Testing a goal-driven account of involuntary attentional capture by motivationally salient stimuli

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Declaration

I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

Signature: …………………………………

C.R.H. Brown

Acknowledgments

It is impossible to thank everyone who has helped me over the past three (and a bit) years with the detail that they deserve, so to keep it brief and broad.

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Dr Nick Berggren for his invaluable assistance on this project.

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Research assistants and undergraduates who assisted with data collection.

The participants for their data.

Contents

Summary

Traditionally, mainstream models of attention have neglected the role of motivationally meaningful stimuli (e.g. threat/reward). These stimuli can cause the rapid and involuntary attraction of attention (attentional capture), and can hence be said to have *motivational salience*. It is sometimes considered that this capture occurs in a stimulus-driven manner (versus goal-driven). I, however, suggest that attentional capture by motivational salience could be caused by a goal-driven mechanism. To test this we asked three overarching questions:

1) Is detecting motivationally salient stimuli considered important?

By using a novel concurrent forced choice task, which isolates the priority of an individual's explicit search goals, we found that individuals believed that it was advantageous to detect and search for motivationally salient stimuli.

2) Can voluntary search goals induce attentional capture?

In Chapter 2 we revealed that task-irrelevant threatening stimuli only captured attention, versus neutral distractors, when participants were searching for that category of threatening stimuli. This goal-driven capture effect was robust yet highly specific, affecting only the single specific semantic category, rather than generalising across all related stimuli (Chapter 3). We found an identical pattern of results for reward associated stimuli (alcohol in social drinkers) in Chapter 4, with capture only occurring in the goal-driven condition. The same was true for smoking related images in Chapter 5, and this occurred independently of current nicotine dependence. Additionally, self-selected search goals were capable of inducing attentional capture, not just instructed goals (Chapter 7).

3) How are top-down search goals initially selected?

Chapter 6 revealed that search goal priority was positively predicted by stimulus importance and expectancy. This task also revealed a contextual cueing effect on search goal priority, whereby threat was prioritised more in a threatening context (versus safe). On the basis of my findings we propose a novel Importance-Expectancy model of attentional goal selection.

Preface

The thesis conforms to article format with tables and figures embedded in the text. The six empirical chapters are preceded by an introduction chapter, and followed by a discussion chapter where the findings are summarised. All references for all chapters are presented in alphabetical order at the end of the thesis. All papers are written in the style appropriate for the journal which they were intended to be submitted to – however, they were all referenced and formatted in APA format. When these empirical chapters are referenced across the thesis they are cited as they would be had they been published, however the corresponding chapter is also referenced.

Chapter 2 – submitted to *Emotion*

Chapter 3 – in preparation for submission to *Psychonomic Bulletin and Review*

Chapter 4 – in press at *Psychopharmacology*

Chapter 5 – under revision at *Drug and Alcohol Dependence* (with integrated results and discussion)

Chapter 6 – written in the style of submission to *Journal of Experimental Psychology: General*

Chapter 7 – written in the style of submission to *Emotion*

I have been the lead author on all papers regarding empirical work and writing. Dr Sophie Forster and Dr Theodora Duka have supervised the empirical work and writing of this thesis. Their involvement is reflected in the order of authorship of the empirical chapters, with final author representing the principal investigator. Dr Sophie Forster has contributed to the writing of the introduction and discussion. Dr Nick Berggren collaborated on Chapters 2 and 3 assisting with the design of the experiment, participant recruitment, and interpretation of the findings.

Data was collected by Kasheena Paryag for Experiment 2 in Chapter 4 for her undergraduate dissertation. The data for Chapter 5 was collected by Zoe Sylvester for her undergraduate thesis, Laura Perryman also assisted in data collection in this chapter as a research assistant.

Chapter 1: Introduction

Distraction by irrelevant information and objects is an everyday occurrence, we can often have the initial intention of focusing on a specific task only for a more interesting or a visually salient object to capture our attention. In the current investigation, we refer to *attentional capture* as the involuntary and rapid allocation of attention towards a stimulus. Comparatively, *attentional bias* refers the general influence of a stimulus on attention, either altering the allocation of attentional resources towards or away from the stimulus, this is not specific to early or purely involuntary attentional processes.

The focus of the current thesis is attentional capture by *motivationally salient* stimuli. This classification refers to stimuli which capture attention purely because of their association with an outcome relevant to an individuals' concerns or goals; if these stimuli did not have an association with a valued outcome then their features would not bias attention. Their salience is therefore dependent on their features signalling motivational relevance. The motivational outcome could be a universal biological need such as avoiding physical harm, or a specific one relevant to only some individuals, such as cigarettes in smokers.

Due to the pervasive nature of distraction, investigation of this topic is essential in order to redress the negative consequences of distraction: lapses in attention have been linked to a large number of road accidents (Beanland, Fitzharris, Young & Lenne, 2013); individuals automatically attend more to threat related stimuli than less anxious individuals (Bar-Haim et al., 2007; Cisler & Koster, 2014), and that this may have a causal relationship with elevated anxiety levels, thus perpetuating anxious states in these individuals (Van Bockstaele et al., 2014); additionally, it has been found that individuals who consume more potentially addictive drugs, such as tobacco and alcohol, selectively attend more to images of these substances (Townsend & Duka 2001; Bradley, Field, Mogg & De Houwer, 2004); and that this may result in elevated craving for these substances which could drive further drug use (Field & Cox, 2008; Field et al., 2016).

Traditionally, experimental research which has explored the fundamental mechanism of attention has employed stimuli such as simple coloured shapes and letters, which did not contain any motivational associations (e.g. Folk, Remington & Johnson, 1992; Theeuwes, 1992). As an unintended consequence, attentional capture which occurs due to a stimulus' associated meaning and value is neglected by mainstream models of attention. Many of the most prominent theoretical models of the last several decades (e.g. Desimone & Duncan, 1995; Theeuwes, 1994; 2010; Itti & Koch, 2001; Buschman & Miller, 2007; Parkhurst, Law & Niebur, 2002; Turatto & Galfano, 2000; Corbetta & Schulman, 2002) share a dichotomous framework composed of two distinct mechanisms; one, a stimulus-driven or bottom-up mechanism in which attention is directed towards a stimulus based on its inherent properties such as brightness or contrast. For instance, we may attend to our phone because the screen lights up when receiving a message,

the sudden change in brightness and colour then catches our eye relative to the background of our desk. The other mechanism posited is a goal-driven or top-down mechanism which guides attention based on the intentions of the individual, and biases attention towards the features and locations of stimuli which are held as a current search goal. In this case, the goal-driven mechanism would guide attention to our phone because we would intentionally decide to text a friend, we would then retrieve the features associated with a phone from memory (e.g. slim black object) and then search for these phone matching features.

Despite being able to account for attention which is allocated in simple psychological tasks, where the main factors are task instructions and stimulus qualities, this dichotomous model of attention does not accommodate attention to many real-world objects. These objects have associated meaning and value to individuals. For instance, our phone is not defined simply by its visual properties or congruence with our current intentions – it has a long history of motivationally relevant events associated with it, ranging from anxiously checking online maps when we're lost in an unfamiliar city, to the pleasant experience of receiving a message from a friend inviting us to a party. The motivational salience we refer to across this thesis is a general term that encompasses several outcomes. These can include emotional/affective content, reward/ appetitive or threat/aversive outcomes, positive or negative outcomes, or personally relevant stimuli (for reviews see Carretie, 2014; Le Pelley, Mitchell, Beesley, George & Wills, 2016; Pool, Brosch, Delplanque & Sander, 2016; Sui & Humphreys, 2015). It is the aim of the current thesis to integrate motivationally salient stimuli into current mainstream models of attention.

Mainstream Models of Attention

Within the traditional attention literature, there are multiple theories which draw upon the idea of attention as competing stimulus-driven and goal-driven mechanisms. For instance, the Biased Competition Theory proposed by Desimone and Duncan (1995; see Figure 1) suggests that goal-driven (top-down) inputs directly compete for attention with the stimulus-driven (bottom-up) qualities. The goal-driven mechanism in this model is posited to suppress the input of task-irrelevant objects in order to guide attention to currently relevant objects. To use the phone example, the goal to focus on our work directly competes with the visual input of the phone's screen in our peripheral vision. The stronger the goal to focus on our work the less likely the phone screen is to outcompete the top-down control and distract us from our work.

The idea of competing dichotomous inputs has been a feature in more recent mainstream models of attention as well. However, these models often debate the stage of selection that the goal-driven mechanisms influences attention. For instance, Theeuwes' (2010; see Figure 2) model posits that attention is initially captured by the stimulus qualities; the most salient feature in the visual field is selected from an initial sweep of visual input within a set
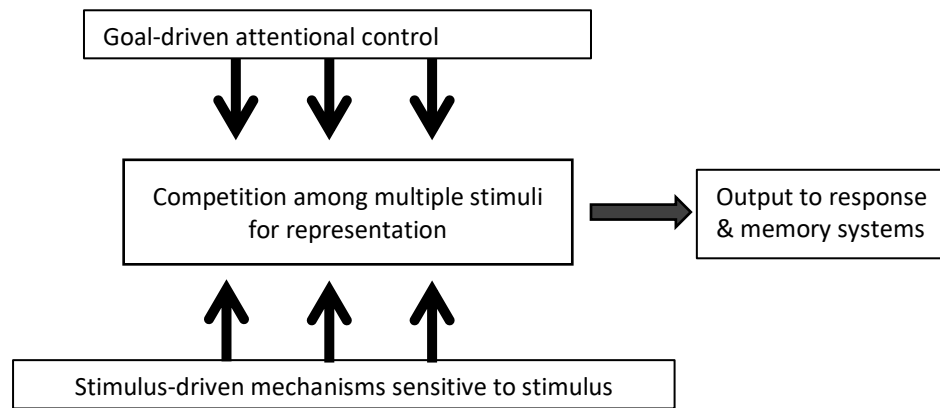
Figure 2. A schematic diagram of the Biased competition model of attention (Desimone & Duncan, 1995).

spatial location or 'window' of attention. It is only after this initial sweep and selection of salient features that goal-driven inputs influence attention, by selecting only the salient information which is relevant to the current task goals. If the selected input is congruent with the current attentional goals of the individual then the features are carried forward for further processing; however, if they are irrelevant then individuals suppress these features and select the next most salient feature in the environment (Theeuwes, 1991; 1992; 2010; Wolfe, 1994; Yantis, 1993; Yantis & Jonides, 1990). For instance, we may be working at our desk, attending to our computer screen; however, when our phone lights up the visual features of the phone are perceived as the most salient in the visual field and are selected. However, because they are inconsistent with the goal to finish work, after this initial capture top-down goals suppress the phone's features. This class of model suggest that a stimulus-driven mechanism captures attention early, involuntarily, and dominates attention prior to the modulating influence of an individual's current goals.
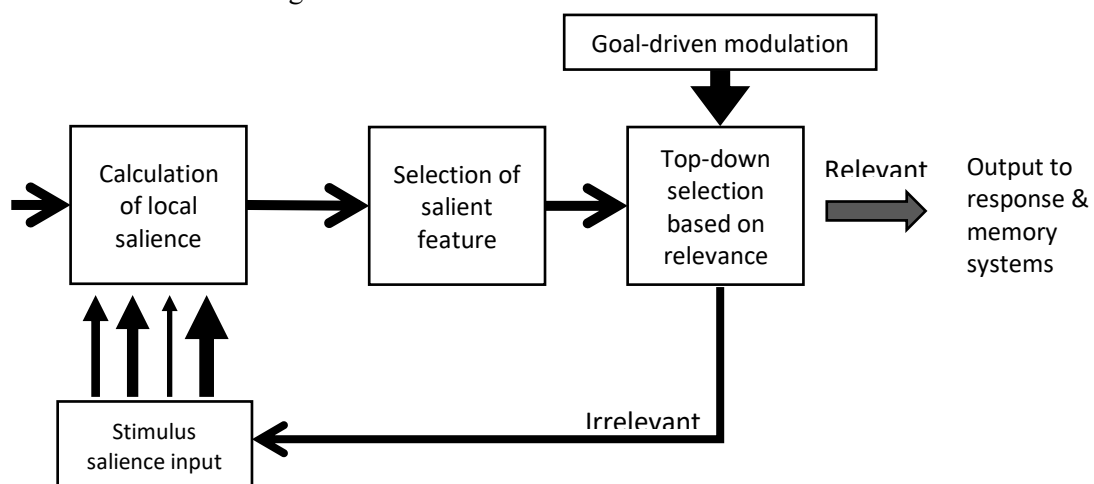
Figure 1. A schematic diagram of the dichotomous model of attention outlined by Theeuwes (2010).

On the other side of the debate are models which suggest that goal-driven input influences attention at the earliest stage of stimulus selection. These models posit that attentional capture by a stimulus is contingent upon whether the features of a stimulus match what an individual is already searching for. The resultant distraction by these stimuli is known as *contingent capture.* Within this contingent capture framework, even bright and colourful distractors do not capture attention unless they share the same features which an individual is searching for. For instance, it has been found that when an individual is given a goal to search for a specific coloured feature, object, or category, any stimulus which matches the features of the specified goal capture attention, and that when these same stimuli do not match the features of the current goal then these stimuli no longer capture attention (Folk, Remington & Johnson, 1992; Folk, Leber & Egeth, 2002; 2008; Wyble, Folk & Potter, 2013). Interestingly, the contingent capture within these tasks occurred when distractors appeared in a task-irrelevant location and participants knew that the distractor was to be ignored.

This model would suggest that our phone on our desk would only capture our attention if we were searching for the features associated with the phone to begin with, and that if we were focusing fully on our work then the phone would not capture attention even if it were the most salient feature in the environment. However, once an individual prioritised the features of their phone and the search goal became active, then the phone would capture attention regardless of whether the individual meant to attend to it at that moment. This theory posits that a goal-driven mechanism influences attention early and despite having voluntary origins, can result in an involuntary shift of attention to any stimulus feature which is congruent with the contents of the search goal. Therefore, stimulus features may not be the primary driver of attentional capture, but rather the current goals of the individual.

In summary, mainstream models of attention generally posit a dichotomous model, but differ in regard to the stage at which the goal-driven mechanism influences attention. For example, Theeuwes' (2010) model suggests that goal-driven influences play a role in filtering and selecting salient stimuli which have already captured attention; whilst the contingent capture model initially proposed by Folk et al. (1992) would suggest that the goal-driven mechanism influences attention at the earliest level of stimulus selection.

Theoretical Integration of Motivationally Salient Stimuli into Models of Attention

Despite mainstream models of attention often not including the motivational salience of the stimuli, there has been a history within the clinical and individual differences literatures of investigating how these stimuli affect attention. These investigations have included a large array of stimuli associated with reward (e.g. money, erotic images, food, illicit drugs, alcohol, tobacco) and threat (e.g. mutilation and death images, fearful or angry faces, dangerous animals; for reviews and meta-analyses see: Pool et al., 2016; Bar-Haim et al., 2007; Pergamin-Hight, Naim, Bakrmans-Kranenburg, van Ijzendoorn & Bar-Haim, 2015; Field & Cox, 2008). Within

these tasks, it is found that motivationally salient stimuli capture attention despite being no more visually salient than neutral stimuli, yet they exhibit characteristics which some theories of attention propose are stimulus-driven (e.g. Theeuwes, 2010). For instance, attentional capture by motivationally salient stimuli has been found to emerge even when distractors are only presented very briefly (e.g. ~100ms; Most, Chun Widders & Zald, 2005). This also occurs despite instructions to ignore these stimuli and focus on a specific target, thus suggesting an involuntary capture independent of the current goals of the individual (e.g. Le Pelley, Pearson, Griffiths & Beesley, 2015). This has led some researchers to posit that the attentional capture by motivationally salient stimuli can be considered stimulus-driven (e.g., Carretie, 2014; Bishop, 2007; 2009).
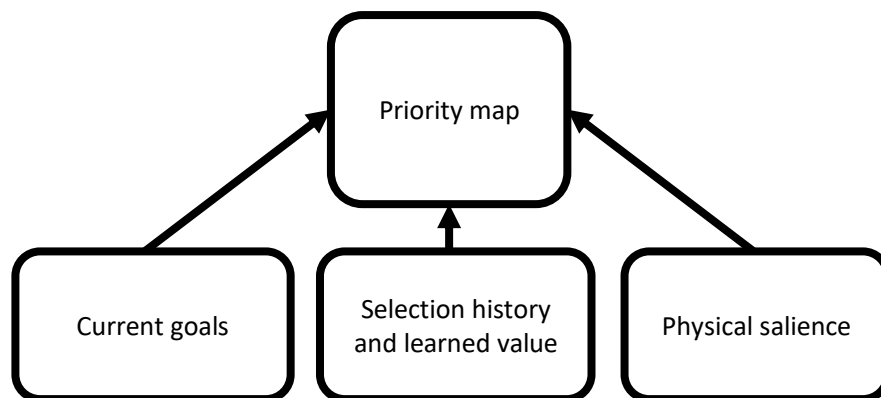
Figure 3. Schematic diagram of the different inputs to a priority map as proposed by the selection history framework (based on figure in Awh, Belopolsky & Theeuews, 2012). The priority map refers to the selection space which various neural inputs feed into, attention is then directed towards the largest peak of activation from the sum of these inputs (Zelinsky & Bisley, 2015). Selection history and value encompasses a range of stimuli which are associated with any motivational outcome or was previously task-relevant.

More recently, models of attention have begun to integrate motivationally salient stimuli with more traditional models of attention (see Figure 3). These models are based predominantly on conditioning experiments, which reveal that once a coloured shape has been repeatedly paired with financial reward or an aversive electric shock it captures attention, much like conventional motivationally salient stimuli (e.g. faces; Langton, Law, Burton & Schweinberger, 2008), despite being no more visually salient than an unconditioned stimulus (e.g. Anderson, Laurent & Yantis, 2011; Schmidt, Belopolsky & Theeuwes, 2015). This has led to the conclusion that, once a stimulus has become associated with a motivationally salient outcome, the stimulus' features take on an *incentive value* (Le Pelley et al., 2016; Berridge & Robinson, 2016). Similarly, a stimulus' *selection history* has been found to capture attention, meaning that a feature which was previously a task-relevant target continues to capture attention even though it is no longer relevant (Awh et al., 2012). It has been suggested that both value and selection history constitute a distinct third mechanism, which is neither goal-driven nor stimulus-driven. Despite the third mechanism being characterised as distinct from stimulus-driven attention, it is thought to influence attention early on prior to the guidance of a goal-

driven mechanism, in a stimulus driven manner (Awh et al., 2012; Munneke, Hoppenbrouwers & Theeuwes, 2015). In the current thesis we shall refer to goal-independent attentional capture as stimulus-driven in reference to earlier models of attention to emotion (Öhman & Minneka, 2001; Amaral, Price, Pitkanen, & Carmichael, 1992; LeDoux, 2000). In Chapter 8, however, we shall address the relation of our findings to more recent models of attention to motivationally salient stimuli, which suggest a third mechanism which drives attentional capture (e.g. Awh et al., 2012).

Potential Goal-Driven Mechanism of Attentional Capture by Motivational Salience

In the current thesis, we shall propose an alternative to the above accounts: namely, that motivationally salient stimuli could actually be integrated into the existing dichotomous model of attention as a goal-driven mechanism. Attention to these stimuli is often considered involuntary because they contradict the task instructions. However, as mentioned above, the contingent capture literature suggests that the current voluntary search goals of the individual can drive involuntary attention to task irrelevant stimuli (Folk et al., 1992). Once an individual assumes a search goal for an object or category, stimuli which match the features of this search goal capture attention regardless of where they appear in the visual field (Folk et al., 2002; Eimer, 2015; Wyble et al., 2013). Further, contingent capture research has shown attentional capture by goal-congruent stimuli under conditions which are thought to reflect the influence at pre-attentive stages, such as when the distractors are masked or presented very briefly (Ansorge, Horstmann & Scharlau, 2011)

Given that a goal-driven mechanism appears to have a substantial involuntary effect over attention it could be that an individual's current attentional goals could play a role in distraction. For this to be the case individuals would have to hold long-term search goals for motivationally salient stimuli. This is possible, given that it is beneficial to search for these stimuli in the environment rather than intentionally focus attention on less motivationally relevant goals. It would be unusual for an individual to search for a stimulus which was not related to a beneficial outcome at the expense of pursuing goals which could ensure an individuals' safety or personal gain. Participants may therefore want to detect motivationally salient stimuli because of their relevance to long-term goals to avoid danger and seek rewarding outcomes (see Chapter 6 for further discussion). Within previous investigations, participants were often instructed to search for a target stimulus which was less motivationally salient than the distractor. It may be that instead of always tuning attention towards the target, participants' own long-term goals to detect motivationally salient stimuli were active during the task and competed for the guidance of attention. In the phone example, the reason that we may be distracted by our mobile phone is that we may want to talk to our friends, and despite needing to do work, we may be periodically more motivated to look at our phone rather than our computer,

meaning that the features of the phone capture attention because of their congruence with the search goal.

Previous investigations may not have explored this possibility because of the nature of the experimental paradigms used to measure the interference from motivationally salient distractors (see Figure 4). Specifically, these tasks may have reduced the ability to distinguish between stimulus-driven and goal-driven attention because the motivationally salient distractors appeared in a potential target location. These distractors cannot, therefore, be considered truly task-irrelevant (Forster, 2013). There is no evidence or theory which suggests that an individual can intentionally attend to a location whilst entirely ignoring the features which are present there. Further, participants would actually be impeded in completing the task if they attempted to inhibit the locations where the target would appear. Hence, any stimuli appearing in relevant locations necessarily receive a certain degree of top down priority, and the task aims can only be completed by attending to all the locations to find the target. This is, therefore, not evidence of attentional capture, which is the initial early allocation of attention to the stimulus, but instead disengagement from the distractor after intentionally deploying top-down attention to its location.

Interestingly, it has been found that when a motivationally salient stimulus (e.g. fearful face or stimulus associated with an electric shock) does appear in a task-irrelevant location, away from where the target could appear, then attentional capture is not always found (Reeck, LaBar & Egner, 2012; Notebaert, Crombez, Van Damme, Durnez & Theeuwes, 2013). Evidence, therefore, suggests that the spatial location of the distractors in the previous tasks may have played a causal role in the involuntary capture by motivationally salient stimuli, and that stimulus-driven capture by motivationally salient stimuli may not operate completely independently of goal-driven attention.

More recently, researchers have begun to question the role of top-down goals in attentional capture by motivationally salient stimuli. Evidence from this recent line of research has suggested that top-down attention may be required in order for motivationally salient stimuli to capture attention. This evidence comes from tasks where distraction does not occur when the motivationally salient features are irrelevant to the current task. For instance, when participants are given a competing search goal, such as searching for a specific target shape at the end of a trial, then attention is directed towards this shape and away from threat related stimuli presented in an intervening dot-probe (Vogt, De Houwer, Crombez & Van Damme, 2013). It, therefore, appears that attention to motivationally salient stimuli is not unconditional, as would be predicted by a stimulus-driven or goal-independent mechanism.

Additionally, the attentional capture by motivationally salient stimuli appears to be modulated by task-relevance. There are multiple investigations which reveal that when the motivationally salient content of a stimulus is made task-irrelevant, for instance by instructing

participants to categorise emotional stimuli along a nonaffective stimulus dimension (e.g. categorising emotional faces as male or female; Stein, Zwickel, Ritter, Kitzmantel & Schneider, 2009), or by requiring participants to complete a task with only neutral targets, and never respond to motivationally salient stimuli (e.g. Vromen, Lipp & Remington, 2016), then the affective stimuli no longer capture attention more than matched neutral distractors. Further, when the motivationally salient content is then made relevant to the task, by instructing participants to categorise the stimulus along affective dimensions (e.g. categorise emotional faces as neutral or fearful), or including motivationally salient stimuli as part of the target set, then the typical involuntary attentional capture emerges (see also, Hahn & Gronlund, 2007; Everaert, Spruyt & De Houwer, 2013; Everaert, Spruyt, Rossi, Pourtois & De Houwer, 2014; Lichtenstein et al. 2017; Lichtenstein-Vidne, Henik & Safadi, 2012; Vogt, Koster & De Houwer, 2017). A stimulus-driven account would suggest that motivational salience influences attention independent of the current goals of the individual, which is not always the case. If attentional capture can be blocked by simply instructing participants to direct their attention elsewhere or to another goal, then this suggests one of two things: Either top-down goals can easily overcome the stimulus-driven effect, in which case stimulus-driven capture may not be as pervasive as stated in some models (e.g. Awh et al., 2012; Anderson, 2016). Alternatively, as we will argue, top-down goals are the mediating factor which drives involuntary attention to these stimuli, and that by occupying the participants with a competing goal, they cannot adopt a search goal for the motivationally salient stimuli.

If it is the case that goal-driven attention has a causal role in attentional capture by motivationally salient stimuli, then by manipulating the task-relevance of the motivational content, the previous tasks may have increased or decreased the chance that participants would adopt a search goal for these stimuli. However, it is not clear from these findings whether the involuntary capture was actually *caused* by top-down search goals. It may be that by reducing the relevance of the motivational content, participants were more able to suppress the stimulus-driven input of the motivational salience; and when the motivational content was more task-relevant these individuals were unable to inhibit this motivational input. In the previous tasks top down goals were neither directly measured nor manipulated, therefore we cannot know which interpretation is more likely. Note also that relevance is not universally considered a top-down feature - some forms of relevance have been suggested to have a stimulus-driven element which would not reflect the consequence of a voluntary top-down search goal (see Sui & Humphreys, 2015, for review).

