide evidence for the devaluation-by-inhibition hypothesis. Herein, we showed that a decrease in stimulus value, not a global brake on motor activity, led to a decrease in approach behaviour and an increase in avoidance behaviour. With this knowledge, we can begin to examine the extent to which stimulus value may alter behaviour. If stimulus value is a sort of universal currency that helps to prioritize goal-directed behaviour (Levy & Glimcher, 2012), then response inhibition may impact a broader range of behaviour than initially realized. Specifically, it is possible that response inhibition may impact even the most fundamental biologically driven behaviours such as reward-based behaviour, including the consumption of food and sex. In the following chapters, we will explore the impact of response inhibition on subjective sexual arousal.

Chapter 3

Response Inhibition and Subjective Sexual Arousal: Images

Sexual arousal is a motivational state and, in fact, it has been argued that sexual arousal could be thought of as an emotion (Everaerd, 1988). There is a complex interplay of cognitive and affective factors involved in producing a sexual response (see Chivers, 2017 for review). When sexual responses are generated, stimuli go through two phases of processing: an appraisal phase and a response generation phase (Janssen et al., 2000). During the appraisal phase, the stimulus needs to be evaluated as sexual in order to move to the response generation phase. Moreover, there must be an absence of threat- or worry-related negative affect during the appraisal phase; presence of this sort of negative affect may impede the production of a sexual response.

Recent work has shown that sexual images are appraised as less attractive when they have previously been inhibited compared to when they were previously viewed as targets of response (Ferrey et al., 2012). Moreover, previous response inhibition also decreases approach motivation to view preferred sexual images. Multiple questions arose from this line of work. First, it was unclear how response inhibition led to a decrease in hedonic value and motivated behaviour to engage with preferred sexual images. Second, in the context of producing a sexual response, it was unclear whether the impact of response inhibition on affect and associated viewing behaviour toward sexual images would translate into actual impact on sexual arousal.

There were competing hypotheses that explained how response inhibition led to a decrease in approach related behaviour. One hypothesis was the global-brake hypothesis, which argued that the decrease in approach behaviour subsequent to response inhibition was due to a global-brake on motor responses. This hypothesis was based on research showing a decrease in neural motor activity and predicted a decrease in the ability to generate any motor activity following response inhibition (see Chambers, Garavan, & Bellgrove, 2009, and Stinear, Coxon, & Byblow, 2009 for review; Rubia et al., 2001, Coxon, Stinear, & Byblow, 2006). The second hypothesis was the devaluation-by-inhibition hypothesis, which argued that the affective and behavioural consequences of response inhibition were due to an encoded alteration of stimulus value (see Fenske & Raymond, 2006; Raymond, 2009; Gollwitzer et al., 2014 for reviews). If the devaluation-by-inhibition account was correct, it would mean that response inhibition may have the potential to impact sexual response. The devaluation-by-inhibition hypothesis argued that the devaluation observed after stimuli were inhibited operated through the storing of encoded value; when a stimulus is inhibited, a mental representation of its inhibitory status is encoded with it, decreasing its associated stimulus value which leads to devaluation during subsequent evaluation (Raymond, 2009). With regard to sexual arousal, the stimulus evaluation that occurs as part of the appraisal phase of sexual response (e.g., Stoelru et al., 2012) means that the capacity of a stimulus to evoke sexual arousal may be negatively impacted if its encoded value has been decreased through prior response inhibition. However, before exploring the impact of response inhibition on sexual response, per se, it was important to first test the devaluation-by-inhibition hypothesis against a credible alternative hypothesis that posited that inhibition-related reductions in behavioural responses to motivationally-relevant stimuli can occur without a change in stimulus value.

To test these two hypotheses, in Experiment 1, we examined the impact of response inhibition on both approach and avoidance motivation. The global-brake hypothesis predicted a decrease in both approach and avoidance behaviour following response inhibition. In contrast, the devaluation-by-inhibition hypothesis predicted a decrease in approach behaviour, but an *increase* in avoidance behaviour due to a decrease in value, not a decrease in the ability to generate motor responses. Our findings aligned with the devaluation-by-inhibition hypothesis; not only did ratings of attractiveness of the stimuli decrease, so did the number of key-presses made to obtain views of sexual images. Most importantly, key-presses to avoid viewing non-preferred sexual stimuli *increased* following response inhibition toward non-preferred images. Given this clear support for an alteration in stimulus value, there are potential important implications for how sexual stimuli are processed and encoded.

With this new evidence supporting the idea that response inhibition leads to devaluation through a decrease in stimulus value, we can now test new predictions stemming from the devaluation-by-inhibition hypothesis. Thus far, we do not know whether response inhibition is capable of altering more biologically-significant reward-based behaviour, such as sexual arousal. Experiment 1 showed us that response inhibition alters attraction and motivated behaviour, but would response inhibition cause a decrease in sexual arousal? There is evidence that sexual arousal might be impacted in the same way as ratings of attractiveness and motivated behaviour. For instance, activation of the orbitofrontal cortex (OFC) has been linked to assigning value to stimuli (Doallo et al., 2012). In one response inhibition study, OFC activation was associated with initial response inhibition and remained activated when the stimuli were subsequently evaluated. Authors took this as evidence that the value-related information that helps guide behaviour is represented by OFC activation. The OFC has also been implicated in the valuing of sexual stimuli (e.g., Ishai, 2007; Stoleru, 2012). Indeed, researchers have suggested that OFC activation may be representative of stimulus value as a type of universal currency through which goal-directed behaviour operates (Levy & Glimcher, 2012). If this stimulus value is impacted by response inhibition, then response inhibition may impact sexual arousal in the same way that it impacts other motivated behaviour.

To investigate the impact of response inhibition on sexual arousal, we are measuring subjective sexual arousal. Subjective sexual arousal is self-reported and is commonly used as an indicator of sexual arousal (see Kukkonen, 2015 for review); however, some researchers note that there are important differences between subjective and physiological sexual arousal (see Chivers, Seto, Lalumiere, Laan, & Grimbos, 2010 for meta-analysis). That is, some individuals or groups of individuals self-report arousal levels that are not concordant with their levels of physiological response. Some researchers suggest that this discordance represents an important area of study for examining individual differences (e.g., Chivers, 2017) whereas other suggest that this difference could be due to measurement error (e.g., Kukkonen, 2014 for review). For the purposes of this thesis, we chose to focus on investigating subjective sexual arousal because self-report measures are more similar to measures used in affective evaluation tasks commonly paired with response inhibition. Specifically, we aimed to replicate and extend the findings of Experiment 1 and Ferrey and colleagues (2012), which used self-report methodology; however, given the conflicting results about the concordance between subjective and physiological measures, an investigation of physiological sexual response may yield different results.

For this experiment, we used the same Go/No-go task as Experiment 1; however, the stimuli we used here were more sexually explicit than those in Experiment 1. This change was based on prior research investigating sexual arousal, which has shown robust effects using images of individuals who are fully nude and visibly aroused (erect penises and engorged/lubricated vulvas; e.g., Dawson & Chivers, 2016). Using relatively more potent sexual images was thus anticipated to produce sufficiently high levels of arousal to allow any decreases in arousal due to the effects of the response inhibition task to be clearly evident. Directly assessing the impact of response inhibition on subjective sexual arousal required that we also alter the affective evaluation task from Experiment 1; instead of asking how attractive the images were, we asked participants to instead rate their subjective sexual arousal.

Methods

The methods used in this experiment were an adaptation of those used in Ferrey et al., (2012) and Experiment 1 (Driscoll et al., 2018). Informed consent was obtained from all individual participants included in the study.

Participants

One hundred and twenty seven undergraduate students (65 females, 62 males) were recruited from the University of Guelph participant pool and were aged 18-27 years (*M* = 18.86 years, SD = 1.52 years) at the time they participated in the experiment in exchange for course credit. Only participants who identified as exclusively attracted to males or females (Kinsey score of 0, 1, 5, or 6) were included in this study given that preference (preferred sex vs. non-preferred sex) was defined as a dichotomous variable. Additionally, due to insufficient numbers of androphilic men and gynephilic women in the University of Guelph participant pool, we have chosen to investigate exclusively gynephilic men and androphilic women for the purpose of this study. Five participants were removed from analysis because they indicated that they had difficulty becoming aroused by sexual images and/or videos. Two participants chose to withdraw from the study without explanation. Results are reported for the remaining 120 participants (60 females, 60 males).