In the current investigation we will, therefore, focus specifically on how individuals' current search goals can result in capture by motivationally salient stimuli. Rather than manipulating the relevance of the stimuli by including them in the target set or as part of the target identification response, we will explicitly instruct participants to search for a category of

motivationally salient stimuli, thereby manipulating exactly what features participants are searching for.

a

b

c
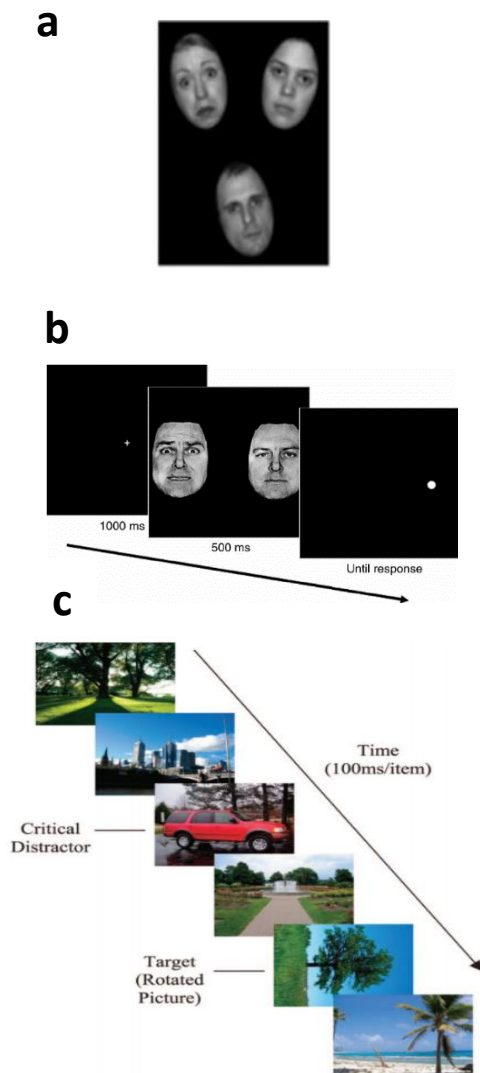
Figure 4. Examples of typical experimental tasks used to measure interference of motivationally salient content on visual attention. Figure 4a. depicts a visual search task (taken from Hodsoll, Lavie & Viding, 2014). Within this task participants have to identify the face which is the odd-one-out orientation (i.e. left or right tilt), the non-target fearful face in this situation would result in slower target detection compared to when all stimuli were neutral faces. Figure 4b. depicts the dot-probe (figure taken from Cooper, Bailey, Diaper & Munafo, 2011). In this task participants are instructed to respond to the location of the dot on the screen (left or right) at the end of the trial. Prior to the dot-probe appearing, an emotional face and a neutral face are presented. If attention is allocated to one face over another, then participants will be slower to respond to the dot if it appears away from that face, and faster to detect it if it appears in the same location of that specific face. Figure 4c. depicts the affective blink RSVP task (Figure taken from Smith, Most, Newsome & Zald, 2006). Within this version of the task participants are instructed to identify the orientation of the only rotated image in the RSVP stream (left or right). Prior to the rotated target image, a distractor image is presented which has previously been associated with a motivationally salient outcome (e.g. aversive shock). Attentional capture is measured by the reduced target identification accuracy when it is preceded by the motivationally salient distractor versus a neutral distractor. There are multiple variations based on these tasks, however, the common feature across these tasks is the positioning of the stimuli in potential target locations, and the requirement that participants have to process the distractor features in order to detect the target.

Testing the Goal-Driven Account of Attentional Capture

If, indeed, attention to motivationally salient stimuli can be integrated into the existing models of attention as a goal-driven effect, then the overarching question must be answered: "can top-down search goals account for involuntary attentional capture by motivationally salient stimuli?". To break this down further we shall use various methods to answer two specific sub-questions which must be addressed if a goal-driven account of attention is possible.

Question 1: Do individuals believe that detecting motivationally salient stimuli is important?

Question 2: Can voluntary top-down search goals for motivationally salient stimuli induce an involuntary attentional capture to goal-congruent motivationally salient stimuli? If so does this extend to self-selected goals?

If answered, these two questions would provide the essential requirements for a goal-driven account of the phenomenon of involuntary attentional capture by motivationally salient stimuli. As well as this basic requirement for the goal-driven account, we intend to elaborate on this account, and explore how a goal may initially be set and how this may operate within real-world contexts. For this reason, we posit a separate question to further explore exactly how a goal-driven mechanism may drive attentional capture by motivationally salient stimuli.

Question 3: How are top-down search goals initially selected?

Do Individuals Believe that Detecting Motivationally Salient Stimuli is Important?
It has long been established in the social and motivation literatures that goal-directed behaviour is directly influenced by the incentive properties of the outcome, and that in order for a goal to be actively pursued individuals must desire the outcome. If a goal is unrewarding then individuals will cease to follow it and will instead pursue a competing goal (for reviews see Deci & Ryan, 2000; Braver et al., 2014). This line of research has, however, not yet been integrated with the cognitive attention literature. we therefore aim to directly test, for the first time, whether individuals consider objects which capture attention in cognitive tasks to be important to detect and therefore search for. This would be the first necessary requirement if a goal-driven mechanism were to plausibly account for attentional capture by motivationally salient stimuli.

In order to determine whether individuals did, indeed, believe that motivationally salient stimuli were important to detect, we created a novel paradigm named the Concurrent Attentional Goal Task (CAGT). In this task participants were presented with a concurrent choice between different pairs of neutral and motivationally salient objects. Each object was presented in a pair with all other objects, thus forcing participants to select which object they believe is more important to detect when both objects are present in a situation. Previously, concurrent choice tasks have been used to determine which one of two valued outcomes is preferred by an individual (e.g. high calorie food versus computer games, or alcohol versus money; Saelens & Epstein, 1996; Murphy & MacKillop, 2006). I, therefore, adapted this forced choice nature of the task in order to isolate the importance of detecting different classes of motivationally salient stimuli, compared to neutral stimuli. Additionally, priority map models of attention propose that multiple neural inputs feed into a single selection space (see Figure 3). The different neural inputs compete for selection, and the cumulative input with the largest peak of activation is then selected and attended to, whilst other inputs are ignored. The forced choice nature of the task mimics this competition between neural inputs, thus the measure of

importance in this task could be considered analogous to how selection may work at the neural level (Fecteau & Munoz, 2006; Bisley & Goldberg, 2010).

Through the multiple paired comparisons, a hierarchy of detection importance can be formed, with more important objects rated more highly, and the forced choice nature of the concurrent choice task automatically resulting in less important objects being rated as lower on this measure. we hypothesised that participants will judge that the motivationally salient stimuli (i.e. threatening and rewarding) objects are more important to detect than neutral objects. The CAGT also allowed me to explore a secondary question, which was whether personality variables associated with attentional captured by threat might predict the importance ratings of the motivationally salient objects. we hence measured trait anxiety (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) and behavioural activation system score (BAS) which is a measure of reward seeking (Carver & White, 1994), using questionnaires, alongside the CAGT performance. we predicted that trait anxious individuals would report that threat was more important to detect than low trait anxious individuals, and high scorers on the BAS would report that detecting reward was more important than low scorers on the BAS.

Evidence has, however, suggested that individuals believe motivationally salient stimuli are emotionally arousing and will respond to approach or avoid them (Austin & Duka, 2010; Carver & White, 1994; Lang, Bradley & Cuthbert, 2005), this investigation would provide the first explicit evidence that individuals believe that these stimuli were important to detect and search for (in other words, deserving of attentional priority). For this method we required a large sample, therefore the task was conducted using online testing resources.

Can top-down search goals for motivationally salient stimuli induce an involuntary attentional capture by goal-congruent motivationally salient stimuli? If so does this extend to self-selected goals? In order for a goal-driven mechanism to account for involuntary capture by motivationally salient stimuli, there must be direct evidence that a top-down goal can induce capture by a broad range of stimuli which signal motivational outcomes. Previous research has found that the relevance of the motivationally salient stimuli to a task seems to modulate whether it captures attention (e.g. Lichtenstein-Vidne et al., 2012; Vromen et al., 2016). This is consistent with a goal-driven effect, there has thus far been no direct test of whether manipulating the current search goal across a task can induce or abolish attentional capture by motivationally salient stimuli. We therefore conducted multiple experiments in Chapters 2, 3, 4, and 5 to test whether this was possible.

The task used across these chapters was based upon the paradigm used by Wyble et al. (2013) which was a variation of the rapid serial visual presentation task (RSVP; e.g. Folk et al., 2002). Within the task, participants were presented with a stream of images in the centre of the screen and were instructed to search for a specific conceptual category of stimuli within this stream. Task-irrelevant distractors which flanked the RSVP stream were presented prior to the

target. It was found that when the distractor was from the same category as the current search goal, then participants were poorer at identifying the target, compared to when the distractor was incongruent with the category currently being searched for. Previous evidence would suggest that this was due to the goal-congruent distractors inducing a spatial-temporal 'attentional blink', whereby finite attentional resources are allocated to features which match the contents of the search goal, and this caused participants to miss a subsequent target in the briefly presented RSVP stream images (Raymond, Shapiro & Arnell, 1992; Folk et al., 2002; LeBlanc, Prime & Jolicoeur, 2008). We adapted this paradigm by presenting categories of motivationally salient stimuli, along with control neutral category, as distractors. Previous research has found that when presented in an RSVP stream, prior to the target, motivationally salient stimuli reduce identification of the target independent of the current search goal, versus neutral images, and induce a phenomenon known as the 'affective blink', whereby the affective or motivational content of the images capture attention involuntarily and cause an attentional blink (Most et al., 2005; McHugo, Olatunji & Zald, 2013). These previous investigations, however, presented the distractors in the central stream of stimuli (see Figure 4). As previously stated, the task-relevant location of the distractor makes it impossible to disentangle the contributions of goal-driven attention and purely stimulus-driven attention to the motivationally salient stimuli. The current paradigm, therefore, avoids task-relevance by presenting the distractors in task-irrelevant locations, outside of the RSVP stream.

In order to manipulate the current search goals of the participants, we instructed them to search for the same motivationally salient category as the distractor in the central stream, or a different category of stimuli incongruent with the motivationally salient distractor category. The general hypothesis was that a goal-driven mechanism would predict that the instructed search goal for motivationally salient stimuli would induce attentional capture by these motivational distractors, and that this capture would be absent when participants were not searching for that category of stimuli. Conversely, if the current goals of the individual had no effect upon involuntary attention to motivationally salient stimuli, then we would predict that these distractors would capture attention across conditions, regardless of whether the contents of the current search goal were congruent with the distractor category.

Due to much of the interpretation being based on a null finding, that is, an absence of capture when distractors were goal-incongruent, we computed Bayes factors to facilitate interpretation. Bayes factors compare evidence for the *experimental hypothesis* and the *null hypothesis* by contrasting the recorded difference between conditions to a prior expected effect size, this being drawn from previous research comparing similar experimental conditions. This analysis provides a value which signifies the magnitude of evidence favouring either the experimental or the null hypothesis. Based on this value, we will be able to interpret whether, compared to a previously expected effect size, the actual data shows evidence for a difference

between conditions, or whether the evidence suggests that there is no difference between conditions. This method will allow me to draw more precise conclusions about whether there is an absence of interference from motivational distractors in some conditions (Dienes, 2008; 2011; 2014; 2016).

In order to test the reliability and generalisability of the goal-driven attentional capture by motivationally salient stimuli, we used a range of aversive (threatening) and appetitive (rewarding) stimuli, all of which have been found to capture attention in visual attention tasks. In Chapters 2 and 3 these distractors included stimuli which have previously been posited to constitute an unconditional stimulus-driven attentional capture, these being emotional faces and threatening animals (Bradley, Mogg & White, 1999; Mogg, Millar & Bradley, 2000; Eimer & Kiss, 2007; Carlson & Reinke, 2008; Peltola, Hietanen, Forssman & Leppanen, 2013; Lipp & Derakshan, 2005; Öhman, Flykt & Esteves, 2001; LoBue & DeLoache, 2008). We also presented aversive stimuli which have been rated as highly emotionally arousing and depict extremely aversive consequences of threat in Chapter 3 (e.g. mutilation), these have also been found to capture attention across previous investigations (Vogt, De Houwer, Koster, Van Damme & Crombez, 2008; Koster, Crombez, Verschuere & De Houwer, 2004; Mogg, Bradley, Miles & Dixon, 2004). Further, in Chapters 3 we presented reward associated distractors which had been found to capture attention in previous research – these being alcohol stimuli in social drinkers (for review see Field & Cox, 2008; Rooke, Hine & Thorsteinsson, 2008). In Chapter 4 we then explored whether personal experience and relevance of the appetitive and aversive images influenced attentional capture, by comparing the distraction by appetitive and aversive smoking cues between nicotine dependent smokers, occasional smokers, and non-smokers.

As well as exploring whether goal-driven attention can induce an involuntary attentional capture by motivationally salient stimuli, we sought to test the boundary conditions of this goal-driven effect. Prior research has suggested that individuals can adopt a broad semantic search goal for a category, and that this can induce contingent capture by distractors from this broad category (Wyble et al., 2013). Within Chapter 3, we therefore, attempted to induce goal-driven attentional capture by all threat related stimuli by instructing participants to search for all threat as a superordinate category. Evidence from this Chapter provides details about the specificity of such a goal-driven mechanism.

As well as testing whether an instructed search goal could induce involuntary attentional capture, as in Chapters 2-5, in Chapter 7 we also investigated whether participants self-selected search goals could also induce a similar attentional capture. To this end, we created a novel goal-competition task which utilised the competition between two valued goal outcomes to force participants to make a choice between them. One of the goals required participants to respond to a target which resulted in a rewarding outcome (reward seeking goal), whilst the other required participants to respond to a different target which results in avoiding an aversive

outcome (threat avoidance goal).We predict that participants who self-report searching for one target (e.g. reward related target) more than the other (e.g. threat related target) will be more distracted by a task-irrelevant distractor which shares the features of the prioritised goal (e.g. reward coloured distractor), compared to individuals who prioritised the competing goal.

Further, we took the opportunity to explore whether any personality or state questionnaire measures predicted self-reported goal preference. If a correlation between these measures were found, it could suggest that stimulus specific attentional capture previously found in clinical samples (e.g. attentional orienting towards threat in trait anxious participants; Bar-Haim et al., 2007) could be mediated by deliberate goal selection, rather than a stimulus-driven mechanism (e.g. Bishop, 2009).

How are Top-Down Search Goals Initially Selected? Top-down goals have typically been operationalised in the attention literature as the instructed goal of an experimental task. Across Chapters 2 – 5,weinvestigated the effect of an instructed search goal on involuntary attention to motivationally salient stimuli. However, in daily life, it seems likely that only a minority of attentional goals are selected in response to explicit external instructions (e.g. we may look for our phone when we are asked: 'can I borrow your phone, please?'). Instead it appears likely that individuals often freely select their own goals based (at least in part) on motivational factors such as their current desires and needs. For example, if we haven't spoken to friend for a while we may want to communicate with them and want to call them on the phone – the goal would be to talk to our friend and the phone becomes the associated target of this goal. Surprisingly, there has never been any work which has investigated how top-down attentional goals are selected over other competing goals in real-world settings. I, therefore, aimed to investigate what factors influenced the selection of one search goal over another, and aimed to contextualise these factors by relating them to imagined real-world settings.

Specifically, we drew upon social models of goal-directed behaviour and motivation, which have investigated the different factors which determine goal-setting. Within this literature, a two factor Importance-Expectancy model has been used to account for whether an individual pursues or neglects a goal; whereby the activation of a goal is determined by both the expectancy of a beneficial outcome from pursuing the goal, and the importance of the outcome to the individual (Lewin, Dembo, Festinger & Sears, 1944; Gollwitzer, 1990; Locke & Latham, 2002; 2006). I, therefore, applied this model of human behaviour to current attentional search goal selection, in order to determine whether participants reported that the prioritisation of a search goal was positively related to an increase in perceived importance of a goal outcome, as well as an increase in expectancy of this outcome. These factors were measured using a modified version of the CAGT, in which as well as measuring detection importance, hierarchies of expectancy of an object appearing and the priority of a current search goal were also measured through the forced choice task.

The results of experiments in Chapters 2 – 5 consistently revealed that the goal-driven mechanism of attentional capture may in fact be specific to the category which was searched for, at the cost of attention to other motivationally salient stimuli. Unless there was a specific mechanism which would allow for accurate prioritisation of an appropriate search goal in a real-world setting, individuals could potentially miss important stimuli in the environment.

In Chapter 6, wepropose that a context dependent search mechanism, in which participants learn what specific category to search for based on previous experience within a context, would allow individuals to search for the most likely motivationally salient object within a specific setting, whilst minimising the cost of missing less likely objects. Therefore, in order to determine whether this contextual cueing mechanism was compatible with the Importance-Expectancy model, we tested the model in two imagined contexts. One of these was a threat associated context (dark alley) and another a safe context (work office). It was expected that the threat associated stimuli would be most prioritised as a goal in the threat associated context, and that these same stimuli would be prioritised less in the safe context. Further, we explored how this contextual cueing effect may influence importance and expectancy. we were also interested in how individual differences in trait anxiety and reward seeking may influence self-reported search goal prioritisation across contexts, and whether these personality differences influenced search goal priority through importance or expectancy. Due to the need to measure individual differences we collected a large sample from an online testing resource.

Based on the answers to these three overarching questions, we will integrate the results into a novel framework of goal-driven attention. This framework will account for how attentional goals are selected, and how these goals may lead to involuntary attentional capture across multiple motivationally salient stimuli.

Chapter 2: Distracted by Your Goals? Top-Down Attentional Capture by Motivationally Salient Stimuli

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Abstract

Attention has long been characterised within prominent models as reflecting a competition between goal-driven and stimulus-driven processes. It remains unclear, however, how involuntary attentional capture by motivationally salient (e.g. threatening or rewarding) stimuli fit into such models. While such effects were traditionally held to reflect stimulus-driven processes, the phenomenon of 'contingent capture' highlights that top-down goals can not only guide voluntary attention, but also paradoxically lead to involuntary attentional capture by goal-congruent yet task-irrelevant stimuli. Here we test an alternative account of involuntary attentional capture by motivationally salient stimuli, in terms of goal-driven rather than stimulus-driven prioritisation processes. To this end we combined the classic 'contingent capture' and 'affective blink' paradigms in an RSVP task with either positive or threatening target search goals. Across five experiments, task-irrelevant positive and threat distractors were presented in peripheral, parafoveal, and central locations. Across all distractor locations, we found that attentional capture by irrelevant threatening distractors was contingent upon the adoption of a search goal for a threatening category – adopting a goal for a positive category conversely led to capture only by positive stimuli. My findings provide the first direct experimental demonstration that involuntary capture by irrelevant motivationally salient stimuli can be induced by voluntary goals, and hence support a top-down account of this phenomenon. we discuss the application of these findings to real-world contexts, as well as implications for cognitive models of clinical disorders.

In daily life, selective attention allows us to make sense of an otherwise overwhelming volume of perceptual input – prioritising the processing of stimuli that are in some way flagged as important (e.g. the words on a computer screen, or a voice over a phone), over stimuli that may have less importance (e.g. email pop-ups, a colleague passing by, or the tactile sensation of sitting in a chair). Some stimuli are selected intentionally, in line with our current goals (e.g. a person might prioritise words on a computer screen due to a goal to write a research paper). Other stimuli, however, are selected in an involuntary manner – for example, while focusing on

our research paper we might nevertheless find our attention captured by a stimulus with high perceptual salience (e.g. a flickering light). Prominent models of attention account well for the above examples within frameworks involving two key drivers of attention: a goal-driven 'endogenous' mechanism which directs attention in a strategic top-down manner, and a stimulus-driven 'exogenous' mechanism which directs attention in an involuntary manner to perceptually salient stimuli (Desimone & Duncan, 1995; Theeuwes, 1994; 2010; Itti & Koch, 2001; Buschman & Miller, 2007; Parkhurst, Law & Niebur, 2002; Turatto & Galfano, 2000). However, in daily life, stimuli may also catch our attention involuntarily, not due to low-level perceptual salience, but rather due to motivational salience – for example, being associated with a potential threat (e.g. a spider on the office wall) or reward (e.g. a chocolate bar on the desk; Cunningham & Brosch, 2012). It is not readily apparent how this form of attentional capture by motivationally salient stimuli can be accommodated within a goal-driven and stimulus-driven dichotomy, which is seen in many mainstream models of attention – indeed, this problem has led to calls for theoretical revisions involving a third driver of attention (Awh, Belopolsky & Theeuwes, 2012; Anderson, 2015; Klink, Jentgens & Lorteije, 2014).

The omission of motivationally salient stimuli from mainstream models of selective attention may have arisen, in part, due to the experimental paradigms which shaped these theories involving simple, affectively neutral stimuli such as basic geometric shapes or letters (e.g. Theeuwes, 1992; Yantis, 1993; Folk, Johnson & Remington, 1992). Such situations limit the likely influences on attention to two factors: the task instructions influencing goal-driven attention, and the perceptual stimulus-driven salience of the components of the stimulus display. This however does not fully represent the complexity of the real-world environment, in which stimuli often have rich semantic and affective associations and are predictive of meaningful outcomes. On the other hand, over the last several decades a rich literature has amassed regarding the study of attentional capture by motivationally salient stimuli. Much of this research was conducted within the context of specific sub-disciplines such as on attentional biases towards drugs and threat in addiction or anxiety (e.g., Robinson & Berridge, 1993; 1998; Franken, Booij & van den Brink, 2005; Cisler & Koster, 2010; Yiend, 2010; Bar-Haim et al., 2007; Van Bockstaele et al., 2014), although more recent work has begun to investigate motivationally salient stimuli within the framework of mainstream selective attention (Schmidt, Belopolsky & Theeuwes, 2015; Notebaert, Crombez, Van Damme, De Houwer & Theeuwes, 2011; Anderson, Laurent & Yantis, 2011; Anderson, 2013; 2015; Chelazzi, Perlato, Santandrea & Della Libera, 2013; Hickey, Chelazzi & Theeuwes, 2010). Based on this, there is considerable empirical evidence to suggest that motivationally salient stimuli can capture attention in a seemingly involuntary manner (e.g. see Carratie, 2014; Cisler & Koster, 2010; Anderson, 2013; 2016; Compton, 2003 for reviews).

Within the framework of the goal-driven/stimulus-driven dichotomy, involuntary selection of motivationally salient stimuli might initially be presumed to be stimulus-driven due to the apparent ability of stimulus-content to override task goals. Indeed, the stimulus-driven view of attentional capture by motivationally salient stimuli has traditionally been the prevalent interpretation of these effects within the relevant literatures (Le Doux, 1995; 1998; Öhman, 1992; Carretie, 2014). Influential theories of attention in addiction and anxiety have suggested that the attentional capture by these stimuli is due to their learnt salience increasing bottom-up perceptual input; with addicted and highly anxious individuals being more sensitive to certain categories of stimulus-specific salience (Robinson & Berridge, 1993; 1998; Field & Cox, 2008; Wiers & Stacy, 2006; Bishop, 2007; 2009; Cisler & Koster, 2010; Mogg & Bradley, 2016).

It is important to note, however, that involuntary attentional capture is not exclusively driven by a stimulus-driven mechanism. In fact, while it may appear paradoxical, there is considerable evidence that *involuntary* attentional capture can in fact occur as an unintended consequence of *voluntary* goal-driven attention (Folk et al., 1992; Folk, Leber & Egeth, 2002; 2008; LeBlanc & Jolicoer, 2005). Compelling evidence from the 'contingent capture' literature suggests that when goal-driven attention is directed to a particular type of stimulus (e.g. a particular colour, shape, or even semantic category), any stimulus which matches the features which are currently being searched for may capture attention, even if they are in some way known to be irrelevant to the task (e.g. being presented in a task-irrelevant location). For example, when instructed to search for a letter of a particular colour in an RSVP stream of other coloured letters, an irrelevant peripherally presented distractor, which shares the target colour, captures attention and results in participants being unable to identify a subsequently presented search target (i.e. producing an attentional blink; Raymond, Shapiro & Arnell, 1992). Importantly, equally salient coloured distractors which do not share the specified target colour do not capture attention. In other words, participants searching for a green letter are typically distracted by peripheral green distractors but not red distractors, while participants searching for a red letter are distracted by red but not green distractors (Folk et al., 2002; 2008; Leblanc & Jolicoer, 2005).

The phenomenon of 'contingent capture' has even been found to occur under conditions which are typically considered indicative of stimulus-driven capture, such as brief or subliminal presentations (Ansorge, Horstmann & Scharlau, 2011; Chen & Mordkoff, 2007). More recently it has been found to extend beyond low-level visual features to broadly defined goals, such as a conceptual category (e.g. stationary or cars, Wyble, Folk & Potter, 2013; Reeder, van Zoest & Peelen, 2015). Critically, contingent capture occurs involuntarily, even though participants know that the stimulus is irrelevant to their current task goals (e.g. because it is presented in an irrelevant location, in which the relevant task stimuli never appear). This has an important implication for accommodating motivationally salient stimuli within mainstream models of

selective attention: The involuntary nature of capture by motivationally salient stimuli does not necessarily imply a stimulus-driven mechanism. Rather, the contingent capture literature implies that such involuntary capture might instead emerge as a consequence of any top-down goals to attend to motivationally salient stimuli.

It is intuitively plausible that individuals might commonly adopt top-down goals which prioritise motivationally salient stimuli. Such goals are often adaptive, allowing individuals to flexibly maximise rewarding outcomes and avoid potentially harmful ones. Indeed, within current theories of motivation, there is a consensus that goal-driven behaviour is determined by the magnitude of a rewarding or aversive outcome and expected probability that the outcome will occur in a given situation (for review see Braver et al., 2014). Due to their association with important potential outcomes, it is logical that individuals would tune their attention system towards these stimuli in order to allow them to respond quickly towards them (Cunningham & Brosch, 2012). It is hence interesting to consider the possibility that some previous experimental demonstrations of attentional capture by motivationally salient stimuli might, in fact, be contingent upon pre-existing goals held by the participants which may be active during the experimental task. We will discuss this possibility in detail in the General Discussion.