Stimuli and apparatus

Stimuli were 192 digital colour photographs of nude and visibly aroused males and females (erect penises and engorged/lubricated vulvas). While many of these images came from a stimulus set used in Dawson & Chivers (2016), additional images were needed to supplement this set and were found on freely accessible Internet sites. Half of the images were males and half were females with both sets containing equal numbers of dark and light haired individuals. Images were displayed on a white background in the centre of the screen, subtending approximately 10.6° x 16.3° visual angle at a viewing distance of approximately 60 cm. A black plus (+) symbol was used for a central fixation cross subtending approximately .90° x .90° visual angle. E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA, USA) run on an Intel Core 2 Duo computer with a 50.8 cm LCD monitor (resolution: 1680 x 1050 pixels) was used to present stimuli and collect behavioural responses.

Design and procedure

The experiment consisted of a Go/No-go and rating task that were the first tasks in a larger program of study investigating sex differences in responding to sexual stimuli. Participants also completed a motivated viewing task, which will be published elsewhere. This motivated viewing task was completed after the Go/No-go and rating task and, therefore, could not have impacted the results reported herein.

Go/No-Go and rating task. As in Experiment 1, participants completed a Go/No-go task followed by a rating task (see Fig. 1). Participants alternated between blocks of 12 Go/No-go trials and 12 rating trials for a total of 16 blocks. During the Go/No-go task, participants were asked to use both index fingers to press the spacebar as quickly as they could whenever the image seen on the screen contained a person with light hair (or dark hair; the cue was switched after 8 blocks and the order counterbalanced between participants) and to otherwise not respond. Each block contained equal numbers of males and females. Images were presented for 600 ms followed by a 1000 ms fixation. During the rating trials, images were presented in the same order and for the same duration as during the previous block of Go/No-go trials followed by a blank display. Participants self-reported their subjective sexual arousal on a scale from 0 (not at all aroused) to 9 (very aroused) for each image.

Questionnaires and debriefing. Participants were asked to fill out a demographic questionnaire. This questionnaire included a modified Kinsey scale to assess self-reported sexual attraction (Kinsey Institute, Indiana University) from "exclusively attracted to females" to "exclusively attracted to males" with the option of "no socio-sexual contacts or reactions". All participants were debriefed before leaving the lab.

Results

An item analysis was used to determine the impact of response statues (Go vs. No-go) and preference (Preferred vs. Non-preferred) on the capacity of sexual images to elicit subjective sexual arousal. There is great variability in the sexual response patterns of groups of individuals (see Chivers, 2017), as well as variability in the images themselves. Across participants, each image appeared as both a preferred and non-preferred stimulus and each image was also inhibited and responded to. Therefore, we conducted a 2x2 repeated measures ANOVA to assess the impact of response status and image type on subjective sexual arousal and paired-samples t tests (two-tailed) for planned comparisons involving simple effects.

Images elicited significantly greater subjective sexual arousal when they were preferred ($M = 5.20$) compared to when they were non-preferred ($M = .78$), $F(1, 191) = 4812.55$, $p = .000$,

$\eta^2 = .96$ confirming their sexual appeal. Images elicited significantly lower levels of subjective sexual arousal when they had been seen as No-go images ($M = 2.87$) compared to when they were seen as Go images ($M = 3.11$), $F(1, 191) = 159.90$, $p = .000$, $\eta^2 = .46$ (See Figure 5). There was a significant interaction between preference and response status, $F(1, 191) = 13.56$, $p = .000$, $\eta^2 = .07$, showing the inhibited images were devalued to a greater degree when they were preferred compared to when they were non-preferred. Indeed, the capacity of preferred images previously associated with response inhibition ($M = 5.04$) to elicit subjective sexual arousal was significantly decreased compared to that of preferred images that were responded to ($M = 5.35$), $t(191) = 10.18$, $p = .000$, Cohen's $d = .21$ and non-preferred images that were associated with response inhibition ($M = .69$) also showed a significantly decreased capacity to elicit subjective sexual arousal when compared to non-preferred images that were responded to ($M = .86$), $t(191) = 7.86$, $p = .000$, Cohen's $d = .22$, but this difference was significantly greater within the preferred images.

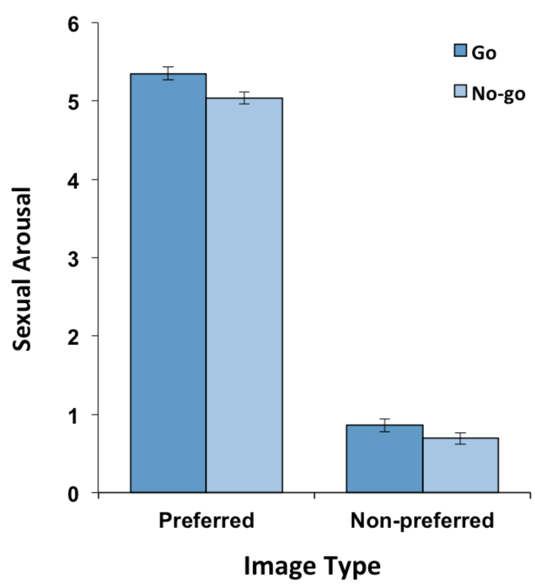

Figure 5. Experiment 2 results. Average ratings of sexual arousal for preferred and non-preferred stimuli according to trial type (Go/No-go). Error bars represent standard errors of the means.

Discussion

This pattern of results showing that images were rated as less sexually arousing when they were associated with response inhibition is consistent with findings of response inhibition impacting the attractiveness of sexual images (Ferrey et al., 2012; Driscoll, Quinn de Launay, & Fenske, 2018). Although the replication of previous results is important, our main extension was investigating if response inhibition had an impact on the capacity of images to elicit subjective sexual arousal. The results of this experiment support the conclusion that response inhibition alters the stimulus value of sexual images and decreases the capacity of the image to elicit subjective sexual arousal. This effect is greater for preferred images than for non-preferred images.

Our results here and in prior work from our lab using both positively-valenced and negatively-valenced stimuli (Frischen et al., 2012; Ferrey et al., 2012; Driscoll et al., 2018) consistently show robust differences in hedonic ratings between stimuli associated with No-go trials and those associated with Go trials, regardless of *a priori* affective status. We have taken these differences in hedonic value as evidence that response inhibition is linked to stimulus devaluation; however, we did find a significant interaction between response status and preference, with the differences between response conditions being greater for preferred than non-preferred images.

This interaction could be due to a potential floor effect within the non-preferred image category as suggested first by Ferrey and colleagues (2012). That is, non-preferred images already lack the capacity to elicit sexual arousal, which limits the extent to which their sexual potency can be reduced. Alternatively, the observed interaction could be because inhibition-related processes only reduce motivational value for appetitive but not aversive or neutral stimuli

(Veling et al., 2008; Chen et al., 2016), or because stimuli associated with behavioural approach (e.g., those to which a Go response has been made) are associated with increased value (e.g., Schonberg et al., 2014). Previous results have shown that inhibition-related decreases in stimulus value do occur for affectively negative or non-preferred sexual stimuli (Frischen et al., 2012; Ferrey et al., 2012); however, our results are nevertheless consistent with Veling and colleagues' (2008) suggestion that stimuli must be appetitive in order to be devalued to the extent that it may be that the inability of non-preferred stimuli to elicit arousal may explain the observed floor effect. The extent to which differences reported in this experiment are solely due to the affective consequences of response inhibition, rather than a combination of inhibition-linked negative affect for some stimuli and active responding-linked positive affect for other stimuli, remains a question that can only be unequivocally resolved with a study that incorporates necessary control conditions (e.g., Chen et al., 2016). This latter issue is addressed directly in Experiment 3.

The results of Experiment 2 are consistent with the view that decreases in the capacity of sexual stimuli to elicit subjective sexual arousal occur because of an inhibition-related decrease in stimulus value. This finding converges with previous work showing the negative impact of response inhibition on the affective evaluation of and motivation to seek and obtain views of sexual stimuli (e.g., Ferrey et al., 2012). It is also consistent with prior evidence that the same neural regions (i.e. orbitofrontal cortex) are implicated both in the devaluation of stimuli associated with response inhibition (e.g., Doallo et al., 2012) and in the appraisal of sexual stimuli during key stages of sexual response (e.g., Stoleru et al., 2012). These findings lend support to the idea that stimulus value represents a universal currency that aids in decision making (Levy & Glimcher, 2012) and shows that inhibition-related alterations in stimulus value have the potential to impact even biologically-significant behaviour, such as sexual response.

Moreover, typically for sexual response, it is necessary that individuals appraise stimuli as sexual and positive (Janssen et al., 2000). Previous work has focused on threat- or worry-related negative affect impacting sexual response in individuals with sexual dysfunction (e.g., Janssen & Bancroft, 2007; Toates, 2009); however, our findings show that decreases in value associated with the stimuli themselves, not just negative affect associated with sexual performance, can decrease feelings of arousal, opening new avenues for potential intervention.

Although this experiment used more explicit images than previous work (Ferrey et al., 2012; Driscoll et al., 2018), sexual response to static images may differ from response to other categories of stimuli. For example, most work done assessing self-reported subjective sexual arousal employs the use of video (Handy et al., 2018) and there are known differences between the processing of static and dynamic stimuli (e.g., Trautmann, Fehr, & Herrmann, 2009). The vast prevalence of video in pornography and high usage rates of such materials (Carroll et al., 2008) also makes clear that extending the results of Experiment 2 with video, represents an important next step in determining the extent to which the impact of response inhibition on the capacity of stimuli to elicit sexual response generalizes to another stimulus type with real-world relevance.

Finally, it is important to note that although ratings of subjective sexual arousal are lower when responses are withheld from preferred images, this does not negate the impact of a priori sexual preference, as a large difference in the capacity of preferred and non-preferred images to elicit arousal remains even after such items have been associated with response inhibition. Like many researchers investigating the role response inhibition may play in creating treatments for compulsive behaviour (i.e. drinking, eating, drug-use, gambling), Ferrey and colleagues (2012) acknowledged that their work could aid in developing treatment for individuals who experience difficulties with such behaviour as compulsively viewing pornography; however, in Ferrey and colleagues' work, as well as in all studies outlined within this thesis, there is consistently a large effect of preference on ratings and behaviour. That is, preferred sex images are significantly more attractive and cause individuals to put forth a greater effort to view images of their preferred sex when compared to non-preferred images regardless off previous response-status (Go vs. No-go) and preferred images never approach levels of non-preferred images even in the No-go conditions. Though response inhibition can impact the magnitude of ratings of attractiveness and persistence of approach-behaviour, it cannot impact the innate preferences of individuals nor do we purport that there is any evidence to suggest otherwise (for further discussion, see de Jong, 2009). In fact, there is much evidence to suggest that attempts to alter the innate preferences of individuals are ineffective and harmful (APA, 2009). This experiment, as well as the rest of the work outlined in this thesis, uses evidence of change in ratings and behaviour to support efforts to uncover how cognitive factors may play a role in creating a sexual response. As such, future research may find ways to integrate knowledge of these cognitive factors when creating interventions for those who struggle to create a sexual response, such as individuals with sexual dysfunction.

Chapter 4

Response Inhibition and Subjective Sexual Arousal: Videos

Previous work has shown that response inhibition impacts the attractiveness of and motivation to engage with sexual images (Ferrey, Frischen, & Fenske, 2012; Experiment 1: Driscoll, Quinn de Launay, & Fenske, 2018), and Experiment 2 showed for the first time that the capacity of sexual images to elicit subjective sexual arousal was decreased when images were associated with previous response inhibition. These results lend support to the devaluation-by-inhibition hypothesis. Specifically, it was hypothesized that inhibited images were rated as less arousing because inhibition-related decreases in stimulus value led to a decrease in their capacity to elicit subjective sexual arousal.

There is evidence that the neural correlates associated with devaluation-by-inhibition may also be operating in the appraisal of sexual stimuli. The orbitofrontal cortex (OFC) has been shown to be active during response inhibition and subsequent evaluation of stimuli (Doallo et al., 2012). The OFC has also been implicated in the evaluating of sexual stimuli during the appraisal phase of some models of sexual response (see Stoelru et al., 2012). Previously, it was thought that if threat- or worry-related negative affect associated with performance were present during the appraisal phase, then sexual response would be decreased (Janssen et al., 2000). The findings from Experiment 2 suggest that inhibition-related alteration in stimulus value may also decrease sexual response. Therefore, the results of Experiment 2 substantiate the rationale for further exploration into the cognitive-affective mechanisms behind sexual response and extend the investigation of the impact of response inhibition from affective and behavioural to arousal-related consequences.

When investigating subjective sexual arousal, many studies use audio-visual materials as sexual stimuli (see Kukkonen, 2015; Handy et al., 2018 for reviews). Indeed, it has been shown that sexually explicit videos are more sexually arousing than other types of explicit content including images (e.g., Laan & Everaerd, 1995). Moreover, as opposed to a single rating of arousal as seen in evaluation of images, physiological and subjective sexual arousal change over the course of the explicit video (Kukkonen, 2015; Landry, Goncalves, & Kukkonen, 2016). Therefore, it is unclear if the results found in Experiment 2, which took a one-time rating of sexual arousal, would remain consistent if measured over the duration of a video.

Additionally, there are differences in the basic processing of static and dynamic stimuli (e.g., Trautmann, Fehr, & Herrmann, 2009). Moreover, researchers investigating the impact of response inhibition on emotion and motivation have yet to use video stimuli. Thus far, the impact of response inhibition on attractiveness, motivated behaviour, and subjective sexual arousal have been investigated using images, but it remains unclear how response inhibition might impact subjective sexual arousal in the context of more dynamic video stimuli. Given the vast prevalence of video in pornography and high usage rates of such materials (Carrol et al., 2008), this represents an important area of inquiry. Here, we use sexually explicit videos to explore the impact of response inhibition on subjective sexual arousal.

There are many different types of sexually explicit video, which differ in their ability to insight feelings of sexual arousal. Videos of couples engaged in intercourse have been found to be more arousing than videos of individuals engaged in masturbation (Chivers, Seto, & Blanchard, 2007). Here, we use video of individuals engaged in solo masturbation because we wanted the methods to remain as close as possible to those seen in other tasks investigating the impact of response inhibition in the context of sexual stimuli (Ferrey et al., 2012; Experiment 1:

Driscoll et al., 2018; Experiment 2). All of these studies used preference (preferred-sex images vs. non-preferred-sex images) as an independent variable and to replicate these studies as closely as possible, we used videos containing one individual of preferred or non-preferred sex. Additionally, instead of asking participants to identify their subjective sexual arousal at one time point, we used a continuous measure of sexual arousal throughout the duration of the video because continuous measures are not impacted by impression management as significantly as discrete measures of subjective sexual arousal (Kukkonen, 2015).

Finally, up until this point, our investigation of the affective, behavioural, and arousal-related consequences of response inhibition has relied on the previous literature to show that response inhibition causes a decrease in stimulus value as opposed to responses causing an increase in stimulus value (e.g., Kiss et al., 2008); however, recently researchers have pointed out that there are other studies showing potential valuation effects that come from responding to stimuli (e.g., Schonberg et al., 2014) and are calling for the inclusion of control conditions in response inhibition tasks (Chen et al., 2016). As such, we included a passive-viewing control condition within this experiment. We predict that the inclusion of this condition will show that the capacity of videos to elicit sexual response is decreased when they have been previously inhibited, but not when they were previously associated with response, or when they were passively viewed in the control condition.

Methods

The methods used in this experiment were an adaptation of those used in Experiment 2. Informed consent was obtained from all individual participants included in the study.

Participants

One hundred eighty three undergraduate students, ages 18 to 27 years (*M* = 18.86, *SD* = 1.5), with normal or corrected to normal vision, were recruited from the University of Guelph undergraduate research participant pool to complete the experiment in exchange for course credit. Two participants were excluded from the analysis because they indicated that they had difficulty becoming aroused while viewing erotic materials. One participant was excluded because they indicated equal attraction to males and females. Results are reported for the remaining 180 participants (90 females, 90 males).