For now, we note that recent studies of attentional capture involving motivationally salient stimuli (particularly threat stimuli) suggest that such capture effects are not unconditional, as might be expected from a strong stimulus-driven account. Rather, evidence increasingly points to a critical modulatory role of task relevance (Hahn & Gronlund, 2007; Everaert, Spruyt & De Houwer, 2013; Everaert, Spruyt, Rossi, Pourtois & De Houwer, 2014; Stein, Zwickel, Ritter, Kitzmantel & Schneider, 2009; Vogt, De Houwer, Crombez, & Van Damme, 2013; Lichtenstein-Vidne, Henik & Safadi, 2012; Lichtenstein et al. 2017). For example, Stein et al (2009) examined the degree to which the emotional expressions of face search targets would heighten the attentional blink (AB) effect (i.e. impeding detection of a second target). Fearful versus neutral targets only produced heightened AB when the target response involved classifying the emotion of the face – when the response was non-emotional (male versus female) the same stimuli showed no difference in the AB effect for fearful versus neutral targets. Such findings appear consistent with the notion of a goal-driven mechanism, which would prioritise stimuli with greater relevance to the current task goals. However, we note that certain manipulations of relevance have also been argued to affect stimulus-driven mechanisms (see Sui & Humphreys, 2015 for review) and many demonstrated effects of relevance might be alternatively accounted for by proposals that the previous 'selection history' of a stimulus captures attention independently of current goals (Awh et al., 2012). Manipulations of relevance are also rather indirect manipulations of goal-driven attention. For example, Stein and colleagues' manipulation of response settings only indirectly manipulates goal driven selection, as participants could conceivably have simply adopted a goal to select

faces across all conditions and activated the response set post-selection. Other studies have manipulated the motivational salience of search targets (e.g. Lichtenstein-Vidne et al., 2012), but within contexts in which motivational salience was irrelevant to the target selection criteria and the instructed task goals were identical across conditions.

A direct test of whether goal-driven mechanisms can play a causal role in involuntary attentional capture by motivationally salient stimuli must meet the following conditions. First, goal-driven attentional settings must be manipulated directly by changing the criteria for selection (e.g. the search goal), such that a task can only be completed by adopting this goal. Second, attentional capture can only be assumed to be entirely involuntary if the task does not require *any* voluntary allocation of attention to the capturing stimulus. Any demonstrations of attentional capture by a stimulus which participants are asked to search for (i.e. a search target), or to a stimulus presented in a potential target location (which necessarily requires some allocation of attention, cf. Forster, 2013), could potentially reflect goal-driven enhancement of voluntary rather than involuntary attentional processes. To my knowledge no prior study meets both of these criteria.

In order to directly test the goal-driven hypothesis we therefore designed a task that would allow us to experimentally manipulate the goal-driven mechanism and measure the effect of this manipulation on involuntary attentional capture by entirely task-irrelevant motivationally salient stimuli. To this end, we fused a contingent capture paradigm from selective attention literature (e.g. Folk et al., 2002; 2008; Wyble, 2013) with the classic affective blink paradigm from anxiety and emotion literatures (e.g. Most, Chun, Widders & Zald, 2005; Smith, Most, Newsome & Zald, 2006; Piech, Pastorino & Zald, 2010; de Oca, Villa, Cervantes & Welbourne, 2012; Failing & Theeuwes, 2015; see McHugo, Olatunji & Zald, 2013 for review). Specifically, participants were instructed to search for a target stimulus defined by its affective category (e.g. positive or threatening), in a central RSVP stream while ignoring peripherally presented distractor images which were either positive, threatening, or neutral. The motivationally salient targets and distractors consisted of stimuli that have been widely used in the affective attentional capture literature - animals and faces (e.g. Lipp & Derakshan, 2005; Fox, Russo & Dutton, 2002; Öhman, 2005; LoBue & Rakison, 2013). Any purely stimulus-driven attentional capture by these motivationally salient stimuli should occur irrespective of task goals. Conversely, goal-driven attentional capture would occur only when the stimuli are congruent with what participants are searching for.

Experiment 1

Methods

Participants. Twenty participants were initially recruited, though one participant was excluded prior to analysis for accuracy being 3 *SD*s below the group mean (16 female, 3 male; Age: $M = 22.37$, $SD = 3$). The sample size was derived from study 2 of Wyble et al. (2013)

which found highly significant contingent capture. The mean accuracy, prior to data transformation for significant skewness, was 54.79% ($SD = 11.3\%$).

Given the well-established correlation of anxiety with attentional capture by threat, we measured both state and trait anxiety in order to compare sample characteristics across previous research and the current experiments (Bar-Haim et al., 2007). Participants' state and trait anxiety were in line with the expected range given participants' age (norms: $M = 36$, $SD = 10$; Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983), state: $M = 32.95$, $SD = 13.16$; trait: $M = 36.95$, $SD = 10.48$. Participants were remunerated with course credits or a small cash payment.

Stimuli. The neutral animal stimuli were a range of animal images sourced from Google images. In total, 391 images of individual animals, without any other salient objects in the scene, were initially selected. The images were all resized to 300×200 pixels and all writing was removed. These images were rated in a pilot study by 36 participants using a ten-point Likert scale measuring how threatening, cute, positive and negative they were. To select the most neutral animals, a composite affect score was created by averaging these four scales together. 280 images which were rated lowest on this measure were selected for neutral stimuli (Affect score: $M = 3.23$, $SD = .46$, highest score = 4.01; highest positive score = 6.31; highest cute score = 6.83; highest negative score = 4.08; highest threat score = 3.58). From these 280 images we removed images which contained features which could be mistaken for part of the target set. For instance, many images of elephants, walruses, and water buffalo were removed because their horns and tusks could be mistaken for bared teeth. Additionally, we removed one image of a bear because the animal was semantically related to the threat category despite the specific exemplar being neutral, as well as some images of tropical fish and exotic birds because their colours were highly salient. These images were replaced by 35 images of animals which were similar to those ranked in the lowest 150 images on overall affect (e.g. fish, birds, farm animals). Overall, the neutral animals were rated as moderately positive and cute, importantly, all images were rated low on negative and threat scores which was the main focus of the current investigation.

The threatening and cute animal images were partly selected from the International Affective Picture System (IAPS), but in order to provide a greater number of distinct threatening and cute animal images (reducing potential habituation effects) the IAPS images were supplemented with images from Google images. These latter images were selected based on their similarity to cute and threatening animals in the IAPS database (Lang, Bradley & Cuthbert, 2005) - cute animals were usually pets or infant animals, whilst the threatening animals were either predators in attack positions or snakes and spiders. Based on these criteria we collected twelve target images and twelve different distractor images for the cute and threatening animal categories. The 24 images used in the threatening animal category (12 targets and 12 distractors) consisted of six different animals: spiders, lions, tigers, snakes,

sharks, and crocodiles. For the cute category targets and distractors were comprised of six different cute animals: kittens, puppies, pandas, red pandas, ducklings, and rabbits. Again, twelve images appeared as targets and twelve different images as distractors. For both cute and threatening categories, all six types of animals appeared as both targets and distractors, but not the individual images. To validate the images, arousal and valence ratings were collected again from participants in Experiments 3, 4, and 5 (see Table 2) which confirmed that these images were considered to have negative valence and be highly arousing. All unlicensed images and their ratings are available online via the Open Science Framework (link: osf.io/mr5yk).

The images were presented using E-prime 2.0 on a Dell OptiPlex 780 PC, displayed on a 16inch monitor with a screen resolution of 800×600. The experiment was conducted in a dimly lit room. Participants viewed the screen from 59cm away, this distance was kept constant by using a chin rest. All images in the central RSVP stream measured 6°×4.02°. The distractors measured, 8.09°×5.35°, these were larger relative to the central target due to visual acuity being poorer at peripheral locations. The distractors were presented above and below the central RSVP stream with a gap of .5° separation from the target. Trials were controlled so the specific animal presented as a distractor was never the same as the target animal.

Procedure. See Figure 5 for an example trial sequence in the experimental paradigm. Participants were given the following instructions at the start of the task: "You will be shown several images of animals in quick succession. You must look out for either a 'cute' (e.g. baby or pet) or 'threatening' animal (e.g. predator or poisonous). You will be instructed which type of animal you are looking for before each trial. At the end of each trial you must write out the name of the cute/threatening animal using the keyboard. The target image will always appear in the centre of the screen. Occasionally two other images will appear at the top and bottom of the screen, you must ignore these images.". Search goal reminders were also presented at the beginning of each trial in order to ensure goal maintenance. The cute or threatening target stimulus was presented in a nine frame RSVP stream consisting of eight other neutral animal stimuli which were randomly selected from the total pool of neutral stimuli. Each stimulus frame was presented for 100ms with no inter-stimulus interval. The target stimulus appeared at positions five, six, seven, or eight in the RSVP stream an equal number of times within each block, and was counterbalanced across conditions. The peripheral distractor stimulus was consistently presented two slides prior to the target at Lag 2, and this was the only distractor-target relationship. These peripheral distractors were two images presented above and below the central stimulus position. The distractor was presented at Lag 2 because the current thesis focused on involuntary attentional capture, rather than later differences in attentional disengagement. The attentional blink produced by Lag 2 distractors reflects the earliest onset of attentional capture, and would therefore not reflect differences in disengagement that would occur at later lags (cf. McHugo et al., 2013). One of these stimuli was always a neutral animal

stimulus which was randomly selected from the pool of neutral animal images. The other distractor stimulus could either be a threatening animal, cute animal, or another neutral animal. Within each condition the distractor image appeared an equal number of times above and below the central stream. At the end of each trial, the participant typed out the animal they identified as the cute or threatening target using the keyboard and pressed the 'Enter'. The dependent variable was the percentage of trials that participants accurately reported the correct cute or threatening animal which had been presented.
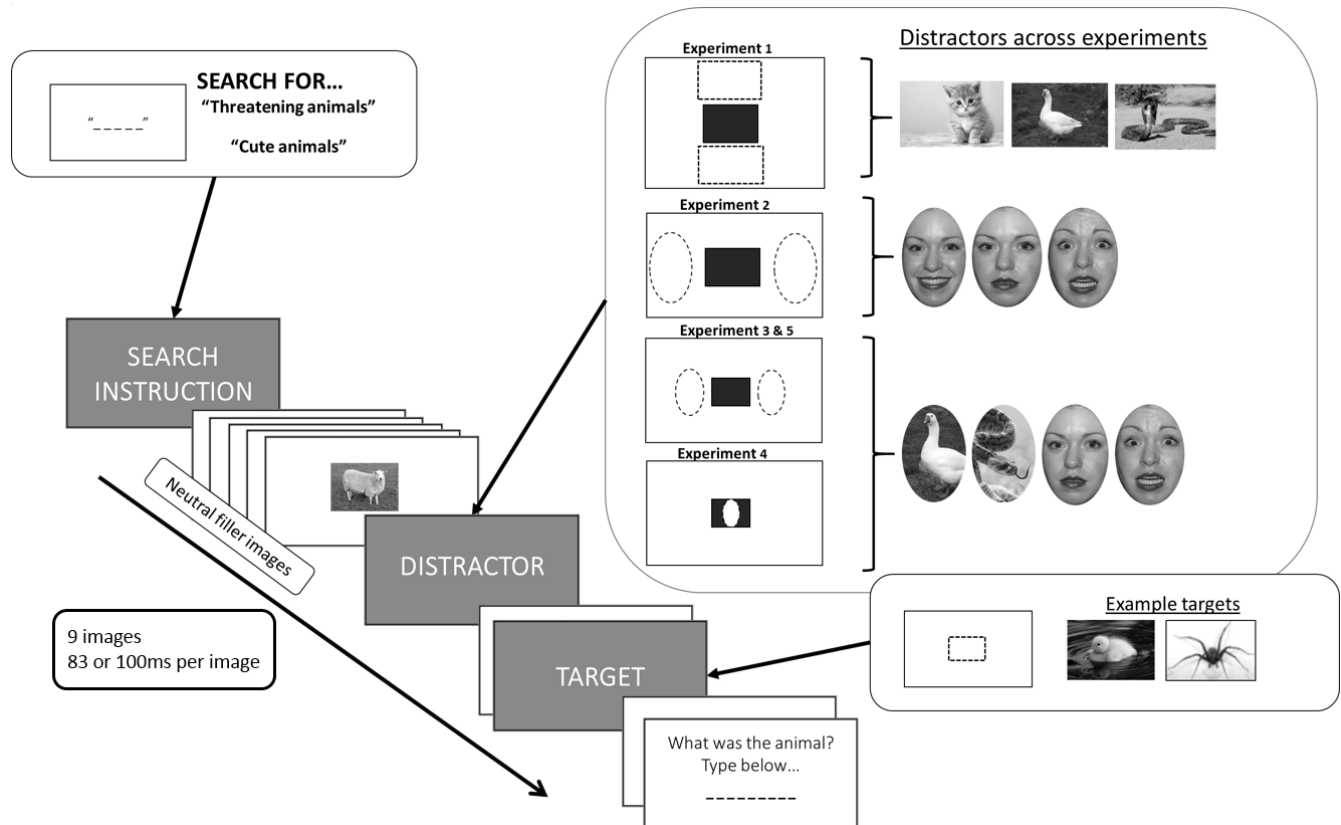
Figure 5: Structure of a single RSVP trial and example stimuli from across 5 Experiments; 9 images were presented per trial for either 83 (in Experiment 5) or 100ms (in Experiments 1-4) per image with no inter-stimulus interval. Examples of the instruction frame depict how the search instructions were presented in Experiments 1-4, Experiment 5 differed by instructing participants to search for happy and scared faces. The distractor and target frame examples depict the categories of images which appeared as stimuli, as well as the location of the distractor in each task, as symbolised by dashed lines. In Experiments 1-4, threatening and cute animal targets were presented, whilst in Experiment 5 happy and fearful face targets were presented. At the end of the trial participants were either required to type out what the specific animal target had been (Experiments 1-4), or whether the motivationally salient target had been present or absent from the RSVP stream (Experiment 5).

Before the main task, participants completed an eight-trial practice block with four cute targets and four threat targets (the specific images used in these practice trials were different from the set used in the main experiment). For the main task, participants completed six blocks of 36 trials each, with a period of rest every two blocks, the duration of which was determined by the participant. The search condition blocks were presented in an alternating format (e.g. cute-threat-cute-threat-cute-threat). The block order was counterbalanced between participants,

with half the participants completing a threat search block first. When blocks were not separated by a rest period, a text warning was presented for 3000ms alerting the participant that the search goal had changed. Other than search goal, which was manipulated between blocks, all within participant factors were fully counterbalanced within each block.

Scoring. The percentage of correctly identified animals was recorded as the outcome measure for analysis. In order to objectively score this measure, an excel formula was applied which marked a trial as correct when the spelling of the target animal matched the spelling of the response. To make sure that the responses were readable for this formula they were coded prior to the analyses. During the coding process the experimenter was blind to both the distractor conditions and the correct answers. Incorrectly spelt answers were corrected to the most similar animal included in the set of images[1]. Animals judged to be subordinate to the potential target animal were changed to the superordinate animal (e.g. black widow was changed to spider). A superordinate category answer was marked to the closest subordinate target, but only if there was only one possible animal within that category which it could be (e.g. 'reptile' could be either a crocodile or snake, so was left incorrect; but 'insect' was changed to spider). Additionally, if a participant wrote the mature version of the infant target animal it was changed to the correct version (e.g. dog was changed to puppy). To remain consistent across answers, changes were made universally to all answers made by a single participant, meaning that once a change was made to an answer it was also made for all identical answers that individual participant had made. Scoring rules were developed prior to Experiment 1 based on the pattern of responses from a pilot experiment.

Analytic strategy. Data from experiments 1, 2 and 4 were significantly skewed (skewness ratio > 1.96) therefore an arcsine transformation was applied to the data. All statistics were performed upon the arcsine transformed data. For ease of interpretation, graphs are presented with untransformed data. Note, the results remained unchanged with respect to patterns and significance when untransformed data were analysed. Analyses were performed using SPSS and R-studio for Bayesian analyses (R-studio team, 2015).

To supplement the main analysis, we computed a Bayes factor in order to determine whether any null effects were due to insensitivity or a true null effect. A Bayes factor compares evidence for the *experimental hypothesis* (motivationally salient stimuli will result in greater attentional capture) and the *null hypothesis* (motivationally salient stimuli will not result in attentional capture). The Bayes factor ranges from 0 to infinity, values less than 1 indicate that there is support for the null hypothesis, whilst values of greater than 1 indicate that there is

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[1] Some participants answered "chick" to the "duckling" target. This was accepted as correct due to the two animals being highly visually similar, and there being no chicks amongst the stimulus set, thus meaning that it was not mistaken for another target image. Additionally, "fox" was accepted as "red panda" for the same reasons. These changes were applied universally to all the participant's responses whilst the experimenter was blind to any of the correct target animals and conditions.

support for the experimental hypothesis. The strength of this evidence is indicated by the magnitude of the Bayes Factor; values greater than three or less than .33 indicate substantial evidence for either the experimental or null hypothesis. A value closer to 1 suggests that any nonsignificant result may be due to insensitivity and any difference is 'anecdotal' (Jeffrey, 1961; Dienes, 2008; 2011; 2014; 2016).

The Bayes factor was computed using a modified version of Baguley and Kaye's (2010) R code (retrieved from Dienes, 2008). To compute the factor, we used a half-normal distribution which estimates that smaller differences are more probable than large difference. The mean of this distribution was set to zero, which reflects a null hypothesis of zero difference. we used a half-normal distribution due to the previous evidence in the literature that the effect would be directional; specifically, that motivationally salient stimuli would capture attention more than neutral stimuli. The standard deviation of this distribution was set based on the prior expected effect size. For Experiment 1 this was a plausible effect size of 15% [2], however, based on the new data collected we revised this prior to 13% for subsequent experiments. All Bayesian analyses were performed using arcsine transformed data if a transformation was performed. All direct comparisons between conditions were tested using Bayes factors, however, *p*-values were also computed using two-way paired samples t-tests to facilitate comparison to previous results.

Results and Discussion

A 2×3 ANOVA with the factors of current search goal (cute/ threatening animal) and distractor category (cute/ threatening/ neutral animal) was performed on mean accuracy (Table 1). This revealed that there was no significant difference in the accuracy with which participants detected cute versus threatening targets, $F(1, 18) = 1.60$, $p = .222$, $\eta^2_p = .08$. There was a significant main effect of distractor, $F(2, 36) = 7.51$, $p = .002$, $\eta^2_p = .30$, with the cute and threatening distractors resulting in significantly lower performance than neutral distractors.

Importantly, this effect was qualified by a highly significant interaction between target and distractor, $F(1.69, 30.47) = 16.11$, $p < .001$, $\eta^2_p = .48$ (Huynh-Feldt corrected). In order to plot the interaction more clearly, we created a motivational distractor effect score by subtracting the accuracy when the distractor was cute or threatening from the neutral distractor condition, both for cute and threat search conditions (see Figure 6). Performance when the distractor was a

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[2] The prior used to determine the width of the half-normal distribution was taken from Wyble et al. (2013) Experiment 2, due to this being the most methodologically similar to the current design. This yielded a plausible effect size of 15% difference in performance, reflecting the difference between distractors that were congruent and incongruent with a current search goal. Additionally, this is in line with the effect size of 14% decrement in accuracy after attentional capture by the threatening stimuli used in the original affective blink task (Most et al., 2005 - Experiment 1). In order to update the prior based on relevant information, the largest effect size from Experiment 1 (13%) was used as the prior for all subsequent analyses. Based on our sample size we used an adjusted standard error by applying the following equation: SE*(1 + 20/df*df) (Dienes, 2008; 2011).

cute animal was lower when the target was also a cute animal, and a similar pattern was also observed for threatening distractors when the target was also threatening. Thus, participants were significantly poorer at identifying the target when the distractor category matched the current search goal.

	Search goal	Distractor	Mean (% accuracy)	SE
Experiment 1 (*n* = 19)	Cute search	Cute animal	52.93	4.11
		Threat animal	64.98	3.84
		Neutral animal	65.68	3.41
	Threat search	Cute animal	60.67	3.77
		Threat animal	51.18	3.58
		Neutral animal	61.05	3.83
Experiment 2 (*n* = 18)	Cute search	Happy face	56.00	3.94
		Fearful face	56.80	4.39
		Neutral face	58.86	4.49
	Threat search	Happy face	51.27	3.31
		Fearful face	52.70	3.38
		Neutral face	54.07	3.69

Table 1. Mean and Standard error for accuracy across all target and search conditions within Experiment 1 and 2. Data presented are arcsine transformed to account for significant skewness.

In order to investigate whether there was any evidence of stimulus-driven attentional capture by motivationally salient stimuli, we compared target identification accuracy between motivationally salient and neutral distractors within each search condition. As can be seen in Figure 6, motivational distractor effects associated with the motivationally salient versus neutral distractors were *only* observed when the distractors shared an affective category with the current search goal: cute distractors had significantly lower performance than neutral distractors when participants were searching for the cute target, $t(18) = 4.98$, $p < .001$, $B_{H(0,15)} = 14896.33$, and threat distractors had significantly lower performance relative to neutral distractors in the threat search condition, $t(18) = 3.88$, $p = .001$, $B_{H(0,15)} = 224.34$. Strikingly, there was no reduction in performance when the motivationally salient stimuli were incongruent with the current search goal; cute animal distractors resulted in the same accuracy as neutral distractors in the threat search condition, $t(18) = .16$, $p = .876$, $B_{H(0,15)} = .19$. The same was true of threatening distractors in the cute search condition, $t(18) = .34$, $p = .738$, $B_{H(0,15)} = .19$. Note that the Bayes factors for both effects are under one third and hence confirm that the null results reflect an absence of attentional capture rather than insensitivity. Therefore, there was substantial evidence that, within the current task, motivationally salient distractors only captured attention when they were congruent with current top-down search goals.
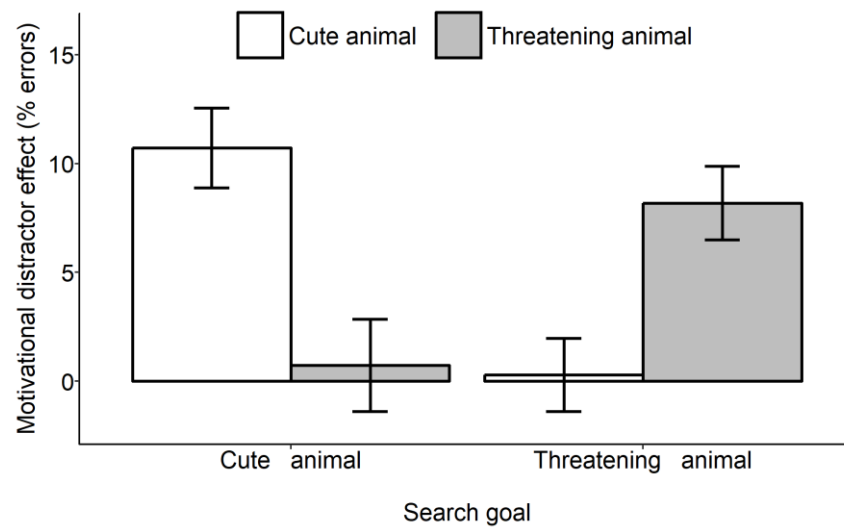
Figure 6. Motivational distractor effects (% correct neutral distractor - % correct motivationally salient distractor) for cute and threatening animal distractors across both cute and threatening animal search conditions in Experiment 1. Error bars represent within-subjects standard error.

The results of Experiment 1 provide direct evidence that involuntary attentional capture by motivationally salient stimuli can be induced via the adoption of a congruent top-down goal, even when they are completely task-irrelevant. Furthermore, the results demonstrate a striking absence of any attentional capture effects from either positive or threatening stimuli when these did not share an affective category with the current top-down goal. The latter absence of goal-irrelevant attentional capture initially appears to challenge the widely held stimulus-driven view of attentional capture by motivationally salient stimuli.

Experiment 2 attempted to replicate the current findings using another well-established class of motivationally salient stimuli: emotional faces.

Experiment 2

In order to provide a more extensive test of whether stimulus-driven attentional capture could be found in the current task, Experiment 2 repeated the design of Experiment 1 using fearful and happy face stimuli as distractors. Fearful face stimuli are one of the most widely used stimuli in attention to threat paradigms, and have been found to reliably activate neural regions associated with threat processing even at brief presentations (e.g. the amygdala; Bishop, 200). Further, attentional capture by emotional faces, especially fearful faces, appears in infancy (5 – 7 months old), suggesting it is a rapidly learnt motivationally salient stimulus and should be universally captivating across participants (Peltola, Hietanen, Forssman & Leppanen, 2013).

Experiment 2 was also designed to further clarify the nature of the goal-driven attentional capture effects in Experiment 1, by investigating generalisability. Contingent capture effects have previously been found to extend across visually diverse stimuli belonging to a semantic category, such as 'furniture' or 'sports equipment' (Wyble et al., 2013).

Experiment 2 was therefore designed to test whether the contingent capture effects found in Experiment 1 might extend beyond the specific stimulus category (e.g. 'threatening animals') to the broader affective category (e.g. 'threat'). If the emotional faces captured attention more when they were congruent with the affective category of the search goal (i.e. threatening animal search goal - fearful face distractor), this would imply the ability to adopt a broad attentional setting for an entire affective category rather than a specific sub class of affective stimuli.

Methods

Participants. Twenty participants were initially recruited, though 2 participants were excluded prior to analyses for taking an excessively long time to complete the search task (over 50 minutes, compared to the typical task duration of 20-25 minutes)[3], leaving 12 female and 6 male participants (Age: $M = 21.78$, $SD = 2.39$). The mean accuracy, prior to data transformation, was 51.29% ($SD = 11.86\%$). Participants' state and trait anxiety were above the expected range given participants' age, state: $M = 41.5$, $SD = 8.39$; trait: $M = 39.34$, $SD = 7.9$. Participants were remunerated with course credits or a small cash payment.

Stimuli and procedure. The stimuli and methods were identical to those used in Experiment 1, except that the threatening, cute, and neutral animal distractors were replaced with fearful, happy, and neutral faces taken from the NimStim database, which have been widely used in both emotion processing and attentional literatures (Tottenham et al., 2009). Twelve fearful faces, twelve happy faces, and twelve neutral faces were selected; they all shared the same 12 identities, so were matched on every feature except emotion. As in previous instigations which found attentional capture by fearful faces (e.g. Hodsoll et al., 2011), we ovalled the faces to remove any non-emotional identifying features of the outline, such as jaw line or hair style. To occupy the opposite distractor location not occupied with the face distractor, we presented one of twelve different skin patches. These were the same size and shape as the face distractors, and were created from a close up of the skin of these distractor faces but did not contain any facial features.

Due to the face stimuli being taller than animal images, distractors were presented to the left and right of the target in an upright position. In order to compensate for the increased distance from the centre of attention, the images were enlarged so they measured, $11.33° \times 7.49°$. They were presented with a gap of .5° between them and the central RSVP stream.