Stimuli and apparatus

Videos used during the viewing and sexual-response phase were two ten-minute films each containing exclusively nude women or men engaged in solitary masturbation. Each film was a combination of five separate two-minute clips each depicting a different individual. These videos were obtained from a stimulus set used by Huberman & Chivers (2015). 240 images depicting screenshots of these videos were used as stimuli during the response inhibition phase. Stimuli were displayed on a white background in the centre of the screen, subtending approximately 10.6° x 16.3° visual angle at a viewing distance of approximately 60 cm. E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA, USA) and PsychoPy software (Peirce, 2009) run on an Intel Core 2 Duo computer with a 50.8 cm LCD monitor (resolution: 1680 x 1050 pixels) were used to present stimuli and collect behavioural responses.

Design and procedure

Response inhibition phase.

The first phase included a Go/No-go task with 15 blocks of 16 go/no-go trials. Go/No-go trials required participants to identify whether the person depicted in the stimuli was male or female. Each block contained an equal number of male and female images. Images were each presented for 600 ms followed by a 1000 ms fixation. Two-thirds of participants were asked to press the spacebar when the sex of the image corresponded to the sex of the go cue (half of these participants were told to press the spacebar for females and half for males). The remaining one-third of participants were assigned to a control condition in which they were asked to identify whether each image depicted a male or female person, but were not asked to make or withhold any responses.

Viewing and sexual-response phase.

Participants were assigned to watch either the male or female video. During the video, using a slider at the bottom of the screen, participants were instructed to report their feelings of sexual arousal from 0 (not at all sexually aroused) to 9 (extremely sexually aroused). To operationalize subjective sexual arousal into a dependent measure, responses were averaged into one-minute bins (e.g., Landry, Goncalves, & Kukkonen, 2016) and the bin with the highest arousal was taken as the peak for each video (e.g., Huberman & Chivers, 2015).

Questionnaires and debriefing.

Participants filled out the same demographic questionnaires as in Experiment 2. All participants were debriefed and given the opportunity to ask any questions before leaving the lab.

Results

As in Experiment 2, an item-based analysis was used to determine the impact of response status (Go vs. No-go vs. Control) and preference (Preferred vs. Non-preferred) on the capacity of video clips to elicit subjective sexual arousal. An item-based analysis was chosen to control for variance associated with the sexual preferences of participants as well as variability in the videos themselves. We conducted a 2x3 repeated measures ANOVA to assess the impact of image type (preferred vs. non-preferred) and response status (Go vs. No-Go vs. Control) on subjective sexual arousal and paired-samples *t* tests (two-tailed) for planned comparisons involving simple effects.

Overall, videos showed a significantly greater capacity for eliciting subjective sexual arousal when they were preferred (M = 3.56) compared to when they were non-preferred (M = 1.49), $F(1,9) = 168.16$, $p = .000$, $\eta^2 = .95$, confirming their sexually appealing quality. There was also a main effect of response status, $F(2,18) = 32.71$, $p = .000$, $\eta^2 = .78$ and a significant interaction between preference and response status, $F(2, 18) = 20.55$, $p = .000$, $\eta^2 = .70$ indicating a greater effect of response status when videos were preferred compared to when they were non-preferred (See Figure 6). Indeed, when videos were preferred, their capacity to elicit subjective sexual arousal was significantly decreased when they were associated with response inhibition (No-go, $M = 3.01$) compared to when they were associated with response (Go, $M = 3.92$), $t(9) = 8.05$, $p = .000$, Cohen's $d = .93$ and when they were viewed in the control condition ($M = 3.73$), $t(9) = -7.21$, $p = .000$, Cohen's $d = .83$. Additionally, when videos were preferred, there was no significant difference in their capacity to elicit subjective sexual arousal when they were responded to compared to when they were viewed in the control condition, $t(9) = 1.71$, $p = .121$. The capacity of non-preferred videos to elicit subjective sexual arousal was not significantly impacted when they were associated with response inhibition (*M* = 1.42) compared to when they were viewed in the control condition (*M* = 1.52), $t(9) = -1.15$, $p = .280$, nor were there differences in the capacity of non-preferred videos to elicit subjective sexual arousal when they were inhibited compared to when they were responded to (*M* = 1.42) $t(9) = 1.26$, $p = .240$ or between non-preferred videos when they were responded to compared to when they were viewed in the control condition, $t\ (9) = .05$, $p = .963$.

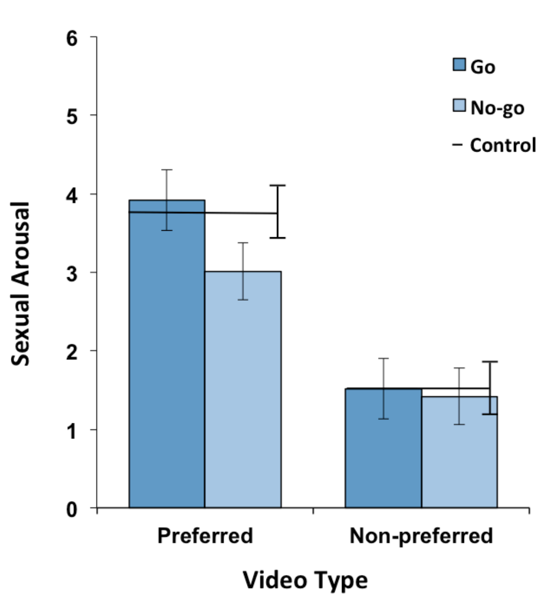

Figure 6. Experiment 3 results. Average ratings of sexual arousal for preferred and non-preferred stimuli according to trial type (Go/No-go/Control). Error bars represent standard errors of the means.

Discussion

The devaluation-by-inhibition hypothesis was used to predict that the capacity for videos to elicit subjective sexual arousal would be decreased when the videos were associated with previous response inhibition compared to when they were previously associated with response or viewed in the control condition. Indeed, the results of this experiment offer further support for this hypothesis. Not only do these results replicate previous findings, they extend the examination of the impact of response inhibition to dynamic stimuli. Previously, research investigating devaluation-by-inhibition had only used images; however, especially when examining the impact of response inhibition on sexual arousal, it is important to consider potential differences that may arise when using more dynamic stimuli such as video (e.g., Laan & Everaerd, 1995). For the first time here, we have shown that response inhibition decreases the capacity of videos to elicit subjective sexual arousal.

Additionally, there have been mixed results in the response inhibition literature. Some researchers have claimed that responding to stimuli may result in an increase in valuation (e.g., Schonberg et al., 2014) and that differences seen between Go and No-go conditions are due in part to this positive affect associated with response (Chen et al., 2016). Previous work leading to the devaluation-by-inhibition hypothesis had shown attentional inhibition of images resulted in devaluation compared to images that were attended to as well as when compared to novel baseline images (e.g., Raymond et al., 2003); however, whether the devaluation of sexual stimuli seen as a result of response inhibition is exclusively due to a decrease in stimulus value associated with response inhibition and not due to a combination of this negative affect combined with response-linked positive affect could not be ascertained without the use of appropriate control conditions. Here, we included a control condition; we exposed participants to the Go/No-go task, asking them to view the screenshots from the videos but not to respond to any image category. They then viewed their assigned video and rated their levels of sexual arousal. This control condition represented an adequate condition from which to discern whether differences between Go and No-go conditions in previous work was due to differences between Go and passive-viewing conditions, differences between No-go and passive-viewing conditions, or both. We found that there were differences exclusively between No-go and passive-viewing conditions, while there were no differences seen between Go and passive-viewing conditions. This indicates that the inhibition-related decrease in stimulus value is driving the effect.

We did find a significant interaction between response status and preference, with the differences between response conditions being greater for preferred than non-preferred videos. This is similar to findings of Experiments 1 and 2 and could be a result of different factors. First, is a potential floor effect as suggested first by Ferrey and colleagues (2012); that is, non-preferred videos are not very sexually arousing to begin with. Alternatively, the interaction could be due to inhibition-related processes reducing motivational value for appetitive but not aversive or neutral stimuli (Veling et al., 2008; Chen et al., 2016); however, given previous results showing devaluation for positive, negative, and neutral stimuli (Frischen et al., 2012) as well as the likelihood of this interaction being due to a floor effect, we do not think this is the case. Although we do not think that response inhibition impacts appetitive and aversive stimuli differently, given that sexual arousal is a unidirectional construct, unlike affective valence, it could be that a stimulus needs to be able to elicit arousal in order to be devalued. The inability of non-preferred videos to elicit sexual arousal could explain why an inhibition-related decrease in stimulus value did not manifest itself with non-preferred items.

Overall, this experiment has shown that videos are less sexually arousing when they have been previously inhibited. This effect of response inhibition could be due to a decrease in stimulus value leading to less-positive evaluations during the appraisal phase of sexual response (Janssen et al., 2000). It is hypothesized that when participants were asked to report their feelings of subjective sexual arousal, their previous response inhibition of the stimuli they were viewing caused their experience of sexual arousal to be decreased compared to individuals who responded to the stimuli they were viewing; however, because we employed an item analysis, it is not possible to make conclusions on an individual level. We chose to use an item analysis here because there is such variability in what individuals and groups of individuals find arousing (Chivers, 2017). Examining the videos themselves as members of each condition lessened this variability from individual participants, but does not allow for conclusions to be made about the experience of the individuals. More research is needed to explore if individual differences impact how individuals or groups of individuals respond to response inhibition. What can be concluded here is that both images (Experiment 2) and videos (Experiment 3) were rated as less sexually arousing when they had previously been inhibited compared to when they were previously viewed but not associated with response inhibition. This indicates that response inhibition decreases the capacity of sexual stimuli to elicit subjective sexual arousal.

Chapter 5

General Discussion

Goal-directed behaviour allows humans to effectively engage in the world around us, and requires the prioritization of relevant information as well as the inhibition of distracting information. Attention is a set of neural mechanisms through which goal-directed behaviour operates; attention directs the processing of stimuli that are relevant and inhibits the processing of stimuli that impede goal-directed behaviour (Raymond, 2009). It has long been established that emotion guides attention (Eastwood, Smilek, & Merikle, 2001; Vuilleumier & Schwartz, 2001) and more recently, it has also been shown that attention and emotion are bi-directionally linked (Vuilleumier, Armony, & Dolan, 2003). Specifically, stimuli that are ignored or to which a response is withheld, are liked less than stimuli that have been targets of attention or response; this effect is thought to operate through inhibition (see Fenske & Raymond, 2006; Raymond, 2009; Gollwitzer et al., 2014 for reviews).

The devaluation-by-inhibition hypothesis has been put forward to explain this inhibition-related stimulus devaluation. It states that when a stimulus is ignored or a response is withheld, a mental representation of the inhibitory status of the stimulus is encoded with the representation of this stimulus, decreasing its associated stimulus value; when the stimulus is encountered subsequently, this encoded stimulus value is re-instantiated which leads to decreases in reported liking as well as decreases in approach behaviour (Raymond, 2009; Ferrey et al., 2012). Though there have been many studies providing support for the devaluation-by-inhibition hypothesis, another line of work hypothesized that decreases in approach behaviour subsequent to response inhibition is due to a global brake on motor activity (see Chambers, Garavan, & Bellgrove, 2009, and Stinear, Coxon, & Byblow, 2009 for review). These competing hypotheses, devaluation-by-inhibition and global-brake, predicted the same outcome for approach behaviour following response inhibition, but had different implications. The alteration in stimulus value predicted by devaluation-by-inhibition may represent a fundamental currency through which goal-directed behaviour operates (Levy & Glimcher, 2012) and could have implications for other human experiences, such as reward-based behaviour including sexual arousal. Sexual arousal is a motivational state that is impacted by cognitive mechanisms including attention (Janssen et al., 2000; de Jong, 2009). In order to explore whether response inhibition has arousal-related consequences, we first needed to determine how response inhibition was leading to decreases in motivated behaviour.

In Experiment 1, we designed new methods to test the competing hypotheses for behaviour change following response inhibition. Previously, Ferrey, Frischen, and Fenske (2012) showed that sexual images were rated as less attractive following response inhibition in a Go/No-go task. They also showed that participants were less willing to press a key to obtain views of their preferred images after they had been inhibited. Both the devaluation-by-inhibition and global-brake hypotheses predicted this decrease in approach behaviour following response inhibition; however, these two hypotheses predicted opposite outcomes for avoidance-motivated behaviour. Global-brake predicted a brake on all motor activity, and thus predicted fewer key presses following response inhibition no matter if the stimuli were appetitive or aversive. On the other hand, devaluation-by-inhibition predicted an *increase* in avoidance behaviour because of a decrease in stimulus value. In fact, this is what we saw; participants rated stimuli as less attractive, pressed a key fewer times to obtain views of preferred stimuli, and pressed a key more times to avoid viewing non-preferred stimuli when stimuli had been inhibited instead of when they had been targets of response (Experiment 1: Driscoll et al., 2018).

With this evidence for the devaluation-by-inhibition hypothesis, we were able to move onto exploring the relationship between response inhibition and sexual arousal. The sexual information-processing model of sexual response holds that there are two phases to sexual response: an appraisal stage and a response generation phase (Janssen et al., 2000). It is during the appraisal phase that we suspect response inhibition may have consequences. The presence of threat- or worry-related negative affect during this phase has been shown to decrease sexual response (Janssen et al., 2000) and common neural correlates of the evaluation of sexual stimuli (i.e. the orbitofrontal cortex: Stoleru et al., 2012) were also implicated in the affective consequences of response inhibition (Doallo et al., 2012). We predicted that inhibition-related alteration in stimulus value might have similar consequences for subjective sexual arousal that it did for other motivated behaviour and evaluations of attractiveness (Experiment 1). In Experiment 2, we built on previous work exploring the affective consequences of response inhibition; we asked participants to complete a Go/No-go task and rate their sexual arousal in an affective evaluation task. We found that when images were seen as No-go images, that is, when responses were withheld from these images, they were rated as less arousing than when they were the targets of response. These findings suggested that the inhibition-altered stimulus value might have the ability to decrease sexual response.

In Experiment 3, we extended the findings of Experiment 2 with more dynamic video stimuli. There are differences in sexual arousal over time when viewing sexually explicit video (Kukkonen, 2015; Landry et al., 2016) and dynamic stimuli are more arousing than static stimuli (e.g., Laan & Everaerd, 1995). Here, we replicated and extended our previous findings by showing that withholding responses to screenshots of to-be-viewed video decreased the capacity of the video to elicit subjective sexual arousal compared to when the screenshots had been targets of response. Moreover, we also included a passive-viewing control condition to show that differences in the capacity to elicit subjective sexual arousal based on response status were due to inhibition-related devaluation and not response-related valuation as suggested by some researchers (e.g., Schonberg et al., 2014; Chen et al., 2016).

Overall, these results have important implications both academic and applied. Academically, these results broaden the implications of the devaluation-by-inhibition hypothesis and further knowledge about the basic cognitive mechanisms involved in sexual response. These results show that response inhibition has implications for a wider range of thoughts and behaviour than originally realized. Specifically, response inhibition may impact more fundamental reward-based behaviour, such as sexual arousal. On an applied level, this basic knowledge obtained may eventually aid in designing interventions for individuals struggling with compulsive sexual behaviours or those struggling to produce a sexual response.

Devaluation-by-inhibition: Attraction and Motivated Behaviour

Competing accounts of inhibition-related stimulus devaluation

Overall, this thesis provides further evidence for the devaluation-by-inhibition hypothesis, which states that the affective and behavioural consequences of response inhibition stem from a decrease in encoded stimulus value. Indeed, this inhibition-related decrease in stimulus value has been observed across a variety of tasks such as attentional (e.g., Raymond et al., 2003; 2005; Fenske et al., 2004; 2005; Kiss et al., 2007; Martiny-Huenger et al., 2014), response- (e.g., Frischen et al., 2012; Ferrey et al., 2012; Kiss et al., 2008), and memory-related inhibition (e.g., De Vito & Fenske, 2017; Vivas et al., 2016), with a wide-variety of stimuli, including motivationally relevant stimuli, such as sexual images (Ferrey et al., 2012). Recently, behavioural consequences of response inhibition have also been reported, with decreases in behaviour toward appetitive stimuli following response inhibition (e.g., Houben et al., 2011).