Results and Discussion

As in Experiment 1, a 2×3 ANOVA was performed with target search category (cute/ threatening animal) as one factor and distractor category as the second (happy/ fearful/ neutral faces). This revealed that there was a non-significant difference between cute targets and threatening targets, $F(1, 17) = 1.63$, p = .219, $\eta^2_p = .09$, as well as a nonsignificant main effect of

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[3] Including these two participants did not alter the significance values or pattern of my findings.

distractor, $F(2, 34) = 1.84$, p = .174, η^2_p = .1. The interaction between target and distractor was also non-significant, $F(2, 34) = .04$, p = .961, η^2_p = .002. Therefore, unlike Experiment 1, there was no significant difference in identification accuracy between any of the distractor conditions across either search condition. As in Experiment 1, we plotted a motivational distractor effect score to clearly present the distraction compared to the neutral distractor (see Figure 7).
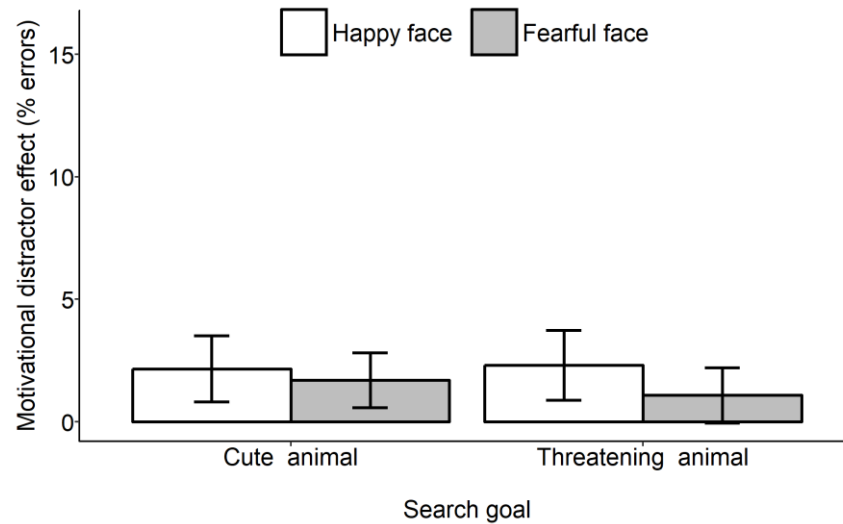
Figure 7. Motivational distractor effects (% correct neutral distractor - % correct motivationally salient distractor) for happy and fearful face distractors across both cute and threatening animal search conditions in Experiment 2. Error bars represent within-subjects standard error.

To investigate whether there was any evidence of stimulus-driven capture, comparisons were made between motivationally salient distractors and neutral distractors within each search goal condition. The Bayesian analysis revealed that evidence favoured the null hypothesis across all conditions. When the distractor was a fearful face there was greater evidence for the null hypothesis than the experimental hypothesis, this was true for both cute and threatening search conditions, $t(17) = 1.08$, $p = .297$, $B_{H(0,13)} = .43$ and $t(17) = 0.88$, $p = .389$, $B_{H(0,13)} = .28$, respectively. This was also true for happy faces in both cute and threat search conditions, $t(17) = 1.28$, $p = .218$, $B_{H(0,13)} = .64$ and $t(17) = 1.24$, $p = .232$, $B_{H(0,13)} = .61$, respectively. Overall, the Bayes factors were closer to 0 than 1, therefore, evidence favoured the null rather than the experimental hypothesis, although the Bayes factors revealed that the data were insensitive.

Experiment 2 hence did not find evidence of stimulus-driven attentional capture independent of current search goals, nor of the generalisation of goal-driven capture to an affectively related category. It should be noted, however, that the distractors in Experiment 2 were presented further away from fixation than those in Experiment 1, to accommodate the stimulus dimensions. It was therefore important to rule out the possibility that this difference could have reduced sensitivity to find distractor effects in Experiment 2. For example, these forms of attentional capture might be dependent on a fuller processing of features which is made

possible at more central locations. In order to allow a more direct comparison of the two distractor categories used in Experiments 1 and 2, a third experiment was conducted in which both motivationally salient faces and animal distractors were presented in identical locations.

Experiment 3

The aim of Experiment 3 was to (1) replicate Experiment 1's finding of goal-driven attentional capture by affective stimuli, and (2) further test the possibility that this goal-driven attentional capture might generalise beyond the specific stimulus category (e.g. 'threatening animals') to the broader affective category (e.g. 'threat'). To allow direct comparison of these potential specific and more generalised goal-driven attentional capture effects, we incorporated both distractor categories into the task, removing any differences in stimulus location which could affect attentional capture. Participants performed the same central animal search task as in Experiments 1 and 2, while ignoring distractors that were either threatening animals, fearful faces, or neutral animals and faces. We chose to focus on threatening stimuli rather than both positive and threatening stimuli, in order to compare to previous literature which has focused particularly on threat (cf. Yiend, 2010; Cisler & Koster, 2010). We expected to replicate Experiment 1's finding that threatening animal distractors would interfere with target identification, but only in the threatening animal search condition. It was unknown whether, having controlled for differences in distractor location, these contingent capture effects would now also generalise to the fearful faces (i.e. revealing interference from these stimuli exclusively in the threat search condition).

Methods

Participants. Twenty participants were initially recruited, though one participant was excluded prior to analysis for accuracy being 3 *SD*s below the group mean, and another because of a programming error (12 female, 6 male; Age: $M = 20.89$, $SD = 2.65$). The mean accuracy prior to data transformation was 52% ($SD = 15.52\%$). Participants' trait anxiety was higher than the expected range given participants' age, state: $M = 36.83$, $SD = 8.77$; trait: $M = 47.17$, $SD = 10.62$. Participants were remunerated with course credits or a small cash payment.

Stimuli and procedure. The stimuli and procedure in Experiment 3 were identical to Experiments 1 and 2, though in order to compare the effect of emotional faces and threatening animals within a single experiment, the following changes were made to the design; a 2×2×2 within-subjects design was used: Target type (cute/ threat) × Distractor type (animal/ face) × Distractor valence (threat/ neutral). Additionally, all images were reduced in size in order to place them in a parafoveal vision (>2.5° eccentricity), rather than peripheral vision (> 5°; cf. Toet & Levi, 1992). This meant that images in the central RSVP stream measured 3.44°×2.29°, and distractors measured 2.98°×4.58° visual angle at 59cm viewing distance from the screen. The distractors were presented to the left and right of the central RSVP stream with a gap of .5°

between the central image and the distractor. The order of distractors and targets was pseudo randomly generated in order to prevent the distractor being the same animal as the target, or regular pairings of distractor and target emerging by chance.

Stimuli were taken from the same pool of images as Experiments 1 and 2. The neutral animal distractors were six images of six different animals (capybara, sheep, pig, catfish, goose, pigeon), these exemplars never appeared as part of the central stream. Similarly, six separate threatening animals were selected from those used in Experiment 1. Six fear and six neutral faces were selected to be distractors from those used in Experiment 2. Both fear and neutral faces shared the same individual identities, meaning that the only difference was their emotion. As in Experiments 1 and 2 one distractor image appeared per trial - the opposite side distractor location was occupied with an oval patch of skin or animal texture (e.g. fur or feathers). Twelve skin and twelve animal texture exemplars were created from close up images of faces and animals. Texture patches were presented only alongside their congruent distractor type (i.e. skin patch alongside face distractor), and were randomly selected across the block. To remove size differences between the animal and face distractors, all distractors were ovalled leaving only the key features of both animals and faces. They were both presented in an upright position during the experiment.

Six threatening animal images and six cute animal images were selected to be targets from those used in Experiment 1 and 2[4]. Each target category was made up of the same six different animals presented in Experiments 1 and 2. 192 neutral filler images were selected to appear in the central RSVP. All target and distractor images were rated by participants from Experiments 3, 4 and 5 ($N = 54$) along dimensions of arousal and valence using a self-assessment manikin (see Table 2; Bradley & Lang, 1994). Ratings from each individual experiment produced a similar pattern of results.

	Mean arousal (SD)	Mean valence (SD)
Threatening animals	6.48 (2.26)	3.24 (1.82)
Cute animals	3.61 (2.3)	7.83 (1.44)
Neutral animals	2.82 (1.73)	5.56 (1.79)
Fearful faces	4.73 (2.22)	3.1 (1.25)
Happy faces	3.9 (1.98)	7.19 (1.51)
Neutral faces	2.61 (1.58)	4.6 (1.24)

Table 2: Ratings of target and distractor images by participants within Experiments 3-5 for stimuli included in their respective experiment. Ratings of each category represent the average of both distractor and targets together. Maximum positive valence was 9, maximum negative valence was 1, 5 reflects neutral valence. The highest arousal rating was 9, whilst an arousal rating of 1 was reflects low arousal. All motivationally salient stimuli were significantly more arousing, and either more positive or negative than their neutral counterparts in the expected directions, all p's < .005.

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[4] The crocodile stimuli were replaced due to very poor performance in identifying these targets in Experiment 1 and 2. These were replaced with images of crocodiles which were more visible.

Procedure. Participants completed four blocks of 48 trials each, with the cute search blocks and threat search blocks were structured in an alternating format (i.e. cute-threat-cute-threat-cute-threat), the order of which was counterbalanced between participants. Rest periods occurred after every two blocks. Prior to the beginning of a block a warning was presented for 3000ms, alerting participants that the search category was changing from the previous block. Within both cute and threat search blocks the four types of distractor were presented with equal probability, these appeared equally to the left and the right of the target. The target could appear at position five, six, seven or eight in the RSVP stream, whilst the distractor was always presented at Lag 2, two stimuli prior to the target position. Except for search goal, all within subject variables were counterbalanced within each block. After the experiment was completed the participants were asked to rate the images using the 9-point self-assessment manikin for arousal and valence (cf. Bradley & Lang, 1994). All distractors and target images were rated in a random order. Finally, participants completed the STAI (Spielberger et al., 1983).

Results and Discussion

Identification accuracy across the eight conditions (see Table 3) was analysed in a $2\times2\times2$ repeated measures ANOVA: search goal (cute/threatening) $\times$ distractor type (face/animal) $\times$ distractor valence (threat/neutral). The analysis revealed that there was a nonsignificant difference between accuracy in the cute animal search goal versus threatening animal search goal, $F(1, 17) = 1.37$, $p = .259$, $\eta^2_p = .07$. Additionally, there was no significant difference between face distractors and animal distractors, $F(1, 17) = .42$, $p = .524$, $\eta^2_p = .02$. There was, however, a marginally significant effect of distractor valence, $F(1, 17) = 4.24$, $p = .055$, $\eta^2_p = .2$, with threatening distractors resulting in lower performance relative to neutral distractors. Search goal did not significantly interact with distractor type, $F(1, 17) = .69$, $p = .417$, $\eta^2_p = .04$, however, it did significantly interact with distractor valence, $F(1, 17) = 7.14$, $p = .016$, $\eta^2_p = .30$. Distractor type also interacted with distractor valence, $F(1, 17) = 6.36$, $p = .022$, $\eta^2_p = .27$. Importantly, the three way interaction was significant, $F(1, 17) = 7.25$, $p = .015$, $\eta^2_p = .299$. In order to clearly illustrate the interactions, we plotted results as a motivational distractor effect score (see Figure 8); unlike previous Experiments the motivationally salient distractor was only subtracted from the neutral distractor of the same type. This clearly demonstrated that threatening animal distractors resulted in lower performance relative to neutral animal distractors, but only when participants were searching for threatening animals, not when they were searching for a cute target. Conversely, fearful face stimuli did not interfere with target identification relative to neutral faces in either search condition.

	Search goal	Distractor	Mean (% accuracy)	SE
Experiment 3 (*n* = **18**)	Cute search	Fear face	51.62	4.42
		Neutral face	50.69	4 .51
		Threatening animal	50.69	4.61
		Neutral animal	48.38	4.21
	Threat search	Fear face	53.94	3.68
		Neutral face	53.24	3.99
		Threatening animal	47.92	3.30
		Neutral animal	59.49	4.4
Experiment 4 (*n* = **18**)	Cute search	Fear face	69.46	4.35
		Neutral face	67.99	3.88
		Threatening animal	64.93	3.87
		Neutral animal	64.85	3.62
	Threat search	Fear face	58.83	3.57
		Neutral face	59.09	4.16
		Threatening animal	32.92	2.39
		Neutral animal	64.16	3.36
Experiment 5 (*n* = **18**)	Happy search	Fear face	81.00	2.70
		Neutral face	87.5	1.65
		Threatening animal	88.00	1.87
		Neutral animal	88.56	1.83
	Fearful search	Fear face	76.61	2.89
		Neutral face	87.39	2.64
		Threatening animal	89.28	2.23
		Neutral animal	91.94	1.73

Table 3: Mean and Standard error for accuracy across all target and search conditions within experiment 3-5. Data for Experiment 3 and 5 is untransformed, whilst data from Experiment 4 has been arcsine transformed to account for significant skewness.

To investigate whether there was any evidence of stimulus-driven capture, comparisons were made between each motivationally salient distractor and the matched neutral distractor of the same type. This was performed across both search conditions. The pairwise comparisons revealed that threatening animal distractors resulted in lower performance relative to neutral animals in the threatening animal search condition, $t(17) = 5.46$, $p < .001$, $B_{H(0,13)} = 109073.60$, but there was no evidence of attentional capture in the cute search condition, $t(17) = 1.27$, $p = .221$, $B_{H(0,13)} = .07$. There was, also, no difference between fearful face and neutral face distractors in either the threatening animal search condition or the cute animal search condition, $t(17) = .27$, $p = .787$, $B_{H(0,13)} = .17$ and $t(17) = .34$, $p = .737$, $B_{H(0,13)} = .17$, respectively.

All Bayes factors were below .33, thus revealing that there was substantial evidence that there was no involuntary attentional capture by motivationally salient stimuli, relative to neutral stimuli, independent of goal-driven capture effects.
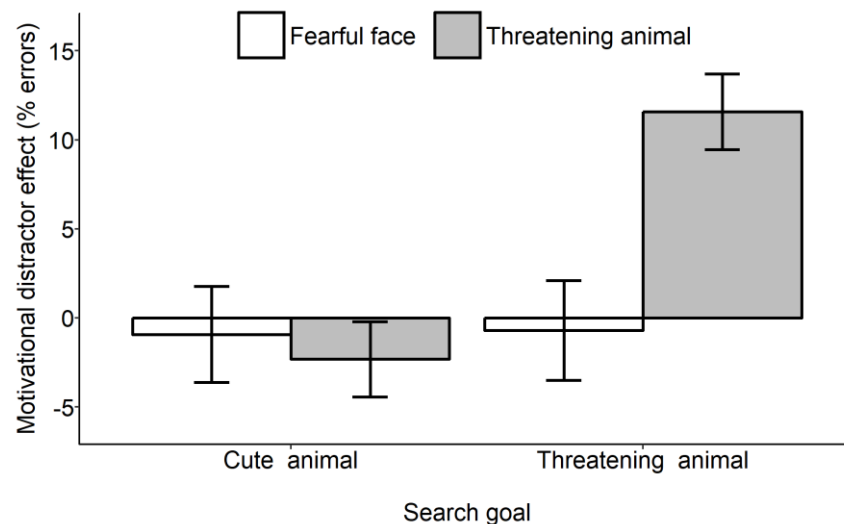
Figure 8. Motivational distractor effects (% correct neutral distractor - % correct motivationally salient distractor) for fearful face and threatening animal distractors across both cute and threatening animal search conditions in Experiment 3. Error bars represent within-subjects standard error.

Experiment 4

The results of Experiment 3 replicated the findings from Experiments 1 and 2, showing that motivationally salient threatening stimuli only involuntarily captured attention when they were congruent with current search goals. Again, this was only found for threatening stimuli which matched the specific category of the searched for target; incongruent fearful faces did not capture attention at all. The lack of interference from goal-incongruent threat distractors in Experiments 1 - 3 contrasts with previous affective blink studies, which found evidence for apparently stimulus-driven attentional capture by threatening and positive images within the context of a similar RSVP task. One potential reason for this could be that all previous investigations presented the motivationally salient distractor in the central RSVP stream, and it may therefore be that these stimuli only involuntarily capture attention when participants can fully perceive the distractor stimulus. Belopolsky and Theeuwes (2010) found that when participants focused their attention on a central RSVP stream, peripheral salient distractors did not cause an attentional blink; however, when participants had to broaden their 'attentional window' by focusing on peripheral target locations, a salient distractor captured attention. Further, in other visual search tasks when participants were instructed to focus attention to a specific location away from a fearful face or a threat associated stimulus, there was no evident attentional capture effects (Reeck, LaBar & Egner, 2012; Notebaert, Crombez, Van Damme, Durnez & Theeuwes, 2013).

It may be, therefore, that stimulus-driven capture only occurs when it appears within the attentional window (cf. Notebaert et al, 2013; Belopolsky & Theeuwes, 2010). To my knowledge, this would be consistent with all previous research on attentional capture by motivationally salient stimuli; previous paradigms including the dot-probe, exogenous cueing task, pictorial Stroop task, visual search task, and affective blink task have all presented the distractor within the attentional window and in a potential target location (see General Discussion (section 7.3) for further discussion of these tasks). If motivationally salient stimuli which are incongruent with current search goals only capture attention when they appear within the attentional window, then my current design would not detect this. To test whether this could explain the lack of stimulus-driven effects within my task, we replicated Experiment 3 using centrally presented rather than peripheral distractors.

Methods

Participants. Nineteen participants were initially recruited, though one participant was excluded prior to analysis for accuracy being 3 *SD*s below the group mean (16 female, 2 male; Age: $M = 22.44$, $SD = 4.83$). The mean accuracy, prior to data transformation, was 55.79% ($SD = 8.52\%$). Participants' state and trait anxiety were within expected range given participants' age, state: $M = 37.84$, $SD = 9.2$; trait: $M = 39.5$, $SD = 9.87$, Participants were remunerated with course credits or a small cash payment.

Stimuli and procedure. The task and procedure were nearly identical to Experiment 3 with the exception that the distractor appeared in the central stream. These distractors were marked as task-irrelevant by being presented as a $1.53°×2.29°$ oval which was presented within a grey rectangle amongst the other stimuli which were all complete rectangular images. This change resulted in one fewer neutral filler image per trial, leaving a total of 168 neutral animals images selected to appear across the experiment. Additionally, for the purposes of counterbalancing, the number of target locations in the RSVP stream was reduced to positions six, seven and eight. As in previous Experiments, the distractor appeared two slides prior to the target position (i.e. Lag 2).

Results and Discussion

As in Experiments 3, a 2×2×2 ANOVA was performed. The main effect of search goal was significant, $F(1, 17) = 14.88$, $p = .001$, $\eta^2_p = .47$, with cute animals identified more accurately than threatening animal targets. The main effect of distractor type was also significant, $F(1, 17) = 12.03$, $p = .003$, $\eta^2_p = .41$, with animal distractors resulting in lower performance overall compared to face distractors. Additionally, the main effect of distractor valence was also significant, $F(1, 17) = 22.57$, $p < .001$, $\eta^2_p = .57$, revealing that threat related distractors resulted in lower performance than neutral distractors. The interaction between search goal and the different distractor type was marginally significant, $F(1, 17) = 3.89$, $p = .065$, $\eta^2_p = .19$. Current search goal also significantly interacted with distractor valence, $F(1, 17)$

$= 28.78$, $p < .001$, $\eta^2_p = .63$, as did distractor type and distractor valence, $F(1, 17) = 26.26$, $p < .001$, $\eta^2_p = .61$.

Importantly, the three way interaction between target category, distractor type, and distractor valence was significant, $F(1, 17) = 29.13$, $p < .001$, $\eta^2_p = .63$. As in Experiment 3, fearful faces were no more distracting than neutral faces in either search condition, whilst threatening animal distractors resulted in a significant reduction in accuracy, but only in the threatening animal search condition. The large magnitude of this single effect appears to account for all other significant interaction terms, as clearly shown in the motivational distractor effect plot (see Figure 9).
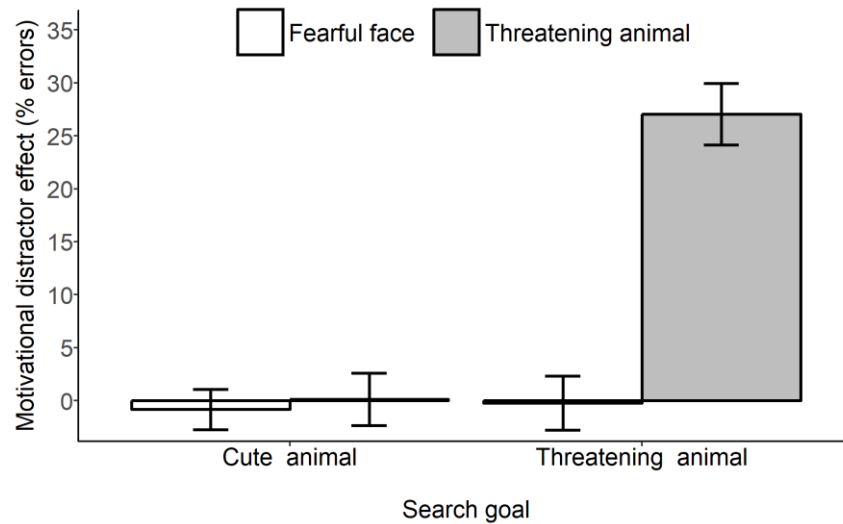
Figure 9. Motivational distractor effects (% correct neutral distractor - % correct motivationally salient distractor) for fearful face and threatening animal distractors across both cute and threatening animal search conditions in Experiment 4. Error bars represent within-subjects standard error.

To investigate whether central presentation of the distractors resulted in any evidence for stimulus-driven capture of attention, comparisons were made between motivationally salient distractors and neutral distractors of the same type across both search conditions, as they had been in Experiment 3. This revealed substantial evidence for the null hypothesis (B < .33) across all conditions when the distractor was incongruent with the specific category which was searched for: in both cute and threatening animal search conditions fearful faces were no more distracting than neutral faces, $t(17) = .61$, $p = .549$, $B_{H(0,13)} = .12$ and $t(17) = .002$, $p = .998$, $B_{H(0,13)} = .23$, respectively. The same was true for the threatening animal distractors which were no more distracting than the neutral animal distractors when participants were searching for the cute animal, $t(17) = .02$, $p = .986$, $B_{H(0,13)} = .24$. When the threatening animal distractor was presented in the threatening animal search condition there was substantial evidence for attentional capture relative to matched neutral stimuli, $t(17) = 8.05$, $p < .001$, $B_{H(0,13)} = 92559632336$.

Experiment 4 replicates the previous results by demonstrating that attentional capture by motivationally salient stimuli, specifically threatening animals, was entirely dependent upon goal-driven search conditions. Interestingly, the magnitude of the motivational distractor effect score for the goal-congruent threatening animals was significantly larger than that found in Experiment 3, $t(34) = 3.97$, $p < .001$, $B_{U(0,27)} = 474.24$; all other p's $> .432$, $B_{U(0,27)} < .19$.[5] This is in keeping with previous evidence that centrally presented distractors interfere more with task performance than more peripheral distractors (Beck & Lavie, 2005). It would appear, therefore, that the more visible the distractor features, the greater the effect of goal-driven capture. It is notable that, despite this apparent advantage, no evidence for stimulus-driven attentional capture was found.

I have interpreted the contingent capture effects seen in Experiment 1, 3 and 4 as support for the goal-driven account of involuntary capture by motivationally salient stimuli. However, an alternative account of contingent capture effects has previously been proposed in terms of low-level priming of the visual features from previous trials (cf. Theeuwes, 2013; Lamy & Kristjansson, 2013; Belopolsky, Schreij, Theeuwes, 2010). The selected target features on one trial is argued to transiently prime the same low-level features on the subsequent trial, causing attention to be directed towards these features because of their 'selection history' as a previous target.

It is important to consider whether this 'selection history' account might alternatively explain the results. The relatively long duration of the trials (~5s) makes inter-trial priming effects somewhat less plausible, as there would likely be time for transient priming to dissipate. Moreover, as the motivationally salient stimuli were composed of multiple visually heterogeneous animals, on many trials the target features would be unlikely to prime the features of the subsequent distractor stimulus, e.g. a lion target would be unlikely to prime a spider distractor. However, given that some of the targets did share features (e.g., bared teeth or open mouth for the threatening animals; large eyes and fluffy fur for the cute animals), it was important to directly test an alternative explanation of the effects in terms of low-level inter-trial priming.

To this end, we conducted an additional analysis of the results from Experiments 1, 3 and 4 examining interference only from the spider distractors, which did not share any features with the other threatening animals. In order to preclude any transient priming effect, we excluded the trials which had been preceded by a spider target within the previous two trials,

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[5] B_U signifies a uniform distribution where small effects are equally probable as large effects, which was selected due to the lack of previous knowledge about this specific comparison (cf. Dienes, 2008; 2011). We expected a directional effect, with centrally positioned distractors yielding higher distractor costs. The minimum effect size was set to zero, whilst the maximum plausible effect size was selected based on the greatest difference which we found in the current investigation: 27%, taken from the transformed data of Experiment 4.

thus precluding any transient priming effect. This led to the removal of 26.2% of the spider distractor trials from the threat search condition. Even with the potentially primed trials removed, we found that the motivational distractor effect score was significantly greater in the threat search condition than the cute search condition, thus, a highly significant goal-driven contingent capture effect still remained when primed distractors were excluded ($M = 33.96$, $SE = 3.11$ vs $M = 6.46$, $SE = 3.2$; $t(54) = 6.75$, $p < .001$; $B_{H(0,13)} = 84381753$). Furthermore, we note that this effect was consistent across all three experiments: Experiment 1 $t(18) = 2.45$, $p = .025$, $B_{H(0, 13)} = 7.01$; Experiment 3 $t(17) = 3.68$, $p = .002$, $B_{H(0, 13)} = 96.17$, and Experiment 4 $t(17) = 6.71$, $p < .001$, $B_{H(0, 13)} = 1999083$.

The above analysis demonstrates that the contingent capture effects are not dependent on inter-trial priming. We note that this does not rule out the possibility that selection history can influence attention in other paradigms and contexts, but it does discount it as an account of the current results.