Some researchers had suggested that decreases in approach behaviour following response inhibition might not be caused by a decrease in stimulus-encoded value. Instead, they linked this effect to evidence of neurophysiological suppression of motor activity (Sohn, Wiltz, & Hallet, 2002), including reductions in cortico-spinal excitability and diminished motor-evoked potentials (e.g., Hoshiyama et al., 1996; Leocani et al., 2000). These researchers proposed that decreases in approach behaviour subsequent to response inhibition were consequences of reductions in motor-related neural activity are thereby were thought to underlie reductions in the propensity to execute a specific behaviour (see Chambers, Garavan, & Bellgrove, 2009, and Stinear, Coxon, & Byblow, 2009 for review; Rubia et al., 2001, Coxon, Stinear, & Byblow, 2006). This line of work hypothesized a global brake on behaviour following response inhibition.

In this thesis, we tested the competing hypotheses purporting to explain the behavioural consequences of response inhibition and showed unequivocal support for the devaluation-by-inhibition hypothesis over the global-brake hypothesis. In order to do this, we created new methodology to investigate avoidance motivation. Not only did the Experiment 1 aid in determining the underlying mechanisms of inhibition-related behaviour change, this represented the first exploration into avoidance behaviour for this effect. Previously, it had been shown that response inhibition impacted approach-related behaviour toward appetitive stimuli such as alcohol (Houben et al., 2011), food (Veling et al., 2017 for review), and gambling behaviour (Stevens et al., 2015), but it was unclear whether response inhibition would impact avoidance related behaviour as well. The finding that stimulus-based response inhibition can negatively impact ratings of attractiveness, reduce their capacity to elicit behavioural approach, and increase their capacity to elicit behavioural avoidance suggests that changes in both subjective evaluations and motivated behaviour may be linked to change in representation of stimulus value common to both processes.

Beyond devaluation-by-inhibition and global-brake, other competing hypotheses exist to explain inhibition-related stimulus devaluation. For instance, Dittrich and Klauer (2012) suggest that devaluation of distractors or task-irrelevant stimuli is due to evaluative coding of the stimuli during task instructions. The evaluative-coding hypothesis states that simply instructing participants to withhold a response from some stimuli and respond to others impacts their affective rating. Dittrich and Klauer (2012) propose that distractors are coded as negative and targets as positive due to prior associations linking avoidance to negative items and approach to positive items (Chen & Bargh, 1999); however, De Vito, Al-Aidroos, & Fenske (2017) directly tested the devaluation-by-inhibition and evaluative-coding hypotheses against each another in an experiment that tracked an event-related potential (ERP) commonly associated with inhibition (i.e., the Pd component).

De Vito and colleagues had participants view sets of two abstract shapes on a screen and instructed them to ignore one and memorize the other. Participants were then presented with sets of two distracting stimuli; one of the stimuli were coloured to match the memorized item, and the other to match the ignored item. Participants were subsequently asked to rate the cheerfulness of the memorized and ignored distractors as well as novel shapes. De Vito and colleagues predicted that distractors that matched the memorized item would require more inhibition than the ignored items in order for participants to maintain the representation of the memorized item in working memory; therefore, they predicted that memory-matching distractors would be rated as less cheerful because of inhibition-related devaluation. Conversely, the evaluative-coding hypothesis predicted that the distractors matching the previously ignored item, the memory-nonmatching distractors, would be rated as less cheerful because they had previously been coded negatively when participants were instructed to ignore them. Overall, De Vito and colleagues found ERP evidence that inhibition was being applied to distractors that matched the colour of a target being held in working memory. Additionally, these memory-matching distractors were rated more negatively than memory-nonmatching distractors. The authors attributed these findings to inhibition-related devaluation, and showed that their findings were inconsistent with the evaluative-coding hypothesis (De Vito et al., 2017).

The experiments in this dissertation were not designed to test predictions against the evaluative-coding hypothesis. Specifically, participants were explicitly instructed to respond to some stimuli and to refrain from responding to others. Proponents of the evaluative-coding hypothesis may suggest that our findings are due to negative associations as an artefact of the instructions given to participants (e.g., Dittrich & Klauer, 2012); however, we consider the evidence of experiments such as De Vito and colleagues (2017) to suggest that our observed inhibition-related decreases in affective evaluations, motivated behaviour, and sexual response are due to decreases in stimulus value and not to task instructions.

Although devaluation-by-inhibition has been tested against both the global-brake and evaluative-coding hypotheses, the role of conflict in inhibition-related stimulus devaluation is a question that has yet to be resolved. For instance, it has been shown that neutral words were rated more negatively when they were associated with conflict during a Stroop task than when they were associated with nonconflict (Fritz & Dreisbach, 2013). Some researchers have taken the affective consequences of conflict and tied them to inhibitory process. For example, in one study, researchers investigated the Uncanny Valley effect (Ferrey, Burleigh, & Fenske, 2015).

This effect shows that stimuli that resemble humans but are not completely human (i.e. images with animal or robot likeness) are disliked. The authors suggest that this effect is due to inhibition of conflicting representations of the image and they showed that dislike was greatest when stimulus-related conflict was greatest, that is, when it was most difficult to distinguish if the image was human or not (Ferrey et al., 2015). These researchers saw inhibition and conflict as tightly linked; however, other researchers have suggested inhibition-related devaluation is in fact an effect driven exclusively by conflict and not inhibition (Chetverikov & Kristjánsson, 2016). Chetverikov and Kristjánsson (2016) argue that affect is related to the predictability of stimuli; they propose that negative affect arises if uncertainty is present (if correct predictions are hard to make), if something difficult to predict based on past experiences, or if two predictions do not agree (i.e. conflict is present). Specifically, they suggest that distractors in visual search tasks are disliked compared to targets because the conflict they create is associated with negative affect (Chetverikov & Kristjánsson, 2016); however, it is not clear that negative affect generated by conflict is sufficient to cause decreases in subjective sexual arousal as seen in this dissertation.

Here, we examined the impact of response inhibition on subjective sexual arousal. Some researchers have investigated the role of negative affect on sexual response. In fact, many models of sexual response cite threat- or worry-related negative affect as a factor that may decrease sexual response (e.g., Janssen et al., 2000); however, research on more global feelings of negative affect such as guilt and shame, or mood-related negative affect showed mixed results with regards to having an impact on subjective sexual arousal (Peterson & Janssen, 2007). It is possible that response inhibition is leading to a decrease in sexual response through negative affect. For instance, stimulus-associated negative affect present during the evaluation phase of sexual response (Janssen et al., 2000) may be contributing to the observed decrease in subjective sexual arousal; however, with the methods used in this dissertation, it is impossible to disentangle if this negative affect is a product of decreased inhibition-related stimulus value, conflict, or a combination of both. Additionally, given the conflicting evidence of the impact of negative affect unrelated to threat or worry on sexual response (e.g., Peterson & Janssen, 2007), it is unclear whether more general negative affect alone is sufficient to impact sexual response.

Instead of attempting to disentangle the affective consequences of conflict and inhibition and speculate on their relative roles in decreasing sexual response, it may be more fruitful to consider how sexual stimuli are evaluated. For instance, it has been shown that orbitofrontal cortex activation is associated with the evaluation of sexual stimuli (e.g., Stoleru et al., 2012; Ishai, 2007). Doallo and colleagues (2012) also showed that OFC activation is associated with devaluation-by-inhibition. This overlap in neural evidence combined with the other evidence we've shown for devaluation-by-inhibition (i.e. decreased evaluations of attractiveness, decreased approach motivation, and increased avoidance motivation following response inhibition) implicate response inhibition in the findings of decreased capacity for inhibited stimuli to elicit subjective sexual arousal. Indeed, a decrease in stimulus value impacting the evaluation of sexual stimuli is consistent with previous theories of sexual response (i.e. Stoleru et al., 2012; Janssen et al., 2000). The role of both conflict and stimulus-based negative affect in sexual response could represent an area for future research.