Experiment 5

Experiments 2-4 found no evidence of attentional capture from emotional faces, despite using the exact same face stimulus set that has previously elicited involuntary attentional capture in a multitude of experimental tasks (Tottenham et al., 2009). However, in the current experiments, the faces never directly matched the task's top-down goal. Experiment 5 sought to test whether the face stimuli would be capable of capturing attention in the current paradigm when they match top-down task goals. To this end, we modified the task search goals, so that instead of searching the central stream for cute or threatening animals, participants were now instructed to search for happy or fearful emotional faces. We presented the identical distractor stimuli to those used in Experiments 3 and 4, in order to see whether current search goals could induce involuntary attentional capture by emotional faces which was absent in the previous experiments.

Methods

Participants. Eighteen participants were recruited for this experiment (11 female, 7 male; Age: $M = 21.06$, $SD = .54$). The mean accuracy, prior to data transformation, was 86.28% ($SD = 1.16\%$). Participants' trait anxiety was above the expected range given participants' age, state: $M = 36.72$, $SD = 2.31$; trait: $M = 43.39$, $SD = 3.18$. Participants were remunerated with course credits or a small cash payment.

Stimuli and procedure. The experiment structure was similar to Experiment 3, with the exception of the following changes. Firstly, participants were instructed to search for happy faces, instead of cute animals, and scared faces instead of threatening animals. There were two blocks of 96 trials, one for the happy face search, and one for the fearful face search. The order of these blocks was counterbalanced between participants. An additional change to the paradigm was that participants had to identify whether the emotional face was present or absent

on each trial. They responded using the 'c' and 'm' keys, the key-response assignment was counterbalanced between participants. The target was present on half of trials, when it was absent the target was replaced by an upright neutral face. Pilot testing revealed that participants were performing at ceiling, thus the stimulus presentation time was reduced to 83ms per frame with no inter-stimulus interval. Unlike the RSVP of previous Experiments which were composed entirely of animal images, the neutral filler stimuli were composed of two neutral animals selected from the previous pool of neutral images, three inverted faces, and either three or four upright faces, depending on whether the target was present or absent. The multiple types of filler stimuli were presented in a random order in each trial, their purpose was to increase the difficulty of the task. In total, 48 neutral animals were presented in the central RSVP stream, alongside 72 upright faces and 72 inverted faces all with different identities. The neutral face stimuli were taken from the Productive Aging Laboratory Face database (Minear & Park, 2004). The target stimuli consisted of three happy faces and three fearful faces of the same identities. These were taken from the NimStim database (Tottenham et al., 2009). These target images could appear at positions six, seven or eight in the RSVP, appearing equally at each position. As before, the distractors appeared two frames prior to the target. Distractor and target faces were selected so that different ethnicities and genders appeared equally across distractors and targets in each individual condition. Additionally, neutral filler images were selected so that male and female faces were equally represented, and that different ethnicities were presented approximately equally. Thus, the face stimuli appeared as a heterogeneous stream of facial features. An eight-trial practice block preceded the task with equal happy and fearful targets and equal present and absent trials. Stimuli presented in the practice were not presented in the rest of the experiment, and distractors in the practice block consisted of black ovals.

Results and Discussion

As in Experiments 3 and 4 we conducted a 2×2×2 ANOVA, although the search goal factor was changed to happy/fearful search conditions. The main effect of search goal was non-significant, $F(1, 17) < .01$, $p = .983$, $\eta^2_p < .01$. The main effect of distractor type was, however, significant, $F(1, 17) = 12.3$, $p = .003$, $\eta^2_p = .42$; in a striking reversal of previous results, the face distractors resulted in lower performance overall compared to animal distractors. The main effect of distractor valence was also significant, $F(1, 17) = 15.57$, $p = .001$, $\eta^2_p = .48$, with threat related (i.e. fearful face or threatening animal) distractors resulting in lower performance than neutral distractors. Critically, the distractor type interacted with distractor valence, $F(1, 17) = 6.09$, $p = .025$, $\eta^2_p = .26$, revealing that while significant interference was observed from fearful versus neutral faces, $t = 3.7$, $p = .002$, $B_{H(0,13)} = 120.72$ there was no effect of valence in relation to the animal distractors, $t = 1.15$, $p = .267$, $B_{H(0,13)} = .35$, the Bayes factor appeared to favour a true null finding.

The interaction between distractor type and current search goal failed to reach significance, $F(1, 17) = 3.$, $p = .094$, $\eta^2_p = .16$. Current search goal also did not significantly interact with distractor valence, $F(1, 17) = 2$, $p = .175$, $\eta^2_p = .11$, although as can be seen in Figure 10 the numerical trend was in the direction of contingent capture (i.e. greater attentional capture by threat in the fearful face versus happy face search condition). Additionally, unlike previous experiments the three way interaction between search goal, distractor type, and distractor valence was nonsignificant, $F(1, 17) = .3$, $p = .593$, $\eta^2_p = .017$.

Rather, fearful faces resulted in lower accuracy relative to neutral faces, across both the fearful face and the happy face search conditions, $t(17) = 3.86$, $p = .001$, $B_{H(0,13)} = 219.77$, $t(17) = 2.18$, $p = .044$, $B_{H(0,13)} = 3.3$, respectively. The Bayes factor showed stronger evidence for attentional capture within the congruent search condition, as predicted by a goal-driven effect, although there was still evidence of capture in the incongruent search condition.
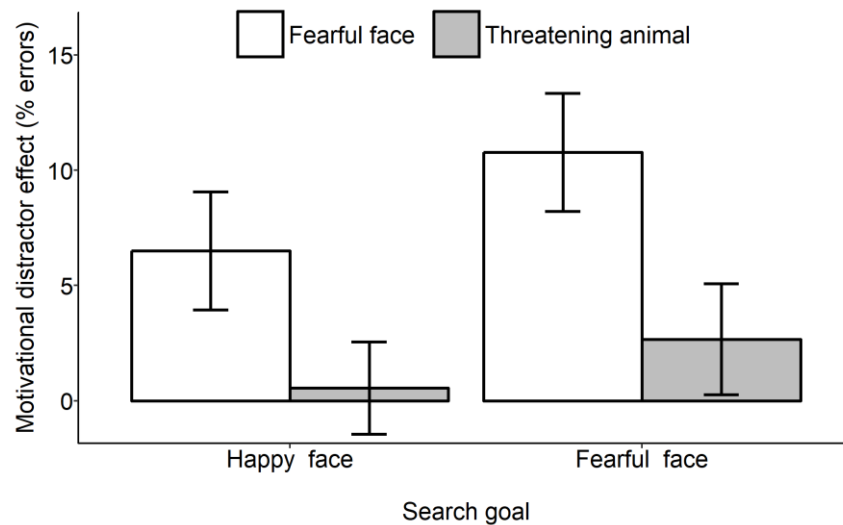
Figure 10. Motivational distractor effects (% correct neutral distractor - % correct motivationally salient distractor) for fearful face and threatening animal distractors across both happy and fearful face search conditions in Experiment 5. Error bars represent within-subjects standard error.

The unexpected significant attentional capture by fearful faces in the happy search condition might at first glance be assumed to be evidence of stimulus-driven attentional capture. However, it is hard to reconcile a stimulus-driven interpretation of this effect with the fact that, across four experiments, we *only* observed this effect when the task search categories were changed from animals to faces. This dependence of the attentional capture effect on the central task stimulus category points to a goal-driven rather than stimulus-driven mechanism.

Why then we did not find a significant within subject goal-driven effects on attentional capture in Experiment 5? We speculate that this may be due to the increased overlap in visual features between the two face affective categories. Unlike the visually distinct cute and threatening animal categories used in previous experiments, happy and fearful faces share

common features such as visible teeth. It has been found that when possible, participants search for a single salient visual feature of an emotional face in a perceptually demanding task (Calvo, Fernandez-Martin & Nummenmaa, 2012). Participants would only have to hold a top-down search goal for salient mouths or eyes to complete the task. This, therefore, would lead all emotional faces to capture attention due to goal-driven effects.

Regardless of Experiment 5's lack of within subject goal-driven effects, the results of the experiments taken together demonstrate that by switching the participants' search goal category from animals (Experiments 2-4) to faces (Experiment 5),we were able to alter which category of motivationally salient distractors captured attention. To directly test this goal-driven effect we conducted a further ANOVA, comparing the results of Experiment 5 with those of Experiment 3. These two experiments were identical in all aspects of distractor presentation but differed in terms of the central task (Experiment 3 involving search for cute and threat animals, while Experiment 5 involved search for happy and fearful faces). A 2×2×2 mixed ANOVA was conducted with the within subject factors of distractor valence and distractor type, and the between subject factor of goal category (animals, faces).

This ANOVA revealed a significant main effect of valence, reflecting that across Experiments threat related distractors capture attention more than neutral distractors, $F(1,34) = 19.43$, $p < .001$, $\eta^2_p = .36$. There were also significant main effects of goal category, reflecting generally higher accuracy during the face search task (Experiment 5) than the animal search task (Experiment 3), $F(1,34) = 79.82$, $p < .001$, $\eta^2_p = .7$; and of distractor category, $F(1,34) = 6.76$, $p = .014$, $\eta^2_p = .17$, reflecting overall increased distraction from faces versus animals. Importantly, there was a significant interaction between goal category and distractor category $F(1,34) = 10.9$, $p = .002$, $\eta^2_p = .24$, reflecting greater attentional capture by faces during the face search task and greater attentional capture by animals during the animal search task. Furthermore, and critically, there was a significant three way interaction of goal category × distractor category × valence, $F(1,34) = 12.17$ $p = .001$, $\eta^2_p = .26$. As can be seen from plotting the motivational distractor effects in Figure 11, fearful faces captured attention relative to neutral faces only during the face search task, $t(17) = 3.7$, $p = .002$, $B_{H(0,13)} = 120.72$, while threatening animals captured attention relative to neutral animals only during the threatening search task, $t(17) = 3.5$, $p = .003$, $B_{H(0,13)} = 47.17$. When the motivationally salient distractor type did not match the goal category no evidence of threat related attentional capture was found, and the Bayes factors confirmed these null results to be sensitive for both distractor types: For threatening animals, $t(17) = 1.15$, $p = .267$, $B_{H(0,13)} = .35$, for fearful faces, $t(17) = .53$, $p = .603$, $B_{H(0,13)} = .09$. No other interactions reached significance (all p's > .66), with the exception of a trend for goal category and distractor valence, $F(1,34) = 4.06$, $p = .052$, $\eta^2_p = .11$, which was driven by the three way interaction reported above.

The above analysis demonstrates that the attentional capture by fearful faces seen in both affective search conditions of Experiment 5 was contingent on the top-down search goal for emotional faces: Despite having identical distractors in Experiments 3 and 5, face distractors only captured attention when the search task goal was modified in Experiment 5 to include faces. The fact that attentional capture by fearful faces in the happy search condition was contingent upon the stimulus category of the central task strongly undermines any account of these effects in terms of purely stimulus-driven processes.
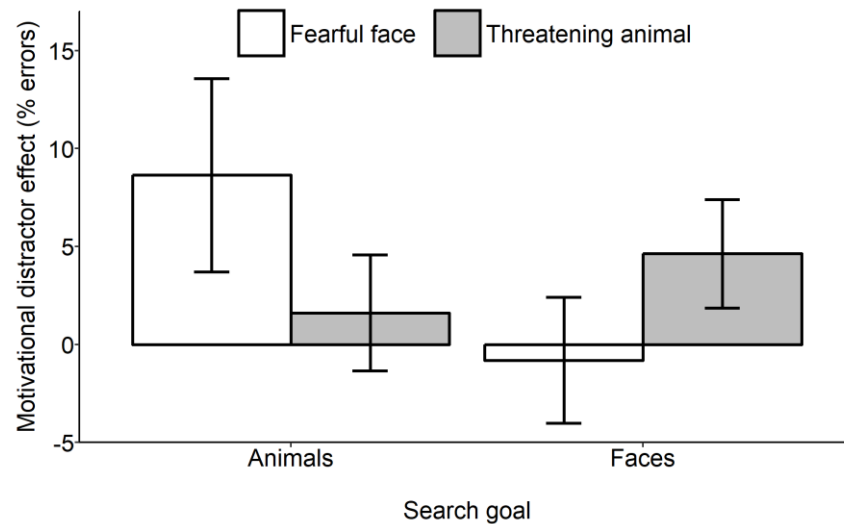
Figure 11. Motivational distractor effects (% correct neutral distractor - % correct motivationally salient distractor) for fearful faces and threatening animal distractors across both animal (Experiment 3) and face (Experiment 5) search goal conditions. Motivational distractor scores were computed after collapsing across search conditions for both Experiment 3 and 5. Error bars represent standard error.

As in previous Experiments, we investigated the possibility of inter-trial priming. To do this we took advantage of the present/absent response required in Experiment 5. The rationale being that when a target stimulus was absent on a trial, the features of the target would not be primed for the subsequent trial, whilst when the target was present the target features would be primed on the next trial. We compared the accuracy on fearful face distractor trials which had not been primed by the preceding trial ($M = 78.9$, $SE = 4.66$) to the accuracy when the distractor was neutral ($M = 87.39$, $SE = 2.64$), both in the threat search condition. Primed trials made up 50% of the total trials. This comparison revealed that even when primed trials were discounted the fearful face distractor was associated with significantly poorer accuracy compared to the neutral face distractor in the fearful face search condition, $t(17) = 4.04$, $p <$ .001, $B_{H(0,13)} = 395.43$. In order to detect any evidence of inter-trial priming, we compared the fearful face distractor trials which had been preceded by a fearful face present trial ($M = 75.03$, $SE = 3.47$) to fearful face distractor trials which had been preceded by a fearful face absent trial, and were therefore unprimed ($M = 78.9$, $SE = 4.66$). If inter-trial priming had influenced performance, then we would expect the unprimed trials to be significantly more accurate than

the primed trials, however, this was not the case, $t(17) = .77$, $p = .452$, $B_{H(0,11)} = .81$[6]. The Bayes factor favoured the null hypothesis but showed the data were insensitive, although we cannot conclude that there was no inter-trial priming, we can conclude that inter-trial priming did not significantly influenced the current findings.

      Internal meta-analysis. Finally, in order to investigate the cumulative evidence for stimulus-driven capture and goal-driven capture across all experiments we conducted an internal meta-analysis using the data across Experiments 1-5 (cf. Goh, Hall & Rosenthal, 2016; Cummings, 2007). To do this, we created three values for each participant using the untransformed data. These consisted of the mean accuracy when the distractor was motivationally salient and congruent with the current search goal, the mean accuracy when the distractor was motivationally salient and incongruent with the current search goal, and all trials when the distractor was neutral.

      I computed the Hedges' g as the effect size using a DerSimonian-Laird random effects model in order to take into account variation between distractor type and position across experiments (Lakens, 2013; DerSimonian & Laird, 1986). This was conducted using the Metafor package in R which weighted each experiment by its sample size (as described in Aloe & Becker, 2012; Viechtbauer, 2010). Additionally, a meta-Bayes factor was calculated based on the overall estimated population mean and standard error across all Experiments, the prior for this analysis reverted to the original 15% taken from Wyble et al. (2013). The overall population mean and standard error were formulated sequentially using Zoltan Dienes online calculator, first combining the effect sizes of Experiments 1 and 2, then combining this posterior mean with the effect size of Experiment 3, then continuing iteratively for all 5 Experiments (Dienes, 2008; see Rouder & Morey, 2011 for discussion of the meta-Bayes factor).

      The goal-congruent vs neutral accuracy ($k = 4$, $N = 73$) effect revealed that there was substantial evidence that goal-congruent motivationally salient distractors were more distracting than neutral distractors, Hedges' $g = 1.22$, $p = .008$, 95% CI [.31, 2.12], $B_{H(0,15)} = 7824360 \times 10^{10}$. Comparing the goal-incongruent motivationally salient distractor accuracy versus neutral distractor accuracy ($k = 5$, $N = 91$) revealed a small effect size which suggested some attentional capture, though the Bayes factor showed an insensitive null effect across Experiments, Hedges' $g = .14$, $p = .352$, 95% CI [-.15, .43], $B_{H(0,15)} = .79$. However, removing the data from Experiment 5 ($N = 73$ remaining participants), where we found evidence of goal-driven effects in the incongruent condition, resulted in a reduction in effect size and a conclusive null finding, Hedges' $g = .05$, $p = .747$, 95% CI [-.27, .38], $B_{H(0,15)} = .14$.

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[6] We set the prior of this comparison to a plausible effect size of 11% with half-normal distribution. The rationale being that if the goal-driven effect was actually due to inter-trial priming, then there should be a difference in accuracy between primed and unprimed trials similar to the magnitude of the total motivational distractor effect, which was 11% in this task.

Thus far, we have not addressed the issue of individual differences. The current task was designed to detect within-subjects differences between goal congruent and incongruent conditions, rather than correlational differences between individuals. To explore whether any differences were apparent across the different tasks, we conducted a Hunter-Schmidt random effects meta-analysis of the distraction between trait anxiety and the motivational distractor effects (Hunter & Schmidt, 1990). Meta-Bayes factors were computed iteratively, sequentially combining the pairs of effect sizes and standard errors. Before analysis we normalised the correlation coefficients with Fisher's z transformation (Dienes, 2008).

The expected effect size was taken from Most et al. (2005) who found a correlation between the attentional bias towards threatening stimuli, in a similar RSVP task, and harm avoidance, a construct strongly related to trait anxiety (Cloninger, 1986). The effect size was $r = .58$, which when standardised with a Fisher's z transformation resulted in a prior of $r_z = .66$. This revealed that across experiments ($k = 4$) the cumulative relationship between trait anxiety and the distractor effects for the threatening animals for both goal congruent and incongruent conditions was non-significant, $r = .08$, $p = .521$, CI 95% [-.15, .31], $B_{H[0, .66]} = .34$, and $r = .10$, $p = .409$, CI 95% [-.14, .34], $B_{H[0, .66]} = .41$, respectively. The cumulative correlation ($k = 4$) between fearful face distractor effects and trait anxiety revealed a non-significant relationship when congruent with the general affective content of the search goal, $r = .01$, $p = .937$, CI 95% [-.23, .25], $B_{H[0, .66]} = .24$. However, when the fearful faces were incongruent with the affective content of the current search goal, a significant positive correlation emerged with trait anxiety and the fearful face distractor effect, $r = .27$, $p = .019$, CI 95% [.04, .5], $B_{H[0, .66]} = 4.23$. This final exploratory analysis produced a sensitive Bayes factor (B > 3), although it must be interpreted cautiously, especially given that the effect did not survive corrections for multiple comparisons ($\alpha = .013$), and the sample sizes collected were small and more sensitive to influence from extreme cases.

General Discussion

The present study reveals that involuntary attentional capture by motivationally salient stimuli can be induced by manipulating current top-down search goals. Additionally, in the current paradigm there was no robust evidence of stimulus-driven attentional capture independent of these top-down goals. This pattern was observed across the visual field, with peripheral, parafoveal, and centrally positioned distractors, and with both positive and negatively valenced stimuli. Involuntary attentional capture occurred only when the distractor matched the specific category the individual was searching for (e.g. affective animals), but not when the distractors were conceptually unrelated to the goal, even though they were congruent with the general affective content of the search goal (e.g. threat related). Traditionally, theories of attention have focused on goal-driven and stimulus-driven mechanisms. In this dichotomy, goal-driven attention is operationalised as that which serves the detection of a target specified

by the experimenter; whilst stimulus-driven attention is directed towards perceptually salient stimuli, which disrupt detection of the target. Attentional prioritisation of motivationally salient stimuli was not explicitly accommodated by this dichotomy (Awh et al., 2012), leading to calls for revised theories including a third independent mechanism. However, the current findings raise the possibility that attentional capture by motivationally salient stimuli could be accommodated within the top-down/bottom-up dichotomy, as an involuntary phenomenon driven by top-down attention. Across five experiments, we demonstrated that involuntary attentional capture by motivationally salient stimuli only occurred when they were congruent with the participants' current search goals. This was true for both threatening and positive stimuli. Thus, top-down search goals appeared to be the primary driver of the attentional capture effects observed in the current study.

Interestingly, the goal-driven distractor effects appeared to be rather specific to the particular category of the search target. When an affectively similar stimulus was not part of the current searched-for category, it was no more distracting than a neutral stimulus. The current results therefore suggest that goal-driven attention does not automatically confer priority on the basis of purely affective associations such as 'negative' or 'positive' emotion. This contrasts with previous studies that have found contingent capture from stimuli semantically associated with a target category (e.g. other clothing images capturing attention during a search for jeans; Nako, Wu, Smith & Eimer, 2014). This might suggest a distinction between the effects of semantic versus affective categories on attention. On the other hand, it could be that the semantically related stimuli used in previous studies shared more low-level visual features than the affectively related stimuli used in the present study.

I note that sematic categories may capture attention through activation of their low-level features. Features that are common across exemplars, or features of stereotypical exemplars, appear to be activated during search for conceptual categories (Nako, Smith & Eimer, 2015; Yu, Maxfield & Zelinsky, 2016; Reeder & Peelen, 2013). However, for more heterogeneous categories, such as the threatening animals in the current investigation, participants are required to maintain several of these category diagnostic features active as a current search goal (see Berggren & Eimer, 2016 for discussion of multiple feature search goals). Importantly, however, the current effects were contingent upon these low-level features being part of a voluntary top-down goal, rather than involuntarily activated through priming effects.

Conventionally, in both attention and emotional regulation literatures, top-down mechanisms have often been characterised as being synonymous with voluntary attention and control (Theeuwes, 2010; Connor, Egeth & Yantis, 2004; Awh et al., 2012; Hopfinger, Buonocore & Mangun, 2000; Pinto, van der Leij, Sligte, Lamme & Scholte, 2013; Oschner & Gross, 2005; Walter et al., 2009; Phan et al., 2005). The current findings highlight that top-down attention should not be conflated with voluntary attention. By recognising that attentional

settings initiated in a top-down manner can have involuntary consequences, it allows the phenomenon of capture by motivationally salient stimuli to be accommodated within existing models based on the top-down versus bottom-up dichotomy. Alternative recent approaches to accommodating motivationally salient stimuli into traditional models of attention have involved proposals of a third mechanism based on 'selection history' (Awh et al., 2012) or value (Anderson, 2014; Le Pelley et al., 2015). Neither of these third mechanism accounts appear to fit the current data. The notion of involuntary capture reflecting the strength of the learned Pavlovian association between a stimulus and a valued outcome is at odds with the finding that both positive and threat related stimuli captured attention *only* when congruent with current search goals; despite these distractors all having consistent affective associations, as revealed by the valence and arousal ratings for these stimuli. Neither can the effects be accounted for in terms of low-level inter-trial 'selection history' (cf. Awh et al, 2012, Theeuwes, 2013). In previous investigations, removing primed trials substantially reduced the 'goal-driven' distractor effect (Lamy & Kristjansson, 2013). However, in each of the present experiments the significant goal-driven effects were unaffected by the removal of trials which could potentially been argued to have been primed by the previous target. Further, perhaps due to the relatively long trial duration in the current paradigm (~5s), we found no evidence of inter-trial priming in any of these experiments. the results are hence inconsistent with 'third mechanism' models, at least in terms of accounting for capture by motivationally salient stimuli. This is not to say that selection history is not found in previous tasks, in which unfamiliar coloured shapes are used as stimuli. It may be that the more complex images and scenes used in the current task are less susceptible to low-level feature priming relative to these simpler stimuli. Nevertheless, the results support a parsimonious account of involuntary attentional capture by motivationally salient stimuli, which positions it within the existing top-down bottom-up framework.

In the current investigation we found that two classic threatening stimulus types, as well as a class of positive stimulus, captured attention in a goal-driven fashion. In future, the results should be replicated with other stimuli, such as reward associated objects or those which are personally relevant to the participant.

The Role of Goals in Clinical Attentional Capture

Viewing attentional capture by motivationally salient stimuli as a form of goal-driven attentional capture also has interesting implications for understanding the attentional capture seen in relation to anxiety, addiction, and eating behaviours. Such rapid orienting biases have traditionally been accounted for in terms of the clinical syndrome or behaviour increasing 'bottom-up' responsivity to certain stimuli (e.g. Bishop, 2007; 2008; Mogg & Bradley, 2016; Cisler & Koster, 2010; Field & Cox, 2008; Robinson & Berridge, 1993; 1998; Wiers & Stacy, 2006; Castellanos et al., 2009). However, it seems plausible that some individuals, such as those who are highly anxious or reward sensitive, would consider certain motivationally salient

goals to be highly important, and hence be more likely to voluntarily adopt these goals in response to contextual cues. Note that attentional capture does not appear unique to conventional affective stimuli – Purkis, Lester and Field (2011) found that attentional capture effects akin to those found among spider phobics in relation to images of spiders, were found among fans of the television show 'Dr Who' in relation to 'Dr Who' related images. This finding is at odds with the traditional view of attentional capture by threat as being hard-wired and stimulus-driven, but is compatible with the view of these capture effects reflecting an involuntary consequence of goal-driven attentional settings.

The specificity of goal contingent capture in the present study is consistent with patterns observed in relation to attentional capture: A recent meta-analysis of the attentional bias to threat in anxiety disorders concluded that threatening stimuli were prioritised more when they were congruent with an individual's specific anxiety disorders (e.g. angry face for social anxiety) compared to when they were incongruent (Pergamin-Hight, Naim, Bakermans-Kranenburg, van Ijzendoorn & Bar-Haim, 2015). Moreover, a meta-analysis using positive and rewarding stimuli (e.g. food, financial reward, smiling faces) found that the relevance of these stimuli to a participant's personal concerns was one of the strongest predictors of attentional capture by these stimuli (e.g. food when hungry or attractive faces when not in a committed relationship; Pool, Brosch, Delplanque & Sanders, 2016). Hence, my proposed goal-driven account of attentional capture by motivationally salient stimuli neatly accommodates established patterns of attentional capture, and has the important implication that these could plausibly be driven by personal concerns and goals rather than unconditional capture effects dictated merely by affective associations.

Can Capture by Motivationally Salient Stimuli Ever be Purely Stimulus-Driven?

I note that although we did not find evidence of stimulus-driven attentional capture, across the experiments, the current data cannot rule out the possibility that this might occur under some circumstances. Certain features of the paradigm may have reduced sensitivity to stimulus-driven effects. First, across all of the experiments the targets were always motivationally salient faces or animals. The main focus of the current investigation was the motivational salience of the distractors, although previous research suggests that the motivational value of targets can also influence task performance. Specifically, motivationally salient stimuli such as spiders, snakes, and stimuli associated with financial reward have been found to "survive" the attentional blink more than neutral images when they appear as targets (Reineke, Rinck & Becker, 2008; Raymond & O'Brien, 2009; Yokoyama, Padmala & Pessoa, 2015). It, therefore, might be argued that the motivational salience of the targets could have overridden the stimulus-driven effect of the distractors. This point, however, highlights the strength of the goal-driven effect in the current paradigm. If the affective content of the search targets in any way enhanced the probability of target detection, the current results clearly

demonstrate that the goal-driven capture was substantial enough to override this effect. As such, any stimulus-driven form of capture obscured by the affective targets would appear to be rather more fragile than the goal-driven capture effects seen here.

Another feature of the design that might conceivably have reduced sensitivity to reveal stimulus-driven effects is the perceptually demanding nature of the central task. Given that higher perceptual task demands are established to reduce attentional capture by distractors (e.g., Lavie, 2005, Forster & Lavie, 2008, Bishop, Jenkins & Lawrence, 2007), it remains possible that a less demanding version of the current task might have revealed stimulus-driven effects in addition to the goal-driven effects observed here. However, if this were the case, then the robust top-down attentional capture effects seen in the current study would imply that goal-driven, but not stimulus-driven, forms of attentional capture are immune to perceptual load effects. For now, we conclude simply that goal-driven attention appears to be more pervasive and effective as a driver of involuntary attention to motivationally salient stimuli, relative to any stimulus-driven mechanism.

Finally, it might be argued that 'stimulus-driven' effects are only found among certain individuals. Bar-Haim et al. (2007) found that in a meta-analysis of 172 studies, threat only reliably captured attention in anxious individuals. The sample sizes of the present experiments were chosen to address within-subjects research questions and as such are underpowered to test for individual differences. Nevertheless, we note that there was a modest cumulative correlation between trait anxiety and goal-incongruent attentional capture from fearful faces. Given the exploratory nature of this analysis we urge caution in interpreting this effect, however, it appears possible that with a larger sample size the current task might reveal similar anxiety related attentional capture by those found in previous research. However, such capture effects are not necessarily indicative of stimulus-driven attentional capture – as discussed above, attentional capture could in fact reflect the participant's own long-term top-down goals resulting in the momentary prioritisation of these stimuli over the current task goals.

Conclusions

To conclude, we have demonstrated that current search goals for motivationally salient stimuli can induce involuntary attentional capture by these stimuli. As such, the data provides direct experimental evidence for a goal-driven account of this form of involuntary attentional capture. We propose that contextual cueing could account for how goal-driven attention is deployed in real-world contexts, and how variation in these factors could account for attentional capture observed in clinical populations. The current findings have implications both for theoretical models of attention, and for understanding the attentional capture seen in relation to clinical disorders such as anxiety and addiction.

Chapter 3: Goal-Driven Attentional Capture by Threat Does Not Generalise Across Affective Categories

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Abstract

Recent research has found that attentional capture by a category of threat can be induced by a top-down search goal, when this goal is congruent with the category of threat. we sought to test the boundary conditions of this goal-driven effect, and determine whether a broad search goal for threat could induce a attentional capture by all threat. Within Experiments 1a and 1b, we instructed participants to search a rapid serial visual presentation (RSVP) stream for all types of threatening stimuli, the search targets consisted of three types of visually dissimilar threat-related categories. Prior to the target, task-irrelevant threat or neutral distractors were presented. Contrary to my predictions, and in contrast to prior results, affective overlap between search goal and threat distractor did not induce goal-driven attentional capture. In Experiment 2, we replicated this sensitive null finding even when the threat distractor category was included as one of the three categories of threat-related stimuli in the search set. In Experiment 3, however, the same threat distractors resulted in poorer performance versus neutral distractors when participants searched for the same specific category of threat as the distractor. The results suggest that goal-driven capture by threat cannot be induced by a broad threat search goal, defined only by affective content, and that only prioritisation of specific category features can result in involuntary capture by threat. This highlights an important boundary condition that must be considered in any goal-driven account of attentional capture by motivationally salient stimuli.

Over the past several decades, threatening stimuli have often been implicated as a category of information capable of automatically and involuntarily attracting attention (e.g., Carretie, 2014). Traditionally, this automatic prioritisation of threat was seen as reflecting a hard-wired and inflexible stimulus driven mechanism (e.g. Öhman, 1995). However, the stimulus-driven account has been challenged by increasing recent evidence that the automatic attentional priority of threat (attentional capture) is not unconditional, as a stimulus-driven account would suggest (Everaert, Spruyt & De Houwer, 2013; Vogt, De Houwer, Crombez & Van Damme, 2013, Lichtenstein-Vidne, Henik & Safadi, 2012), but may instead depend on

some kind of task-relevance of the threatening stimuli (e.g. resemblance to target stimuli or presentation in a potential target location). Such findings have raised the question of whether the attentional capture by threat might reflect a goal-driven, rather than stimulus-driven mechanism. A goal-driven account appears plausible given that it may often be adaptive to voluntarily look out for potential dangers. For instance, walking home late at night we might act to protect our own safety by looking out for broken glass on the floor, a speeding taxi, or a stranger lurking in the shadows.

Recently, we directly tested this goal-driven account of involuntary attentional capture by threat, using an experimental manipulation of attentional goals (Brown, Berggren & Forster, under review – Chapter 2). Across four experiments we found that involuntary attentional capture by irrelevant threatening stimuli could be consistently induced when participants were required to adopt a top-down attentional goal for threat, and eliminated when participants were required to adopt a competing goal. Participants were asked to identify or detect an image from either a threatening or non-threatening target category in a centrally presented rapid stream of visual stimuli (i.e. RSVP task; e.g. Most, Chun, Widders & Zald, 2005). Threatening distractors, including fearful faces and threatening animals only captured attention when they were congruent with the current affective category being searched for. There was no difference in attentional capture when participants were not searching for a category different from the distractor condition. This finding builds on a long line of research which reveals that when individuals search for a specific feature or object, all stimuli which match the contents of this search goal capture attention, regardless of whether they are the intended target (cf. Folk, Remington & Johnson, 1992). My findings extend this research by revealing that a search goal for threatening stimuli can induce an involuntary attentional capture by affective distractors which are congruent with this search goal. This introduces the idea that the involuntary attentional capture by these stimuli, previously observed in models of attention to threat (e.g. Bishop, 2007; 2009), could plausibly be caused by a goal-driven mechanism.

One unexpected finding from the study was that there did not appear to be any generalisation of this goal-driven effect across affective categories. When participants were searching for threatening animals (among other animals), fearful faces were no more distracting than neutral faces, despite these categories of stimuli being related to the defining affective feature of the search goal (i.e. threat). This seeming specificity of the goal-driven attentional capture is somewhat at odds with previous evidence. For example, work by Wyble and colleagues (2013) has demonstrated that participants can hold a search goal for a wide variety of conceptual categories in a very similar RSVP task, and that this can result in contingent capture by distractor which are drawn from the same broad conceptual category despite the exact features of the target and distractor being unknown. Further, evidence that even when there is low visual overlap between the goal and distractor, the search goal can induce involuntary

attentional capture. For instance, when participants learnt an artificial category of heterogenous everyday objects, instructions to search for this category resulted in greater interference from a peripheral distractor object which was also from this same learned category, but objects associated with a different artificial category did not (Giammarco, Paoletti, Guild & Al-Aidroos, 2016). Based on this prior evidence, we ask the question: is there a possibility that individuals can search for threat as a general affective category consisting of multiple types of threatening stimuli?

I note that in the previous study participants were asked to search for a specific category of threat stimuli (e.g. threatening animals). It may be that this search goal manipulation was too specific to induce generalised contingent capture by threatening stimuli (i.e. participants may have adopted a goal for the specific subordinate category of threat, hence excluding other types of threat from top-down attention). The proposed study therefore sought to provide a more extensive test of the possibility that adopting a general attentional goal for the broad affective category of threat would result in contingent capture from all threat stimuli, regardless of their subordinate category. To this end, we used the same RSVP task as Brown et al. (under review – Chapter 2), however, instead of instructing participants to identify a target from a specific category of threat (i.e. fearful faces or threatening animals),we instructed participants to search for "anything which could cause or show pain, death, or signal danger". For the comparative non-threat search goal condition, we asked participants to search for "anything which makes people happy or portrays positive emotion". We predicted that when participants searched for the general category of threatening stimuli in the central stream, peripheral or parafoveal task-irrelevant threat-related distractors, not part of the target set, would capture attention more than a neutral category of distractor. However, when participants are searching for the general positive category this difference should be eliminated.

Experiment 1a and 1b

Methods

For Experiment 1a and 1bweused near identical methods, however, for Experiment 1a the images were larger and appeared in peripheral locations of the visual field; whilst in Experiment 1b the images were smaller and appeared in parafoveal locations of the visual field, in line with previous investigations which have found conceptual generalisation of contingent capture (Wyble et al., 2013).

Participants.

Experiment 1a. 29 participants were initially recruited from the subject pool at the Birkbeck University of London, though two participants were excluded prior to analysis for accuracy being 2 *SD*s below the group mean ($M = 61.78\%$, $SD = 15.05$), thus participants who scored below 31% accuracy were excluded (17 females, 10 males; Age: $M = 25.48$, $SD = 6.87$). The sample size was based on the maximum number of participants that could be recruited

within a week. The final sample size had the statistical power of $\beta = 1$ to detect the effect size previously found for the interaction between search goal and distractor conceptual category in a previous investigation of goal-driven attentional capture by motivationally salient stimuli ($\alpha =$ .05; $\eta_p^2 = .48$; from Brown, Berggren & Forster, under review – Chapter 2; Experiment 1).

Given the well-established correlation of anxiety with attentional capture by threat, we measured both state and trait anxiety in order to compare sample characteristics across previous research and the current experiments (Bar-Haim et al., 2007). Participants' state and trait anxiety were in line with the expected range given participants' age (norms: $M = 36$, $SD = 10$; Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983), state: $M = 33.7$, $SD = 7.68$; trait: $M = 41.23$, $SD = 9.3$. Participants were remunerated with course credits or a small cash payment.

Experiment 1b. 21 participants were originally recruited from the subject pool at the University of Sussex. We, however, excluded 5 participants due to poor performance, for consistency across the replication we excluded participants who scored below 31% accuracy which was the cut-off from Experiment 1a. To ensure sensitivity to interpret potential null effects, the sample size was determined through a Bayes stopping rule, in which we stopped collecting data once the Bayes factor measuring the difference between neutral distractor and the threat distractor in the threat search condition was either above 3 or below .33, as this was the condition in which threat generalisation would occur. The final sample of 16 participants consisted of 12 females and 4 males, with a mean age of 20.94 ($SD = 3.36$). The mean state and trait anxiety scores were, $M = 44.38$, $SD = 8.35$; $M = 44.13$, $SD = 11.44$, respectively.

Stimuli.

Experiment 1a. The stimuli were presented using E-prime 2.0 software on a Dell OptiPlex 780 PC, displayed on a 16inch monitor with a screen resolution of 800×600. The experiment was conducted in a dimly lit room. In total there were nine positive targets and nine threat-related targets, each made up of equal numbers of objects, animals, and faces: three in each category.

The animal images were all sourced from a previous investigation by Brown et al. (under review – Chapter 2). The threatening animals selected for targets were a snake, a spider, and an attacking dog (this final image was sourced from the International Affective Picture System database (IAPS; Lang, Bradley & Cuthbert, 2005). The positive animals included a kitten, a puppy, and a duckling. All of these images were previously rated along dimensions of arousal and valence to confirm their respective associations.

The object images were taken from the IAPS image database or sourced from Google images. The threatening images included a gun, a knife, and a syringe. The knife and the syringe were sourced from online due to them having better visual quality compared to the IAPS images of the same objects. The positive images were all sourced from Google images and were based on general positive categories that did not depend on extensive personal history with the object

(e.g. cigarettes in smokers) but still fitted in with the search goal instruction: "anything which makes people happy or portrays positive emotion". We sourced three images including a bunch of flowers, money in pounds, and a gift wrapped present.

The final subcategory of target stimuli were emotional faces, all these stimuli were sourced from the NimStim database which have previously been used in experiments which found attentional capture by emotional faces (Tottenham et al., 2009; Hodsoll, Viding & Lavie, 2011). The identities of the faces were the same for both happy and fearful targets, meaning that they only differed in their emotional content. These identities included two male faces and one female face. As in previous investigations which found attentional capture of emotional faces we ovalled these faces to remove non-emotional identifying features (i.e. hair).

The neutral filler images presented in the task were also objects, animals, and faces. The neutral faces were an equal split of male and female faces, and were composed of a mixture of different ethnicities. In total there were 48 neutral faces which were sourced from both the NimStim image database (Tottenham et al., 2009) and the Productive Aging Laboratory Face database (Minear & Park, 2004). The neutral objects selected were everyday house hold items, such as shoes, cutlery or furniture. There were a total of 48 of these neutral objects which were sourced from the IAPS image database (Lang et al., 2008). The neutral animal images were sourced from Brown et al. (under review – Chapter 2) and were selected based on their affective ratings being neither threatening or cute. The chosen exemplars consisted of animals such as fish, cows, pigs, and camels. All unlicensed images are listed online via the Open Science Framework (osf.io/ju87s). All images presented in the centre of the screen, measured 6°×4.02°, at a viewing distance of 59cm maintained using a chin-rest.

The distractor images were always human scenes consisting of individuals or groups. These distractor images measured, 8.09°×5.35°, and appeared both above and below the central RSVP stream with a gap of .5° separation from the central image. The positive distractors consisted of nine images depicting people celebrating a marriage or sporting victory, or children playing. The threat-related distractors consisted of nine images of death or mutilation, such as those in a murder scene or a car accident. These affective images were all sourced from the IAPS database (Lang et al., 2005). Such images have all been found to capture attention in similar RSVP tasks (e.g. Most et al., 2005; de Oca, Villa, Cervantes & Welbourne, 2012). The neutral distractor images consisted of 24 different scenes of people doing everyday activities (e.g. people shopping or on public transport). 12 of these were sourced from the IAPS images set (Lang et al., 2005) and 12 from Google images, those taken from online were selected based on their similarity to the neutral images taken from the IAPS database, that is they included different images of the same content (e.g. people at work).

Experiment 1b. The stimuli were identical to Experiment 1a but were resized to fit into parafoveal positions of the visual field. The central image was resized to 3.44×2.29 visual angle,

whilst the distractors were resized to 4.58×2.98° visual angle. The distance between central and distractor images was kept at .5°.

Procedure. See Figure 12 for an example trial sequence in the experimental paradigm. In each block of the search task participants were instructed to search an RSVP stream for either a positive or threatening stimulus. Positive stimuli were described as "any which makes people happy or portrays positive emotion". The threatening stimuli were described as "anything which could cause or show pain, or death, or signal danger". Text search goal cues (i.e. "Positive", "Threat") were also presented at the beginning of each trial for 400ms. The positive or threatening target stimulus was presented in a nine frame RSVP stream consisting of eight other neutral stimuli which were randomly selected from the total pool of neutral stimuli.
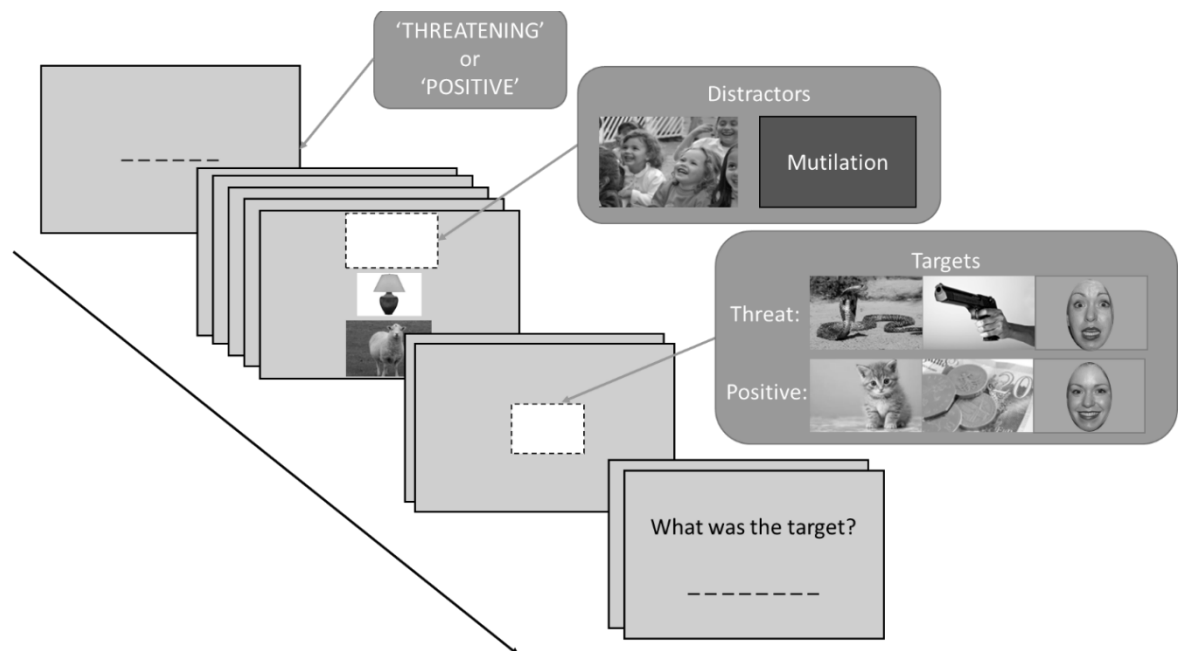
Figure 12. An example trial sequence from Experiment 1a and 1b. The first frame which appeared was a 400ms cue for the search goal for that block, this was either "THREATENING" or "POSITIVE". This was followed by nine frame RSVP stream, with each frame appearing for 100ms. Eight of the images were neutral, and one was the target which appeared at one of four locations (five, six, seven, or eight) in the RSVP stream, and was either a positive image (e.g. smiling children) or threat-related (e.g. mutilation or death). Distractors appeared above and below the RSVP stream and always two frames prior to the target. At the end of the trials, participants typed what they thought the positive or threatening target was using the keyboard. In Experiment 2 and 3, the response was present/absent judgment, which participant made at the end of the trial.

The nine images on a particular trial were made up of three objects, three animals, and three faces, one of which was the target. This meant that when a target was from a particular category, only two neutral fillers were presented from that category.

Each stimulus frame was presented for 100ms with no inter-stimulus interval. The target stimulus appeared at positions four, six, or eight in the RSVP stream an equal number of times, and was counterbalanced across conditions. The peripheral distractor stimulus was

consistently presented two slides prior to the target at Lag 2. These peripheral distractors were two images presented above and below the central stimulus position. One distractor image was always a neutral distractor, randomly selected from the pool of neutral images. The other distractor stimulus could either be a threat-related distractor, positive distractor, or another neutral distractor. Within each condition the distractor image appeared an equal number of times above and below the central stream.

At the end of each trial, the participant typed out the positive or threatening image they identified as the target using the keyboard and pressed the 'Enter' key, this triggered the beginning of the next trial. The dependent variable was the percentage of trials that participants accurately reported the correct cute or threatening animal which had been presented. In total there were four blocks of 54 trials each, with a period of rest every two blocks, the duration of which was determined by the participant. The search condition blocks were presented in an alternating format (e.g. positive-threatening-positive-threatening). The block order was counterbalanced between participants, with half the participants completing a threat search block first. When blocks were not separated by a rest period, a text warning was presented for 3000ms alerting the participant that the search goal had changed. Other than search goal, which was manipulated between blocks, all within participant factors were fully counterbalanced within each block.

Before the main task, participants completed a six-trial practice block, which required them to search for house images amongst a stream of cars, shoes, bricks, and trees, and type out a specific feature of each house. The specific images used in these practice trials were different from the set used in the main experiment.

Scoring. In order to determine the percentage of trials which were correct, the participants' responses were checked against the correct answer using an Excel formula which marked a trial as correct when the spelling of the response corresponded to the spelling of the correct answer. In order to account for spelling and approximate responses, the experimenter coded the participants' responses prior to the Excel formula being applied. The experimenter was blind to both the distractor conditions and the correct answers during this process.

Prior to scoring, the following coding rules were applied to all responses: Incorrectly spelt answers were corrected to the most similar target included in the set of images. Vague descriptions of objects were not allowed, despite being similar to the target if it could also describe another target, e.g. "sharp object" was marked incorrect when the target was a syringe due to it also being descriptive of the knife target. Animals judged to be subordinate to the potential target animal were changed to the superordinate animal (e.g. "black widow" was accepted for spider; "cobra" was accepted for snake). The block context was taken into account, meaning that if the search condition was positive, the answer of "dog" was changed to "puppy", despite dog also being accepted as an answer in the threat search block. Due to

difficulty distinguishing the different faces apart, any description of a fearful face was accepted for all three fearful face targets, i.e. "scared", "shocked", "fear" were all accepted. To remain consistent across answers, changes were made universally to all answers made by a single participant, meaning that once a change was made to an answer it was also made for all identical answers that individual participant had made. The percentage of correctly identified animals was recorded as the outcome measure for analysis.

Bayes factors. To supplement the main analysis, we computed Bayes factors in order to determine whether any null effects were due to insensitivity or a true null effect. A Bayes factor compares evidence for the *experimental hypothesis* (motivationally salient stimuli will result in greater attentional capture) and the *null hypothesis* (motivationally salient stimuli will not result in attentional capture). The Bayes factor ranges from 0 to infinity, values less than 1 indicate that there is support for the null hypothesis, whilst values of greater than 1 indicate that there is support for the experimental hypothesis. The strength of this evidence is indicated by the magnitude of the Bayes Factor; values greater than three or less than .33 indicate substantial evidence for either the experimental or null hypothesis. A value closer to 1 suggests that any nonsignificant result is due to insensitivity and any difference is 'anecdotal' (Jeffrey, 1961; Dienes, 2008; 2011; 2014; 2016).

The Bayes factor was computed using a modified version of Baguley and Kaye's (2010) R code (retrieved from Dienes, 2008). To compute the factor, we used a half-normal distribution which estimates that smaller differences are more probable than large differences. This half-normal set with a mean of zero which reflects the null hypothesis of zero difference. We used a half-normal distribution due to the previous evidence in the literature that the effect would be directional; specifically, that threatening stimuli would capture attention more than neutral stimuli [7]. The standard deviation of this distribution was set to 8%, which reflects the plausible effect size taken from Brown et al. (under review – Chapter 2; Experiment 1). This effect size was taken from the comparisons between neutral baseline distractor and the threatening distractor condition when participants were searching for threatening animals. All direct comparisons between conditions were tested using Bayes factors, however, p-values were also computed using two-way paired samples t-tests to facilitate comparison to previous results.

Results and Discussion

For both Experiment 1a and 1b the identification accuracy for each condition was entered in a 2×3 repeated measures ANOVA with target type (threatening/ positive) and distractor conceptual category (threatening/ positive/ neutral) as the two factors (see Table 4). The main effect of target was significant for both Experiment 1a and 1b, with threat-related

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[7] Following Dienes (2008; 2011), an adjusted standard error was applied based on the sample sizes collected. This adjustment was done using the following equation: $SE*(1 + 20/df*df)$.

targets being more accurately identified than positive targets, Experiment 1a: $F(1,22) = 21.33$, $p = 21.33$, $\eta^2_p = .45$; Experiment 1b: $F(1,15) = 7.73$, $p = .014$, $\eta^2_p = .34$. There was, however, no significant difference between the three distractor conceptual categories in either experiment, Experiment 1a: $F(2,52) = .63$, $p = $; $\eta^2_p = .02$; Experiment 1b: $F(2,30) = .74$, $p = .486$, $\eta^2_p = .05$. Further, against my hypothesis, we found no significant interaction between the current search goal and the distractor conceptual category in these two experiments, Experiment 1a: $F(2,52) = .57$, $p = .568$, $\eta^2_p = .02$; Experiment 1b: $F(2,30) = .96$, $p = .394$, $\eta^2_p = .06$.

In order to test the sensitivity of this null effect we conducted Bayesian pairwise comparisons between the motivationally salient distractor and the neutral distractor in each condition for both experiments. This revealed that when participants were searching for positive targets there was a non-significant difference between positive and neutral distractors, Experiment 1a $t(26) = 1.08$, $p = .291$, $B_{H[0,8]} = .68$; Experiment 1b: $t(15) = 1.21$, $p = .245$, $B_{H[0, 8]} = .75$, and that there was a nonsignificant difference between threatening and neutral distractors, Experiment 1a: $t(26) = 1.25$, $p = .222$, $B_{H[0,8]} = .84$; Experiment 1b: $t(15) = 1.36$, $p = .194$, $B_{H[0, 8]} = .76$. Therefore, there was inconclusive evidence against distraction by both mutilation and pleasant scenes for the positive search goal. However, when participants were searching for the conceptual category of threat, there was a sensitive null difference between positive and neutral distractors, Experiment 1a: $t(26) = .29$, $p = .773$, $B_{H[0,8]} = .21$; Experiment 1b: $t(15) = .36$, $p = .727$, $B_{H[0, 8]} = .26$. Importantly, there was also a sensitive null difference between threatening and neutral distractors, Experiment 1a: $t(26) = .30$, $p = .766$, $B_{H[0,8]} = .28$; Experiment 1b: $t(15) = .36$, $p = .503$, $B_{H[0, 8]} = .13$, thus revealing that there was evidence in favour of the null hypothesis: searching for threat as a conceptual category did not induce a capture by all threat-related images.

		Positive scene distractor	Mutilation scene distractor	Neutral scene distractor
Experiment 1a ($n = 27$)	Positive search goal	53.70 (19)	53.40 (21.29)	55.76 (19.67)
	Threat search goal	69.86 (16.50)	68.72 (16.73)	69.24 (18.07)
Experiment 1b ($n = 16$)	Positive search goal	51.91 (13.60)	52.08 (17.73)	54.17 (16.91)
	Threat search goal	63.19 (12.19)	64.76 (12.03)	63.72 (12.52)

Table 4: Mean and standard deviations for percentage accuracy across all distractor and search goal conditions within Experiment 1a and 1b.