With regards to understanding more about stimulus devaluation itself, there have been some competing ideas for which type of stimuli can be devalued. For instance, some authors suggest that only positive stimuli can be devalued because they are previously associated with approach behaviour (e.g., Veling et al., 2008; Chen et al., 2016). In contrast, the findings of Experiment 1 support previous research that showed devaluation of positive, negative, and neutral stimuli (Frischen et al., 2012) by finding that both preferred and non-preferred images were judged as less attractive when they were inhibited compared to when they were targets of response. This result replicated previous research showing devaluation of both appetitive (preferred) and aversive (non-preferred) images (Frischen et al., 2012; Ferrey et al., 2012); however, unlike affective valence, both approach behaviour and sexual arousal are constructs that are unidirectional in nature. More specifically, affective valence is bidirectional because it can vary from positive to negative with neutral affect represented between the two extremes. In contrast, approach behaviour is unidirectional because a person either is engaged in a behaviour or they are not. Similarly, neutral sexual arousal levels are equivalent to zero sexual arousal; it is also a unidirectional construct that varies only from "not at all" to "very". Adding the avoidance measure to the key press task in Experiment 1 was a way to get around the floor effect seen by Ferrey and colleagues (2012) when they were studying the impact of response inhibition on approach behaviour.

In their study, Ferrey and colleagues (2012) found that approach behaviour was impacted for preferred stimuli only, but there was no effect of response inhibition on non-preferred stimuli. Authors attributed this interaction to difficulty with decreasing a person's motivation to press a key to view images of their non-preferred sex when their motivation cannot decrease below zero motivation. By creating a measure of avoidance motivation, we were able to see the impact of response inhibition in the context of non-preferred stimuli. In fact, we saw the opposite type of floor effect while exploring avoidance behaviour; response inhibition did not increase participants' motivation to obscure images of their preferred sex because they are not motivated to obscure images of their preferred sex to begin with. Importantly, this experiment was able to show that response inhibition still impacts the stimulus value of non-preferred stimuli when measured in a way that allows the effect to be observed.

The significant interactions we observed in Experiments 2 and 3 suggest that we are facing a similar difficulty with floor effects when measuring the capacity of stimuli to elicit subjective sexual arousal because sexual arousal is a unidirectional construct; it is difficult for response inhibition, or any intervention, to decrease sexual arousal in the context of viewing non-preferred stimuli. It is impossible to decrease an arousal level to less than “not at all”. Additionally, unlike with motivated behaviour, it is unclear how to design an experiment to control for the unidirectional nature of sexual arousal; however, by adding a passive-viewing control condition in Experiment 3, we were able to compare whether the significant impact of response inhibition seen in previous experiments was due to an inhibition-altered decrease in stimulus value exclusively, or if there was some impact of response valuation impacting Go stimuli (e.g., Schonberg et al., 2014). We found that, within preferred videos, only videos that had been previously associated with response inhibition, that is No-go stimuli, were rated as significantly different than control videos. Specifically, preferred No-go videos were associated with lower levels of subjective arousal than passively-viewed videos and there were no significant differences between passively-viewed and Go videos. All of these differences were observed within preferred videos, and we attribute the lack of differences observed in non-preferred videos to a floor effect given the unidirectional nature of sexual arousal. Importantly, we do not conclude that response inhibition does not impact the stimulus value of non-preferred stimuli, but that we may need to find a different way to measure this impact given the nature of the construct.

Additionally, given conflicting findings in the literature such as the impact of response inhibition on negative and neutral stimuli (e.g., Veling et al., 2008; Chen et al., 2016), it is important to note that our findings showed consistency. That is, in this thesis we found a consistent impact of response inhibition on attractiveness, behaviour, and subjective sexual arousal. We are aware of the current replication crisis in psychology (e.g., Maxwell et al., 2015) as well as more specific issues with replicating previous findings of the impact of inhibition on motivated behaviour. For instance, Bowley et al. (2013) and Jones and Field (2013) failed to replicate the reduction in alcohol consumption seen by Houben and colleagues (2012). The work in this thesis aimed to replicate and extend previous work by Ferrey and colleagues (2012). We started in Experiment 1 by replicating and extending this work within the same methodology used by Ferrey and colleagues (2012) and continued on to broaden the exploration to include other methods and analyses. Though we used different methodology and analyses across experiments, we showed consistency in the major findings.

In Experiments 2 and 3, we used item-based analyses. Most commonly, psychologists use participant-level analyses, which involve computing a mean for each experimental condition for each participant, typically averaging across the various stimuli within a condition. In this type of analysis, conclusions are generalized to other individuals who might share similar characteristics as the participants in the study, but random effects from the stimuli themselves are ignored. Alternatively, item-based analyses involve computing a mean for each stimulus that represents an average response across participants. This type of analysis considers the impact that variation in stimuli might have on effects, but cannot be generalized to a larger population of participants. Some researchers have chosen to employ item-based analyses when, for instance, the variance associated with their stimuli may be confounding their variable of interest. For example, De Vito

& Fenske (2017) conducted an experiment to investigate the impact of inhibition on affective ratings of words and images in a Think/No-Think task. During this task, participants were asked to rate words and images that ranged from unpleasant (e.g., gun) to pleasant (e.g., baby). They reasoned that the a priori affective status of the items might impair their ability to determine the source of any effect they might find if they used participant-based analyses and instead conducted item-based analyses (De Vito & Fenske, 2017).

Similarly, in Experiments 2 and 3, we chose to use item-based analyses because of the large variation in what individuals find arousing. Indeed, even within groups of individuals sharing the characteristics of sex and sexual attraction (e.g., androphilic females), there are large individual differences in what individuals find arousing (see Chivers, 2017 for review). We used stimuli in both Experiment 2 and 3 that each contained a different individual and in Experiment 3, a different setting. In a review of devices and methods used to measure female sexual arousal, Kukkonen (2015) noted the limitation of preselected stimuli is that these stimuli may be more or less arousing to some participants.

By conducting an item-based analysis, we aimed to ensure that any differences in arousal that we saw were due to our manipulation and not to the *a priori* capacity of the stimulus to elicit sexual arousal. We thereby obtained an average for each item as a preferred Go, No-go, and control item and as a non-preferred Go, No-go, and control item. Indeed, when participant-based analyses were completed on the data from Experiment 2 and 3 as a comparison, the same patterns emerged, but the results were non-significant due to high subject-level variance. By collapsing the ratings across participants to yield one mean per condition for each item instead of collapsing across items to yield one mean per condition for each participant, we were able to more clearly make conclusions about the impact of response inhibition on the capacity for the sexual stimuli to elicit arousal, *per se*.

Although we showed consistency across the two studies using item-based analyses and the participant-based analyses in Experiment 1, we cannot generalize our conclusions from Experiments 2 and 3 to a larger population of individuals. We were able to show that response inhibition decreases the capacity of sexual stimuli to elicit subjective sexual arousal, but in order to make participant-level conclusions, we will need to continue to explore ways to select stimuli in a way that is better tailored to individual participants and would thereby yield effects that are better detectable through participant-level analyses. In order to do this, new methods need to be created to account for variability that exists due to individual differences in what individuals find arousing. For example, if participants were able to bring in or select their own stimuli that they found maximally arousing (as suggested in Kukkonen, 2015) within preferred and non-preferred categories, we may be able to focus on participant-level effects.

Application and future considerations

With regards to impacting motivated behaviour, the findings of Experiment 1 show that attractiveness of and motivation to view sexual images can be decreased. Ferrey et al. (2012) discussed how their work originally showing these effects could be used to aid individuals with problematic sexual behaviour, such as compulsive viewing of pornography. Repeated exposure to Go/No-go tasks, known as inhibitory control training (ICT), has been shown to be an effective treatment for other chronic behaviour, such as problematic alcohol, food, drug, and gambling behaviour (Jones et al., 2016). This thesis provides support for this idea, as it shows that the encoded stimulus value and subsequent approach behaviour is decreased after applying response inhibition to highly motivational images.

However, the literature on ICT is still young and has produced varied results. Inhibitory control is defined as the “capacity to overrule impulsive reactions in order to regulate behaviour in line with long-term goals” (Allom et al., 2015, p. 168). It is thought that inhibitory control can be trained to decrease approach behaviour toward appetitive stimuli such as food and drugs in individuals with associated disorders (e.g., substance use, obesity; Jones et al., 2016). In fact, two meta-analyses have shown that ICT has an effect on health behaviour (Allom et al., 2015; Jones et al., 2016), but the mechanism behind this effect is unclear. Allom et al. (2015) showed that Go/No-go tasks induced the most consistent change in behaviour compared to other inhibitory control tasks, such as the Stop-signal task. This provides support that it might be altered stimulus value, not increased inhibitory control driving these effects. If it is the case that decreases in stimulus value are driving the impact of response inhibition on any significant reduction in behaviour seen in ICT, our results provide evidence that ICT may be a viable option for decreasing behaviour such as compulsive viewing of pornography. Indeed, our results have given support to the idea that stimulus value is a universal currency that can flexibly impact behaviour.