The results from Experiment 1a and 1b revealed that despite the threat-related distractors sharing the same affective category as the broad threat-related search goal, participants were no more distracted by these images than the neutral images. These images are highly arousing and unpleasant and have been found to capture attention in previous investigations. (e.g. Koster, Crombez, Verschuere & De Houwer, 2004).

Experiment 2

In the previous experiments the threat-related distractor was never part of the target set, meaning that there was no feature overlap with the search goal, only affective overlap. Experiments 1a and 1b suggest that involuntary attentional capture cannot be caused purely by affective overlap. However, it might be argued that the search goal induced in Experiment 1 was still rather specific, and cannot rule out the possibility that a broader affective search goal that includes all possible types of threatening stimuli could produce involuntary capture by threat. Experiment 2 therefore examined whether a search goal for multiple threatening objects could result in involuntary attentional capture by one of these objects.

To test this, we included one of the target categories – fearful and neutral faces - as distractor conditions, alongside the mutilation and neutral scene distractor condition (which as in Experiment 1 were not part of the target set). We expected that the fearful faces would interfere more with the task than the neutral faces in this Experiment. We also expected to replicated Experiments 1a and 1b and find no difference between the mutilation and neutral scenes. In this Experiment we also switched the response to a present/absent judgement in order to provide a more time efficient method of measuring target detection across the task.

Methods

Participants. As in Experiment 1b, participants were recruited until all Bayes factors for the pairwise comparisons between neutral and the affective goal-congruent threat-related distractors were sensitive. This being either 3 and above or .33 and below. This led to 16 participants being recruited, of which 12 were female and 4 male. The average age of the participants was 24.31 ($SD = 4.29$). Participants were remunerated with course credits or a small cash payment. Participants' state and trait anxiety were in line with the expected range, State: $M = 45.44$, $SD = 8.57$; trait: $M = 45.82$, $SD = 13.1$.

Stimuli. All stimuli were similar to Experiment 1 with the following exceptions: Due to the present/absent judgement task requiring more images for the increased number of trials, additional images were collected for presentation in the RSVP stream. Further, all images within this task were taken from existing databases with valence ratings in order to exclude any possibility that the previous result was influenced by the inclusion of any stimuli from unestablished system sets. These images included 136 neutral animal images, 136 neutral face images, and 136 neutral objects. The neutral animals were taken from a previous investigation conducted by myself which had been rated along dimensions of threat, cuteness, positive, and negative and were not rated highly on any of these dimensions (Brown et al., under review – Chapter 2). The neutral faces were sourced from the Lifespan Adult Facial Stimuli Database (Minear & Park, 2004). The neutral objects were taken from the IAPS (Lang et al., 2005), Nencki Affective Picture System (NAPS; Marchewka et al., 2014) and the Geneva Affective Picture Database (GAPED; Dan-Glauser & Scherer, 2011) image sets which are all rated along

dimensions of arousal and valence, and were considered low on arousal and were considered neither pleasant or unpleasant.

For the threat target category, eight threatening animal stimuli, eight fearful faces stimuli, and eight threatening objects were presented. The threatening animals were also taken from the previous investigation and had also been rated as moderately arousing and unpleasant, the different types of animal were identical to those presented in Experiments 1a and 1b (Brown et al., under review – Chapter 2). The fearful faces were taken from the NimStim database (Tottenham et al., 2009) and included an equal balance of male and female faces, as well as a range of ethnicities. As with the neutral faces, these were also ovalled. The majority of the threatening objects were taken from the IAPS and NAPS databases, however, to increase the number of stimuli four images were sourced from Google images. These were objects which were part of the IAPS and NAPS image sets but with slightly different features (e.g. orange syringe instead of blue). The exact objects presented were a burning car, knives, syringes, and guns.

For the distractor images, twelve neutral faces and twelve fearful faces were taken from the NimStim database, these shared the same identity and retained the same balance of genders as Experiment 1a and 1b. The mutilation and neutral scene distractor images consisted of twelve neutral scenes and twelve threatening scenes, all taken from the IAPS image set, these included those presented in Experiments 1a and 1b (Lang et al., 2008).

As before, when the distractors were presented above or below the RSVP stream, the opposite distractor location was occupied with another image. For the face stimuli this was a patch of skin texture taken from a closeup of the distractor faces and contained no facial features. Twenty-four of these skin texture patches were presented, and included a range of different skin tones which were matched to the distractor faces. For the scene distractors the opposite target location was occupied with an inverted and blurred social scene taken from online. Twenty-four of these images were created, and contained a similar range of colours to the neutral and threatening scenes, but without the affective or conceptual content.

All images were the same size as in Experiment 1b, with the exception of the fearful and neutral face distractor images presented in parafoveal locations which were resized to $1.57°×2.29°$. In order to match the size of these face stimuli to the other distractor images, faces were presented on a grey rectangle which was the same size as the other stimuli in the same position (i.e. $3.44°×2.29°$).

Procedure. The task was similar to Experiment 1a and 1b, with the following exceptions. Across all trials participants were instructed to search for anything threatening. Participants were given verbal instructions that some of the images may be emotional faces, predatory or poisonous animals, or dangerous objects. It was left deliberately vague what exactly these images would be, and whether these were the only threatening images presented.

At the start of each trial participants were given a 400ms saying cue "Threat-related" to prompt the start of the trial. This was followed by the nine frame RSVP stream, with three objects, three, animals, and three faces, one of which was the target which could appear at position five, six, seven, or eight in the stream. On half the trials the threat-related target was present, on the other half absent. On absent trials, the target position was replaced by a neutral image. This replacement neutral stimulus was selected so that there were always three of each of the different conceptual categories (object, animal, face). All the different targets appeared equally in each within-subjects condition, further, all other within-subject's variables were counterbalanced within each block. At the end of the RSVP stream, a screen with a "?" appeared, after this prompt, participants had to indicate whether they believed a threatening image had been presented on that trial, using the 'c' and 'm' keys, with the response-answer association counterbalanced between participants. In total there were four blocks of 64 trials. At the start of the task participants completed an eight-trial practice block which used the same stimuli as Experiment 1a and 1b.

Results and Discussion

Unlike Experiment 1a and 1b, A-prime (A') detection sensitivity index was the dependent variable, rather than accuracy (see Table 5). A' is a non-parametric analogue of d', this was computed using hit rate and false alarm rate from the present/absent task response (Stanislaw & Todoroff, 1999; Zhang & Mueller 2005). A' ranges from .5, which indicates that a signal cannot be distinguished from noise, to 1, which corresponds to perfect performance. This measure removes potential response bias which can influence binary response measures such as this. A 2x2 repeated measures ANOVA was conducted using A' as the dependent variable, and distractor conceptual category (face/ scene) and distractor affect (neutral/ threat-related) as the within-participants factors. This revealed that there was no significant difference between the two types of distractor image, $F(1,15) = .001$, $p = .98$, $\eta^2_p < .01$. Further, there was no difference between the detection sensitivity on trials when the distractor was threat-related compared to when it was neutral, $F(1,15) = .46$, $p = .456$, $\eta^2_p = .04$. Additionally, against my original hypothesis, there was no interaction between the distractor conceptual category and distractor emotion, $F(1,15) = .08$, $p = .785$, $\eta^2_p = .01$.

		Fear face distractors	Neutral face distractors	Mutilation scene distractor	Neutral scene distractors
Experiment 2 (*n* = 16)	Threat search	.75 (.07)	.75 (.08)	.74 (.07)	.76 (.08)
Experiment 3 (*n* = 24)	Fear face search	.79 (.08)	.83 (.03)	.85 (.03)	.84 (.03)
	Mutilation search	.82 (.05)	.83 (.02)	.78 (.08)	.84 (.02)

Table 5. Mean and standard deviations for A' detection sensitivity across all distractor and search conditions within Experiment 2 and 3.

To determine whether the null finding was sensitive and there truly was no difference between the threat-related and neutral distractors, we conducted Bayesian pairwise comparisons. The prior in this case was $A' = .10$, which was the largest A' raw effect size taken from a similar task using fearful faces as a search goal (Brown et al., under review – Chapter 2; Experiment 5). This revealed that, as in Experiment 1, there was no difference between the detection sensitivity of threat-related scenes relative to neutral scenes, $t(15) = .59$, $p = .567$, $B_{H[0, .10]} = .34$[8]. Further, the Bayes factors revealed that there was no difference between the fearful faces and the neutral faces, $t(15) = .73$, $p = .479$, $B_{H[0, .10]} = .17$. This is despite the fearful faces being part of the target set. It, therefore, appears that even when participants adopted a general search goal for threat, composed of several subordinate conceptual categories of threat, threat-related distractors did not interfere with target detection versus a matched neutral image, even when these images were congruent with one of the subordinate categories of threat.

Experiment 3

The lack of evidence for any goal-driven attentional capture by the fearful faces, even while they were part of the attentional set, strikingly contrasts with my previous findings using a similar paradigm (Brown et al., under review – Chapter 2). Within this previous investigation we found that searching for threatening animals and fearful faces consistently resulted in a strong attentional capture by these categories of stimuli when they appeared in task-irrelevant locations. In these previous experiments, however, participants searched for a single category of threatening stimuli, rather than three. This suggests that goal-driven attentional capture may require participants to be searching for a single category of stimuli rather than multiple categories.

To confirm this, we conducted a final experiment using the same distractors used in Experiment 2, but restricting the search goals to a single category per block. Participants were given search goals for each of the two distractor categories (fearful faces and the mutilation scenes) in separate blocks. we predicted that these threat-related categories would only capture attention, relative to the neutral stimuli, when participants were searching for that specific category in the central stream.

Methods

Participants. Participants were recruited until all Bayes factors for the pairwise comparisons between neutral and threat-related distractors were sensitive. This lead to 24 participants being recruited, of which 18 were female and 6 male. The average age of the participants was 23.5 ($SD = 3.49$). Participants' state and trait anxiety were in line with the

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[8] For convenience, the stopping rule was checked using Zoltan Dienes online calculator (Dienes, 2008) which produced a Bayes factor of .33 for the fearful face distractor versus the neutral face distractor in the threat-related scene search. The subsequent analyses were computed using an R code version of Baguley and Kayes' (2010) calculator, and produced a Bayes factor of .336, and was thus rounded up to .34. Hence the difference with this Bayes factor and the stopping rule of .33 and below.

expected range given participants' age, state: $M = 46.92$, $SD = 9.9$; trait: $M = 46.25$, $SD = 13.29$. Participants were remunerated with course credits or a small cash payment.

       Stimuli and procedure. The task was identical to the Experiment 2 with the exception of the following. Participants were instructed to search a specific category of threatening stimuli. These targets were fearful faces, and scenes of mutilation and death, which participants searched for in different blocks. In total there were six blocks which were made up of 64 trials, with three blocks where participants searched for "Fearful faces" and three where they searched for "Injury and death". These blocks were presented in a mixed order (i.e. Fear – Mutilation – Fear – Mutilation – Fear - Mutilation) with the order counterbalanced between participants. Before each block participants were instructed what the upcoming target category would be, they would then press the space bar to continue to the next block. Additionally, before each trial began participants would be prompted with a text warning for the category, either "Fearful faces" or "Injury and death". The face target set consisted of 12 faces, meaning that in addition to the eight faces used in Experiment 2, four additional fearful face targets were added from the NimStim and Amsterdam Dynamic Facial Expression Set (ADFES; Van Der Schalk, Hawk, Fischer & Doosje, 2011). The stimulus set for scenes of mutilation and death consisted of 12 images that were taken from the IAPS and the GAPED stimulus sets.

       Due to the inclusion of mutilation scenes in the central stream we replaced the neutral animal filler images with neutral human scene filler images. These neutral scene images consisted of 140 images, 19 were sourced from the IAPS database, 41 were sourced from the NAPS database, or and 80 were sourced from Google images, these included the images presented in Experiment 1a and 1b. The images taken from Google were selected based on their similarity to the images from the IAPS and NAPS; they included scenes of people shopping, on public transport, or at work. The neutral objects consisted of 128 neutral objects, which were the same as in Experiment 2, though 8 were removed. The neutral faces consisted of 140 faces, with four male and four female faces from the lifespan database added to those used in Experiment 2 (Minear & Park, 2004). The stimuli presented in distractor locations were identical to those presented in the previous experiment.

Results and Discussion

       I conducted a 2×2×2 repeated measures ANOVA on the A' score (see Table 5), using search goal (fearful faces/ death and injury), distractor conceptual category (faces/ scenes), and distractor valence (neutral / threat-related) as factors. This revealed that there was a significant effect of search goal, $F(1,23) = 5.66$, $p = .026$, $\eta^2_p = .2$, with participants more accurately detecting the fearful faces than the scenes of death and injury. There was also a marginally significant effect of distractor conceptual category, $F(1,23) = 3.32$, $p = .081$, $\eta^2_p = .13$, whereby face distractors resulted in lower detection sensitivity relative to the scene distractors.

The type of distractor did not significantly interact with the valence of the distractor, $F(1,23) = .01$, $p = .956$, $\eta^2_p < .01$. However, the current search goal of the participant did significantly interact with the type of distractor presented, $F(1,23) = 10.48$, $p = .001$, $\eta^2_p = .37$, with both scenes and face distractors resulting in lower detection sensitivity when congruent with the current search goal, relative to when they were incongruent. Current search goal also marginally interacted with the valence of the distractors, $F(1,23) = 4.10$, $p = .055$, $\eta^2_p = .151$, such that when participants were searching for scenes of injury and death, participants were worse at detecting the distractor was threatening, relative to searching for the fearful faces. Importantly, both of these interactions were qualified by a highly significant three-way interaction between current search goal, distractor conceptual category, and distractor threat-relevance, $F(1,23) = 15.71$, $p = .001$, $\eta^2_p = .41$. As can be seen in Figure 13, this interaction reflected interference from the threat (versus neutral) distractors only when these matched the current type of threat being searched for.
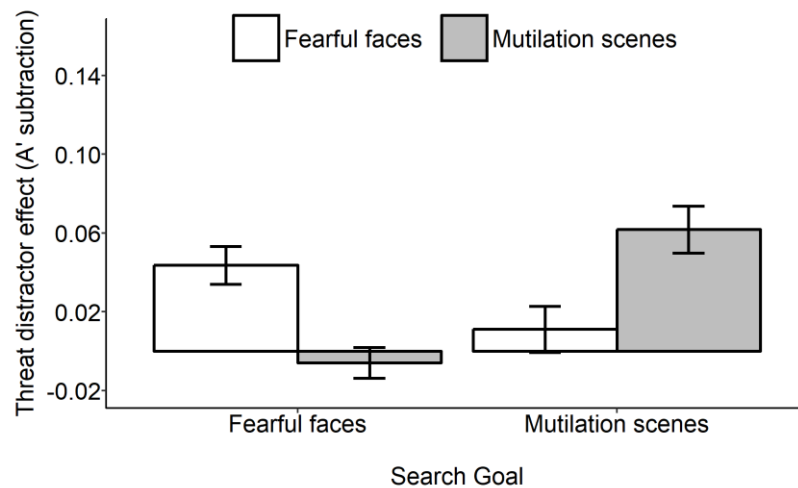
Figure 13. A graph depicting the threat-related distractor effect across both search goal conditions. The motivational distractor effect reflects the difference between the matched neutral distractor and the threat-related distractor on target detection sensitivity (A'). Larger distractor effects depict a greater decrement in target detection sensitivity. Error bars reflect within-subjects standard error.

In order to break down the three-way interaction we conducted four Bayesian pairwise comparisons. These contrasted A' when the distractor was threat-related compared to its matched neutral counterpart, within each search goal conditions. This revealed that when participants were searching for the threat-related scenes, the detection sensitivity did not differ between fearful face distractors and the neutral face distractor, $t(23) = 1.25$, $p = .224$, $B_{H[0, .10]} = .33$. Additionally, the threat-related scene did not differ from neutral scenes in their influence on detection sensitivity of the fearful faces, $t(23) = .88$, $p = .386$, $B_{H[0, .10]} = .04$. Therefore, when incongruent with the current search goal, there was no evidence of attentional capture by threat-related distractors. However, when the distractors were congruent with the current search goal, the threat-related distractors produced a significant decrement in detection sensitivity relative to

the neutral counterpart. This was true for both faces and the mutilation scenes, $t(23) = 3.36$, $p = .003$, $B_{H[0, .10]} = 37.34$; $t(23) = 3.85$, $p = .001$, $B_{H[0, .10]} = 200.12$, respectively.

To demonstrate the consistency and strength of the goal-driven involuntary attentional capture by threat-related categories of stimuli, we conducted a meta-analysis of all conditions from Brown et al. (under review – Chapter 2) and the current investigation where participants were searching for a singular category of threat (see Figure 14). The Hedges' g effect sizes were computed using a DerSimonian-Laird (1986) random effects model in R's Metafor package, and were weighted by sample size (as described in Aloe & Becker, 2012; Viechtbauer, 2010). One cumulative effect size was computed for the threatening distractor when they were congruent with the specific contents of the search goal versus a neutral control distractor. This included Experiments 1, 3, 4 and 5 from Brown et al. and Experiment 3 in the current investigation. This random effects meta-analysis (DerSimonian-Laird) revealed a strong and significant cumulative effect, Hedges' $g = -1.07$, $Z = 3.76$, $p < .001$, 95% CI[-1.62, -.51]. This, therefore, highlights the very consistent phenomena of goal-driven attentional capture by individual categories of threatening stimuli when a single category is the search goal.
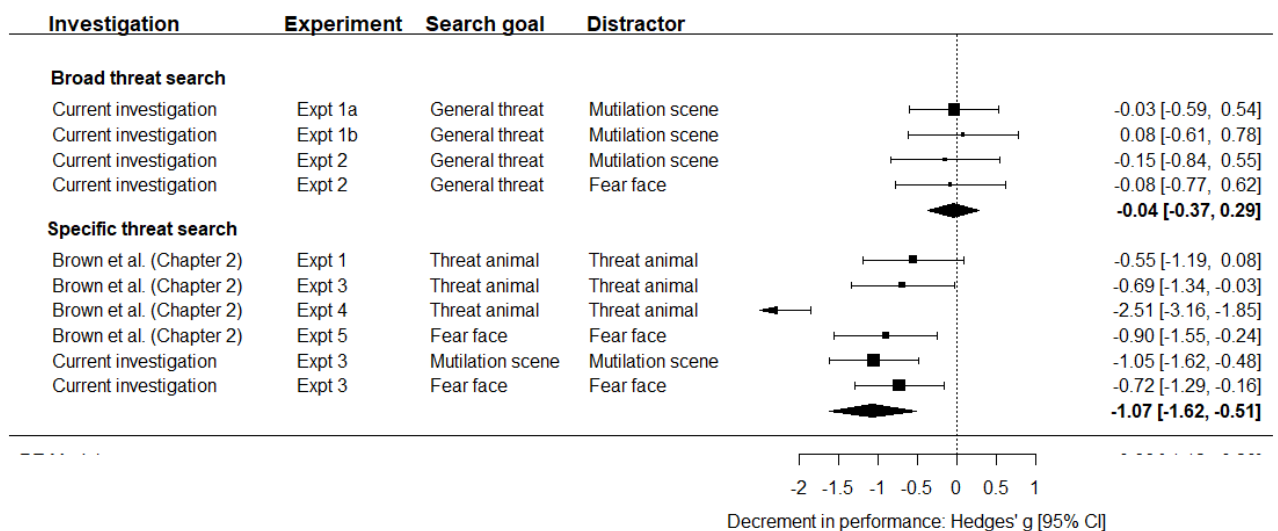
Figure 14. Forest plot depicting the individual and cumulative Hedges' g effect sizes and 95% confidence intervals for the pairwise comparisons between the threat-related distractor versus the neutral control distractor. The comparisons are from conditions where the task-irrelevant distractor was congruent with the participants' current search goal. Effects are separated into conditions where participants searched for a broad category of threatening stimuli, and conditions where participants searched for a specific category of threatening stimuli. Experiments are taken from Brown et al. (under review – Chapter 2) and the current investigation. Cumulative effect size was calculated using DerSimonian-Laird random effects model.

In comparison, a meta-analysis conducted on data from Experiments 1a, 1b, and 2 in the current investigation, where participants were given a broad threat search goal and distractors were from this same broad category, there was no significant evidence of a cumulative goal-driven effect, Hedges' $g = -.04$, $Z = .25$, $p = .805$, 95% CI[-.37, .29]. It, therefore, appears that

there is no evidence of attentional capture by threatening stimuli being induced by general threat associations of the search goal, independent of the specific conceptual category.

General Discussion

Across three experiments, we found that when participants assumed a broad attentional set for threat there was no evidence for attentional capture by threat-related distractors, despite these sharing the same general affective properties. No goal-driven capture was observed even when a third of the targets which made up this search goal were the same as a distractor category; that is, when participants searched for fearful faces, threatening objects, and threatening animals, fearful faces did not interfere with detection of these targets more than neutral faces. However, these same distractors produced striking attentional capture effects when participants searched for a single category of threat-related stimuli, consistent with my previous investigation (Brown et al., under review – Chapter 2). Meta-analyses across experiments conducted in my previous research further confirmed that while searching for a specific category of threat resulted in a large and consistent attentional capture effect by threat, searching for a broad threat category did not. Therefore, based on the current evidence, it appears that involuntary goal-driven attentional capture does not occur when the goal and distractor only overlap along an affective dimension. We, however, did discover that participants could search for multiple conceptual categories of threatening stimuli at one time, and either detect or identify different stimuli from across these visually heterogenous categories. This suggests that at some level, participants were able to hold multiple threat-related category features active as a broad search goal. Critically, however, these did not induce involuntary attentional capture by other task-irrelevant threatening stimuli.

The absence of conceptual generalisation of the threat search goal contrasts with previous research, which has found, in a similar RSVP paradigm, that instructing participants to search for a conceptual category resulted in attentional capture by irrelevant distractor stimuli which were part of this conceptual category (Wyble et al., 2013). One intriguing explanation for the difference between the current results and those of Wyble and colleagues could be a distinction between conceptual and affective processing. Evidence suggests that the gist of conceptual information can be extracted pre-attentively in a reflexive manner, even when the stimuli are presented extremely briefly (e.g. 13ms, Potter, Wyble Hagmann & McCourt, 2014). By contrast, there is some recent support that emotional processing is no longer considered to be preattentive – rather, the emotional content of an image is not always automatically processed, and that instructing participants to search for a non-emotional feature can block processing of the affective content of the image from influencing attention (Everaert, Spruyt & De Houwer, 2013). Further, electrophysiological evidence has demonstrated that the divergence in neural activity between meaningful scenes and scrambled images had an earlier onset compared to the difference between neutral and emotional scenes, thus suggesting that semantic extraction

occurred earlier, and that emotional processing is dissociable from conceptual processing (Attar, Anderson & Mueller, 2010).

It might alternatively be argued, that the results simply show that only a single set of features can be prioritised to induce an involuntary capture (cf. van Moreselaar, Theeuwes & Olivers, 2014; Berggren & Eimer, 2016). If this were the case, then it may be that although threat does exist as a superordinate category, only a small subset of features from this category can be prioritised at one time. Indeed, the mainstream attention literature suggests that individuals search conceptual categories by tuning attention towards a specific set of features which are typical of that category. In support of this idea, Yu, Maxfield and Zelinksky (2016) determined the prevalence of category consistent features across stimuli using computational techniques, they found that participants were faster to detect a target from a category if it contained more of these consistent features. Further, participants are faster to detect targets from categories with a lot of similar features compared to those that are more varied (Hout, Robbins, Godwin, Fitzsimmons & Scarince, 2017). Therefore, there may be mechanistic limitations on how an individual may search for a conceptual category comprised of multiple different features. By this argument, then the reason that Wyble et al. (2013) found goal-driven capture effects by a conceptual category, when we did not, may have been because the conceptual categories the targets and distractors were drawn from were more homogenous and contained more common features, thus allowing participants to search for common features which overlapped with both these stimuli (see appendix within Wyble et al. for full list of search goal categories).

On the other hand, this would not explain why Giammarco et al. (2016) discovered goal-driven capture by a heterogenous artificial category; in this second case, however, Giammarco et al. trained participants on an artificial category learning task until they could report each object's category at 90% accuracy. The participants then searched for these heterogenous categories in an RSVP task, it was found that a task-irrelevant distractor only interfered with target detection if it was from the same category as the current search goal, even though these categories had only been learnt in the same session. It may have been that, due to the extensive training, participants may have learned common features within the category, thus a specific feature based account cannot be discounted. Future research could investigate whether there are differences when participants have undergone extensive training to detect multiple threatening categories, and whether after this training goal-induced attentional capture does occur.

Regardless the above, the present work highlights an important boundary condition that presents a challenge to recently proposed goal-driven accounts of attentional capture by affective stimuli. Growing recent research has pointed to a goal-driven account of attentional capture by affective stimuli, highlighting that this capture often depends on task-relevance

rather than occurring unconditionally (e.g. Lichtenstein-Vidne et al., 2012, Stein, Zwickel, Ritter, Kitzmantel & Schneider, 2009). For instance, by presenting threatening stimuli as a target without explicitly instructing participants to assume a search goal for threat, Lichtenstein-Vidne et al. (2012) found that threatening distractors interfered with target detection, and that this was not the case when the target was neutral. Similarly, in tasks where participants are instructed to judge whether a stimulus is threatening or neutral, an attentional capture by these threatening images is found, conversely, this difference is absent if participants have to judge the same images on non-affective features such as gender (e.g. Stein, Zwickel, Ritter, Kitzmantel & Schneider, 2009; see also, Vromen, Lipp & Becker, 2016; Everaert, Spruyt & De Houwer, 2012). Feature-Specific attention allocation theory (cf. Everaert et al., 2012) has attempted to explain this task-relevance effect by suggesting that all visual information which is currently relevant to an individual captures attention, and that the affective content of a stimulus captures attention because participants are more likely to find it relevant to their aims.