Moreover, both Allom (2015) and Jones and colleagues (2016) reported that ICT has shown short-term effects in the laboratory, but long-term or more generalizable effects are more inconsistent. It remains to be seen if the impact of response inhibition on motivated behaviour observed in this thesis and in previous work (Ferrey et al., 2012) has long-term implications or if these findings would be generalizable outside of the laboratory; however, our results suggest that tasks aimed at reducing stimulus value, such as response inhibition tasks, show promise in their ability to impact even biologically-significant behaviour such as sexual arousal.

Including further investigation of long-term impact and generalizability, there are other applications of this work that remained to be explored. For instance, this thesis aims to expand knowledge of cognitive-affective factors involved in sexual response. Ultimately, this may aid individuals who have difficulty producing such responses, such as those with sexual dysfunction through application of the knowledge obtained herein. With the new insights into the mechanisms behind inhibition-related behaviour change gleaned from Experiment 1, we were able to expand the exploration of the impact of response inhibition in Experiments 2 and 3 from affective and behavioural to arousal-related consequences. This also increased the basic knowledge of the types of cognitive-affective factors that may reduce sexual response (i.e. inhibition-altered stimulus value), which could be tied into existing models (e.g., Stoleru et al., 2012) in future research to expand sites for clinical intervention.

Additionally, although response inhibition could help in controlling compulsive sexual behaviour, it is crucial to note that in all work investigating the impact of response inhibition on affect, behaviour, and arousal, including the work in this thesis, there is consistently a large effect of preference. Individuals have consistently shown that preferred stimuli elicit significantly greater ratings of attractiveness and subjective sexual arousal as well as motivated behaviour. Sexual orientation and what individuals find attractive are innate preferences with strong biological underpinnings (Le Vay, 2017). Response inhibition impacts affect, behaviour, and arousal, but it cannot impact the innate preferences of individuals nor do we purport that there is any evidence to suggest otherwise (for further discussion, see de Jong, 2009). In fact, attempts to influence an individual's sexual orientation are ineffective and cause harm (APA, 2009).

Devaluation-by-inhibition: Subjective Sexual Arousal

Stimulus value as universal currency

This thesis also furthers knowledge about how sexual response operates. Sexual arousal is a motivational or emotional state (Everaerd, 1988) that is impacted by attention (see de Jong, 2009 for review). Typically, sexual stimuli must be appraised as sexual and positive (Janssen et al., 2000) and neural correlates of this evaluation of sexual stimuli (orbitofrontal cortex) show overlap with those seen in neuroimaging studies investigating the devaluation-by-inhibition effect (Stoleru et al., 2012; Doallo et al., 2012). Additionally, previous work has suggested that threat- or worry-related negative affect can impede sexual response leading to sexual dysfunction (e.g., Janssen & Bancroft, 2007; Toates, 2009). Here, we have shown that inhibition-altered stimulus value may have the capacity to decrease sexual arousal. This expands the basic knowledge of the type of cognitive-affective factors that may impede sexual response (i.e. inhibition-altered stimulus value) and could potentially open up new avenues for intervention. Moreover, it supports the idea that stimulus value may be a universal currency (Levy & Glimcher, 2012) and that this universal currency may impact even the most fundamental forms of behaviour, including sex.

Experiment 2 represented the first instance in which the impact of response inhibition on subjective sexual arousal was measured. These results showed that the capacity of images to elicit subjective sexual arousal was decreased when images were associated with response inhibition than when they were viewed as targets of response. While these results expanded the reaches of the devaluation-by-inhibition hypothesis to include arousal-related consequences, this experiment was done using static images. Static stimuli are processed differently (e.g., Trautmann, Fehr, & Herrmann, 2009) and are found to be less arousing than dynamic stimuli (e.g., Laan & Everaerd, 1995). Experiment 3 replicated and extended the findings of Experiment 2 by investigating the capacity of video clips to elicit subjective sexual arousal after images from these videos had been inhibited compared to when they had been targets of response, or passively-viewed as a control measure.

Although Experiments 1 and 2 showed alteration of ratings of attractiveness, motivated behaviour, and subjective sexual arousal, these differences were comparisons between inhibited items and items that were targets of response. Some researchers have claimed that differences seen between Go and No-go conditions are due in part to positive affect associated with response (e.g., Schonberg et al., 2014; Chen et al., 2016). In Experiment 3, we included a control condition to assess if there were any differences in subjective sexual arousal attributable to positive affect associated with responding to stimuli. We found that there were differences exclusively between response inhibition and control conditions, while there were no differences seen between response and control conditions, indicating that the inhibition-related decrease in stimulus value is driving the effect.

Future considerations

While this thesis answered many questions about the devaluation-by-inhibition hypothesis and explored the impact of response inhibition on subjective sexual arousal, there are still many interesting areas for exploration. For instance, Experiments 2 and 3 employed item-based analyses to determine the impact of response inhibition on sexual arousal. We chose to do this because of the variability associated with what individuals find sexually arousing generally (see Chivers, 2017 for review) as well as potential differences in the videos themselves. By employing an item analysis, we were able to compare each video when it was viewed as part of each of the three conditions, minimizing the variability due to individual differences in participants. This allowed us to determine more clearly the impact of response inhibition; however, it does not allow us to make conclusions about the sexual arousal of individuals *per se*. Future work should aim to investigate these questions in light of these individual differences, for example, by creating methodologies that would allow for participants to bring in stimuli that they identified as arousing (Kukkonen, 2015).

There are also individual differences in how individuals and groups of individuals process and respond to sexual stimuli. For instance, sex and sexual attraction interact to produce differences in response to sexual stimuli. Sex-specificity refers to a pattern of sexual response that is dependent upon the sexual relevance of stimuli (i.e. preferred vs. non-preferred sex; Chivers, 2017). Overall, it has been shown that men attracted to women (gynephilic men) and men attracted to men (androphilic men) have response patterns that are largely sex-specific, meaning that they show signs of increased arousal when exposed to their preferred sex, but not when exposed to their non-preferred sex (e.g., Chivers et al., 2004). In contrast, women, specifically women attracted to men (androphilic women), most often show response patterns that are more nonspecific when compared to other groups; however, many studies show that women attracted to women (gynephilic women) have response patterns that are more sex-specific (e.g., Rieger et al., 2015) and there have been a handful of studies showing sex-specific responses from androphilic women as well (e.g., Ponseti et al., 2006; Spape et al., 2014). The reason for the differences in sex-specificity are currently unknown, but there has been much work done in the area of sexual information-processing and arousal to try to account for these differences (Dawson & Chivers, 2014; Snowden & Gray, 2013; Chivers, Seto, & Blanchard, 2007; Spiering & Everaerd, 2007; Prause, Janssen, & Hetrick, 2008; Janssen, Everaerd, Spiering, & Janssen, 2000). It is possible that response inhibition may impact the arousal patterns of groups of individuals differently, which would be an interesting area for exploration. Additionally, the research herein explored the impact of response inhibition exclusively on subjective sexual arousal but there may be differences between subjective and physiological sexual response. Continuing to explore the reaches of the effects of devaluation-by-inhibition by employing psychophysiology measures such as thermographic imaging could shed light on whether response-related negative affect may actually contribute to sexual dysfunction.

Conclusion

This thesis expands the impact of devaluation-by-inhibition to show that the associated inhibition-related decrease in stimulus value affects a wider range of behaviour than originally thought. First, we showed that response inhibition leads to behavioural consequences through a decrease in stimulus value, not through a global brake on neural motor activity. We also expanded the consequences of devaluation-by-inhibition to include increases in avoidance motivation for the first time, addressing a void in the existing literature. Moreover, we broadened the impact of response inhibition from affective and behavioural consequences to show that response inhibition also impacts the capacity to elicit subjective sexual arousal. These finding suggest that stimulus value may be a universal currency through which response inhibition can impact even fundamental reward-based behaviour such as sex. This thesis opens new doors for further exploration into the cognitive-affective mechanisms of sexual response and points to potential areas for intervention with individuals experiencing sexual dysfunction.

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