Our current results, however, clearly demonstrate that relevance to an affective top-down attentional goal is not sufficient to induce goal-driven attentional capture: if this were the case then participants should have been distracted by all threatening stimuli when adopting a search goal for this category. Instead, the results suggest that goal-driven capture by irrelevant threatening stimuli may only occur when that specific type of threatening stimuli (e.g. fearful faces, or threatening scenes) is adopted as an attentional goal. we propose that as well as relevance of a distractor to the current aims, in order for involuntary attentional capture to emerge, there has to be the intention to search for that specific stimulus category, as well as knowledge of what specific features define that category. In the light of the present findings, it appears possible that previous demonstrations of relevance effects could be explained by relevance cueing participants to adopt a top-down search goal for the specific type of threat-related stimuli that also appeared as distractors. For example, in Lichtenstein-Vidne's study participants may have noticed that the targets were all threatening scenes, and adopted a specific attentional goal for threatening scenes.

An interesting question is how such a specific goal-driven form of attentional capture could work in a real-world setting, where participants would be unlikely to search for a specific threat across all situations at the cost of all other search goals. we have recently proposed how such a specific search goal mechanism could operate in a real-world setting (Brown & Forster, under review – Chapter 6). In this novel account we propose that participants use prior knowledge of the associations between a context and the objects that may appear there, in order to determine what specific category to search for. For example, a range of different threatening stimuli might be deemed important to detect (e.g. broken glass, speeding taxi, potential attacker), but contextual cues (e.g. engine noises) would allow prioritisation of specific categories of threat which are likely to appear (e.g. a taxi hurtling in your direction).

The current experiments were designed to investigate a within-participants experimental question, rather than individual differences in attentional capture. However, the specificity of goal-driven attentional capture seen in the present results appears to parallel patterns seen in recent anxiety disorder research. A recent meta-analysis revealed that across a range of anxiety disorders (e.g. phobias, Post-Traumatic Stress Disorder, social anxiety), specific sub-categories of threatening stimuli which were particularly relevant to that disorder (e.g. angry faces in social anxiety) captured attention more than other threatening stimuli (Pergamin-Hight, Naim, Bakermans-Kranenburg, van Ijsendoorn & Bar-Haim, 2015). These rather specific clinical attentional biases, along with the present evidence, are consistent with the notion that individuals assume search goals only for the specific threatening stimuli which are relevant to their concerns. A caveat is that there are conditions such as Generalised Anxiety Disorder (GAD) which seemingly contradict this specific bias, because individuals exhibit anxious symptoms for a range of threatening stimuli across contexts, and produce a more general attentional bias (Bar-Haim et al., 2007). This could be the result of a more stimulus-driven mechanism which result in bottom-up sensitivity to all threatening stimuli; or alternatively, it could reflect a broader goal-driven mechanism where these individuals attempt to search for multiple threatening objects, simultaneously. Indeed, in the current investigation we have shown that it is possible for individuals to search for multiple categories of threat at once, it may be that individuals with GAD are able to prioritise multiple threatening stimuli at once to induce capture across a range of stimuli.

In conclusion, we found no evidence that involuntary attentional capture by threatening stimuli can be induced by a broad threat search goal. Although individuals may be able to search for multiple threat-relevant categories of stimuli at once, we only found involuntary attentional allocation to task-irrelevant threatening distractors when individuals assumed a search goal for that specific category of threat. This finding highlights a boundary condition for goal-driven attentional capture, which must be considered in any goal-driven account of attentional capture by threatening stimuli.

Chapter 4: Attentional Capture by Alcohol Related Stimuli May be Activated Involuntarily by Top-Down Search Goals

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Abstract

Previous research has found that the attention of social drinkers is preferentially oriented towards alcohol related stimuli (attentional capture). This is argued to play a role in escalating craving for alcohol that can result in hazardous drinking. According to Incentive theories of drug addiction, the stimuli associated with the drug reward acquire learned incentive salience, and capture attention. However, it is not clear whether the mechanism by which this capture effect is created is a voluntary or an automatic one, although some evidence suggests a stimulus-driven mechanism. Here we test for the first time whether this attentional capture effect could reflect an involuntary consequence of a goal-driven mechanism. Across three experiments, participants were given search goals to detect either an alcoholic or a non-alcoholic object (target) in a stream of briefly presented objects unrelated to the target. Prior to the target, a task-irrelevant parafoveal distractor appeared. This could either be congruent or incongruent with the current search goal. Applying a meta-analysis, we combined the results across the three experiments and found consistent evidence of goal-driven attentional capture; whereby alcohol distractors impeded target detection when the search goal was for alcohol. By contrast, alcohol distractors did not interfere with target detection while participants were searching for a non-alcoholic category. A separate experiment revealed that the goal-driven capture effect was not found when participants held alcohol features active in memory but did not intentionally search for them. These findings suggest a strong goal-driven account of attentional capture by alcohol cues in social drinkers.

Images of alcohol have been found to automatically capture the attention of individuals who regularly consume alcohol (Field & Cox, 2008; see Rooke, Hine & Thorsteinsson, 2008 for meta-analysis). This attentional capture has been causally implicated in problem drinking: The bias correlates with craving for alcohol (Field, Munafo & Franken, 2009), and training individuals to adopt the bias directly increases craving (Field & Eastwood, 2005). This suggests that attentional bias towards alcohol cues may play a role in the maintenance of hazardous drinking behaviour through elevating the craving for alcohol (Field et al., 2016; although see Christiansen, Schoenmaker & Field, 2015).

Within the prominent attention literature, it is established that the rapid biasing of attention toward a particular stimulus can reflect either stimulus-driven mechanisms, resulting

from the inherent attention-grabbing properties of the stimulus itself, or goal-driven mechanisms, resulting from the voluntary prioritisation of that class of stimulus (Corbetta & Schulman, 2002). Understanding the underlying mechanism which causes attentional capture by alcohol has important implications for understanding models of addiction and for prevention and treatment of alcohol abuse.

A dominant theory of addiction, Incentive Sensitisation Theory (IST), proposes that the attentional capture by alcohol-related stimuli develops as a consequence of the repeated pairings between stimulus and the rewarding effects of alcohol (Robinson & Berridge, 1993; 2001; Berridge & Robinson, 2016). Through the repeated pairings with reward, the alcohol-related features take on a learned *incentive salience*, meaning that the features are now imbued with the ability to 'grab' attention. The exact attentional mechanism is often left ambiguous; however it is often assumed that this capture effect occurs in a stimulus-driven manner. Whereby the incentive salient stimulus induces dopaminergic activity which directly influences selective attention, possibly independent of the intentions of the individual (Berridge & Robinson, 2016; Hickey & Peelen, 2015). The current investigation, will, however, present evidence that the attentional capture could alternatively be accounted for by a goal-driven attentional mechanism.

Evidence for the alcohol attentional capture comes from paradigms such as the dot-probe task, in which participants are instructed to respond to a dot in one of two locations, which are filled prior to the appearance of the dot by one alcohol image and one non-alcohol image (Townsend & Duka, 2001). Heavy drinkers are typically slower to respond to the dot when it does not appear in the location that was previously occupied by the alcohol image, even when this image was presented only for 50ms (Noel et al., 2006). This effect, amongst many others, occurs despite participants being instructed to ignore the alcohol image, which now acts as a distractor, and focus on detecting the target (e.g. Field, Mogg, Zetteler & Bradley, 2004).

It is important to note that the involuntary nature of the alcohol attention capture does not necessarily point to a stimulus-driven mechanism. In fact, over the past 26 years, evidence from the mainstream attention literature has highlighted that involuntary attention should not always be assumed to reflect stimulus-driven mechanisms. Rather, paradoxical as it may seem, involuntary attention can actually be a direct consequence of voluntary top-down goals – a phenomenon known as 'contingent capture' (cf. Folk, Remington & Johnson, 1992). For instance, Folk, Leber and Egeth (2002) found that when participants were given a task goal to search for a specific colour in a stream of briefly presented stimuli (i.e. rapid serial visual presentation - RSVP), only irrelevant distractors which matched the search goal captured attention and interfered with target identification. Equally salient stimuli which did not match the current search goal did not interfere with target identification. Note that this goal-driven capture occurs despite participants being aware that the peripheral distractors were entirely task-irrelevant, and despite the fact that attending to the distractors resulted in failure to identify the

subsequent target. Hence, automatic and entirely involuntary attentional capture can result from a voluntary goal-driven attentional setting.

An involuntary yet goal-driven alcohol attentional capture effect could therefore plausibly occur among individuals who attentionally prioritise the detection of alcohol. Thus, the question raises whether social drinkers are 'on the lookout' for alcohol in their environment, with the result that they automatically notice it even when they are meant to be completing another task. Evidence suggests that heavy drinkers find viewing alcohol stimuli pleasant (Field et al., 2004). Regular social drinkers report enjoying thinking of alcohol, and report that being a drinker is part of their explicit identity (Martino et al., 2017; Lindgren et al., 2013). Given that drinkers find alcohol pleasant to view, and personally relevant, we argue that they may also be likely to adopt a voluntary goal to look out for it.

In terms of IST, the motivational effect of craving has also been found to influence voluntary goal-directed choice (e.g. Mackillop et al. 2010). There is also some evidence that dopaminergic activity is implicated in the voluntary maintenance of top-down goals, not just bottom-up automatic processing of stimuli (e.g. Frank, Loughry & O'Reilly, 2001). Thus, social drinkers who have learnt the incentive value of alcohol may be more motivated to search for alcohol features than non-drinkers, leading to involuntary contingent capture by alcohol stimuli.

A stimulus-driven account would predict that the alcohol attentional capture effect would be found regardless of the current attentional goals. It is notable, however, experimental evidence favouring the stimulus-driven account, is derived from paradigms in which the task cannot be performed without some degree of intentional allocation of attention to the alcohol images. For instance, in previous tasks, (e.g. the widely used dot-probe), the distractors are always presented in an attended location (i.e. the same location as the potential targets). To my knowledge, no evidence has suggested, nor has any theory of attention proposed, that it is possible to entirely ignore the features of a stimulus presented in an attended location. Thus, presenting alcohol images in a potential target location, that must be attended in order to perform the task, would make attentional processing unavoidable. Furthermore, it is notable that no actual cost is incurred by consistently attending to the alcohol images in the dot-probe. Because the images are predictive of the location of the target on 50% of the trials, attending to these images doesn't slow the overall reaction time. Favouring one set of images would give the same overall reaction time as if participants ignored those images, meaning that there is little incentive to try and ignore them. This raises the possibility that previous findings of attentional capture by alcohol might be accounted for by social drinkers voluntarily attending to the alcohol images, given that they find these pleasant and personally relevant and there is no cost for doing so. In fact, when the target probe is consistently presented in a separate location from the alcohol images (e.g. 96% of trials), then attention can be effectively trained away from the alcohol cues (Schoenmakers, Wiers, Jones, Bruce & Jansen, 2007). Thus, for a completely

involuntary attentional capture to be measured the alcohol images must appear in a distinct task-irrelevant location.

In the current investigation, we aim to establish whether the extent to which social drinkers adopt a top-down goal for alcohol can determine whether or not attention is captured by completely task-irrelevant alcohol distractors. To test this, we adapted the RSVP paradigm used by Folk et al. (2002) to include alcohol images. Specifically, we instructed participants to search a stream of rapidly presented everyday objects for either alcohol, or a category of non-alcoholic stimuli, in different blocks. We presented alcohol and non-alcoholic distractor images in completely task-irrelevant parafoveal locations, which participants were instructed to ignore. Note that within this paradigm it is not only possible to completely ignore the distractors, but attending to the distractors would result in the complete failure to detect the subsequent target. Therefore, participants are strongly motivated to avoid any voluntary allocation of attention to the alcohol distractors.

If a goal-driven mechanism can account for involuntary capture of attention in social drinkers, alcohol distractors should selectively disrupt task performance (target detection) when participants are currently searching for alcohol. Conversely, a stimulus-driven attentional capture, operating independent of the current goals of the individual, would result in attentional capture regardless of whether the participant currently holds an alcohol or a non-alcohol search goal.

Experiment 1 a, b, c

I conducted three versions of Experiment 1 to test the replicability of the effect while adjusting for differences in task difficulty. Experiments 1a and 1b were identical, with the exception of the presentation speed which was slowed down from 83ms (1a) to 100ms (1b) in an attempt to equate task difficulty between the alcohol and non-alcoholic goals. Experiment 1c changed the non-alcohol stimulus category from pots/pans to shoes, for the same reason. Additionally, a larger sample was collected for Experiment 1c in order to allow sensitivity to detect a potentially smaller effect.

Methods

Participants. Table 6 presents participants' characteristics from all Experiments. Participant's self-reported drinking related scores were within the range of previous investigations which found attentional capture by alcohol cues (Tibboel, De Houwer & Field, 2010; Ramirez, Monti & Colwill, 2015; Sharma, Albery & Cook, 2001; DePalma, Ceballos & Graham, 2017). Additionally, we note that the sample contained a large number of participants who considered alcohol to have a positive effect, and showed hazardous drinking behaviours: 98% of participants reported expecting some degree of positive arousing outcome from consuming alcohol (scored > 5; Morean, Corbin & Treat, 2012); 78% of the sample were classed as problem drinkers by the AUDIT, and therefore at risk of substance dependence

(scored > 8; Saunders et al. 1993), and 52% were classified as binge drinkers on the AUQ (scored > 24; Townshend & Duka, 2005).

Participants were all members of the University of Sussex student subject pool. Only participants who had consumed alcohol in the last month, and were not currently abstaining, were recruited. All participants were remunerated with either partial course credit or small cash payment. Informed consent was collected prior to participation, and ethics were approved by the University of Sussex ethics committee in accordance with the 1964 declaration of Helsinki.

Sample size calculations were conducted prior to data collection using Gpower software (Faul, Erdfelder, Buchner & Lang, 2009). This revealed that to detect an effect size of $d = .92$ (two-tailed; $\alpha = .05$; $1 - \beta = .8$), a sample of 12 participants was required to detect the goal-driven effect. The expected effect size was taken from a similar task which found goal-driven attentional capture using emotional face stimuli (Brown, Berggren & Forster, under review – Chapter 2). The sample size of Experiment 1b was increased to 16 participants in order to increase the chance of detecting neutral goal-driven capture which was non-significant in Experiment 1a (four additional participants allowed an addition of one participant to each counterbalanced condition). One participant was excluded from Experiment 1a due to a programming error, another from Experiment 1b due to currently abstaining from alcohol. In order to increase the power to detect even small stimulus-driven alcohol capture effect, Experiment 1c used a larger sample of 60 participants based on a power analysis in which the expected effect was based on the 95% lower bound confidence interval of the meta-analytically computed relationship between alcohol consumption and an 'implicit' cognitive bias towards alcohol, as reported by Rooke et al. (2008; $d = .37$, two-tailed; $\alpha = .05$; $1 - \beta = .8$).

	Sex	Age	Units (AUQ)	AUDIT	Positive Arousal (AEAS)
Experiment 1a	7 female 5 male	22 (2.45)	21.43 (25.43)	8.0 (3.77)	7.19 (1.34)
Experiment 1b	13 female 3 male	20.44 (2.06)	12.68 (14.74)	11.94 (6.2)	7.48 (.95)
Experiment 1c	46 female 14 male	21.6 (3.91)	16.49 (11.13)	12.18 (6.0)	7.79 (1.09)
Experiment 2	24 female 19 male	21.37 (2.25)	18.91 (15.05)	13.21 (5.35)	7.71 (1.32)

Table 6. The mean demographic and questionnaire data from across all four experiments, standard deviations are presented in brackets. Units of alcohol was measured by the Alcohol Use Questionnaire (AUQ; Mehrabian & Russell 1978), and reflects the number of units drank in a typical drinking week. The Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, De la Fuente & Grant, 1993) reflects the number of units drank per week, but also the frequency of negative outcome from drinking alcohol. A score of 8 or above suggests a hazardous relationship with alcohol, the maximum score is 40. The positive arousal reflects the mean expectancy of a positive and high arousing outcome (e.g. feeling 'lively') immediately after consuming an acute dose of alcohol, recorded on a scale of 1 to 10. The score is a subscale taken from the Anticipated Effects of Alcohol Scale which reflects the reward stimulation from consuming alcohol (Morean et al., 2012; Bradley, Codispoti, Cuthbert & Lang, 2001).

Questionnaires.

Alcohol Use Questionnaire (AUQ). The AUQ is a 12-item questionnaire which measures the frequency and speed of the weekly consumption of specific alcoholic drinks, which allows the computation of the number of units drank per week and binge score (Mehrabian & Russell, 1978).

Alcohol Use Disorder Identification Test (AUDIT). The AUDIT is a 10-item scale which measures both the frequency and amount of alcohol consumed, but also the negative behavioural consequences from alcohol, e.g. when drinking is concerning to others (Saunders et al., 1993).

Anticipated Effects of Alcohol Scale (AEAS). The AEAS is a 22-item scale that measures the expected emotions immediately after consuming an imagined amount of alcohol (4 drinks for females, and 5 drinks for males). The scale is composed of 4 subscales varying along dimensions of arousal and valence (Morean et al. 2012). The main subscale of interest was the positive high arousal factor, as this factor will indicate whether individuals perceived alcohol to be rewarding (cf. Bradley et al., 2001).

Stimuli. Across all experiments stimuli were presented using E-prime 2.0 software on a Dell 1707FP. The resolution was set to 1280×1024 and the viewing distance was maintained at 59cm using a chin-rest. Example stimuli are presented in Figure 15, and all stimuli are available online via the Open Science Framework (osf.io/9n8yq).

All target and distractor stimuli were images of single objects on a plain white background. The images within each category were selected so that they formed a heterogenous visual category with multiple features, textures, and shapes. The alcohol stimuli were selected so that there were equal numbers of exemplars of spirits, wine, and beers – and half of these stimuli were presented in glasses, the other half in bottles. Pots/pans images were selected so that there were a variety of materials and colours which formed the category (e.g. ceramic, steel, copper). Approximately half the exemplars were frying pans, the other half pots. The shoes were selected so that there were multiple different types of shoe (e.g. sports trainers, high heels, boots, men's formal shoes). Men's shoes and women's shoes were presented approximately equally, though there were some unisex shoes presented. These image selection criteria thus encouraged participants to form a search goal for a general category of objects, rather than any single feature.

The angles which the shoe and alcohol images appeared was more uniform than the pots/pans, we therefore rotated several exemplars from these categories so that these categories were matched on the variability of stimulus orientation. The alcohol target category contained 12 full colour images of different types of alcohol. In Experiments 1a and 1b the non-alcohol target category contained 12 images of different types of pots/pans. In Experiment 1c the non-alcohol target category contained 12 images of shoes.

Three categories of distractor images were presented in each experiment: alcohol, pots/pans, and shoes. In Experiments 1a and b the shoe category was included as a completely goal-incongruent category (i.e. not matching either task search goal), while in Experiment 1c the pots/pans were the goal-incongruent category. Each distractor category was composed of 16 images which were visually similar to the target images of the same category, but were never the same exemplars. All distractor and target images appeared an equal number of times within each condition. The distractors appeared to the left and right of the central stream with a gap of .5° between them. All centrally presented distractors measured 3.44°×2.29°, whilst the parafoveal distractors measured 2.98°×4.58°.
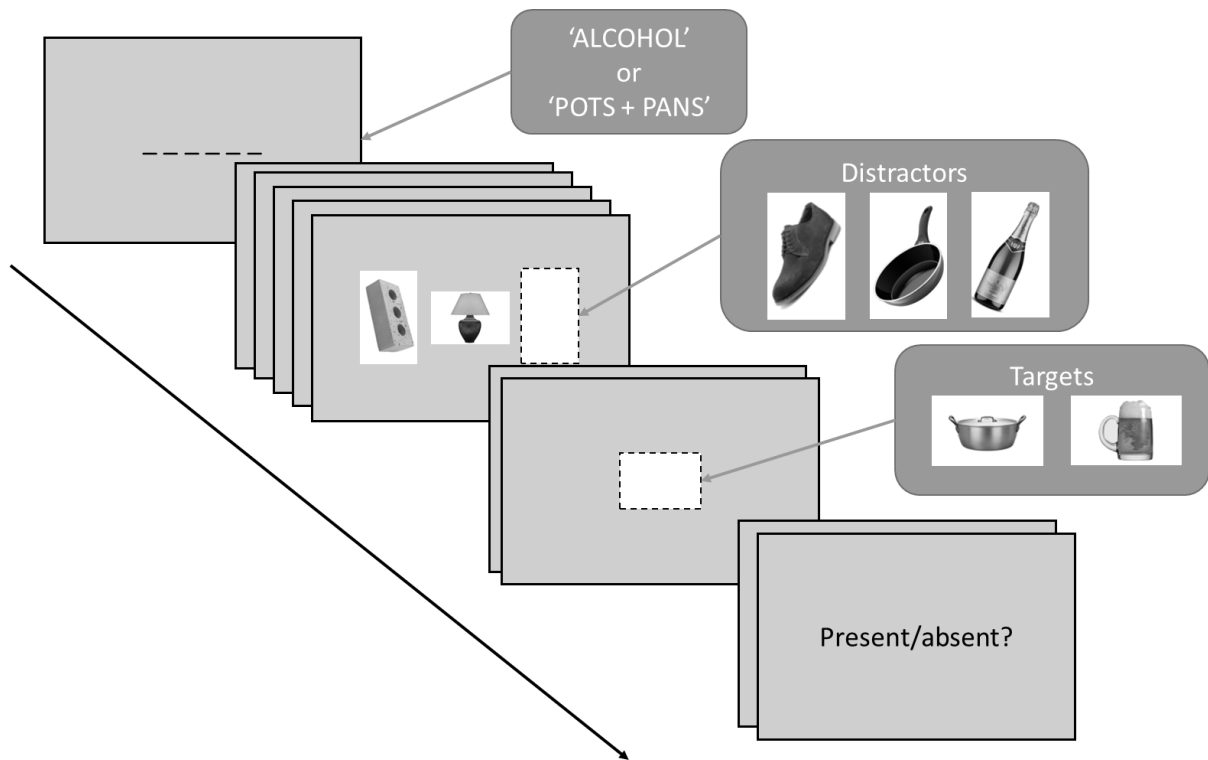
Figure 15. Structure of a single RSVP trial and stimuli used across the 4 experiments. At the start of each trial participants were presented with a 400ms prompt, with the target type for that block: alcohol or pots/pans (Experiment 1a, 1b) or alcohol or shoes (Experiment 1c). Each of the subsequent 9 images in the RSVP appeared for 83ms (Experiment 1a) or 100ms (Experiments 1b, 1c and 2) without inter-stimulus interval. In Experiment 2 there was no prompt because they always had to detect cars in the RSVP stream; however, a pots/pans image or alcohol image was presented at the start of each trial for participants to retain in memory for the duration of the trial. At the end of each trial participants identified whether a target had been present or absent. The irrelevant distractors were identical across all experiments, whilst the target type varied depending on what the search goal was (Experiment 1a: pots/pans, alcohol; Experiment 1b: pots/pans. Alcohol; Experiment 1c: shoes, alcohol, Experiment 2: cars).

In total 408 non-alcoholic filler images were selected to appear in the central stream. These were composed of 24 different everyday household objects with 17 different exemplars of each of these objects (see Appendix for full list of non-alcoholic items stimuli). An additional 48 non-alcoholic object images were selected to appear as fillers in the parafoveal locations, these were composed of the same 24 object categories with two exemplars from each category.

The parafoveal filler served to fill the other distractor location not occupied with an alcohol, shoe, or pot/pan distractor. All stimuli were sourced from Google images and appeared in isolation from other objects on a white background. During the task, these images were presented on a grey coloured screen (RGB: 192, 192, 192). All images appeared four times across the experiment. Due to potential similarity to the shoe targets, in Experiment 1c socks were removed from the filler stimuli and were replaced with 19 lamp images; 17 in the central set, two in the parafoveal set.

RSVP task. In Experiment 1a participants were instructed to search in a central RSVP stream of nine images for an object from a specific category, each image appeared for 83ms. The task consisted of two blocks of 96 trials, in one block participants were instructed to search for "ALCOHOL", in the other "POTS + PANS", and this search order was counterbalanced between participants. Participants received 400ms reminders of what the search goal was before each trial, i.e. "alcohol" or "pots and pans". At the end of each trial participants had to report whether they believed the stimulus from target had been present or absent. Responses were made using the 'c' and 'm' keys, with the key-response assignment counterbalanced between participants. On half of the trials the target was present, the other half it was absent. The response screen contained only the words "present/absent?", and disappeared once the participants had responded.

When present, the target image could appear at positions five, six, seven or eight in the RSVP stream. When absent that particular position in the stream was filled with a filler image. Distractor images appeared to the left and right of the central stream, one position was filled with either a shoe, pot/pan, or an alcohol distractor, whilst the other position was occupied with a filler image of the same size. Shoe, pot/pan, and alcohol distractors each appeared on a third of the trials in each block. These distractors always appeared two images prior to the target (i.e. Lag 2). All within participants' variables were counterbalanced within each block.

Before the task started participants completed a 16-trial practice block of equal alcohol and pot/pans targets, randomised within this block. Participants were verbally instructed before the main task, that the target category would only vary between blocks, not between trials, and that the participants should ignore every image outside of the central stream.

Changes were made to Experiment 1b due to the pot/pans targets being more difficult to detect than the alcohol targets in Experiment 1a. We, therefore, slowed the stimulus presentation time down to 100ms per image. This is more in line with previous RSVP tasks which have found stimulus-driven attentional capture by affective stimuli (Most, Chun, Widders & Zald, 2005).

Despite the slower presentation time in Experiment 1b, pot/pan targets were still detected less accurately than alcohol targets, therefore we switched the non-alcoholic targets in Experiment 1c to salient shoe images. The trials now started with an instruction to search for

"SHOES" instead of "POTS + PANS". The prompt for the response screen was also changed from "Present/absent?" to a single '?' to avoid any influence of word order on responding.

Procedure. For Experiment 1a and 1b, participants were tested in a dimly lit testing room at the University of Sussex. After providing informed consent, participants were given task instructions, and then completed the practice block with supervision from the experimenter, after which they completed the RSVP task on their own. Participants then completed a pen and paper versions of the AUDIT, AUQ, and AEAS in a random order. The experiment took approximately 25 minutes to complete. In Experiment 1c the procedure was identical to Experiment 1a and 1b, with the exception that the questionnaires were presented using Inquisit 5 in order to automate randomisation of the questionnaire order. Half the participants completed the questionnaire prior to the RSVP task, and half afterwards.

Analytic strategy. Across Experiments 1a, 1b, and 1cweconducted the same analyses. The dependent variable we used was A prime (A') detection sensitivity index, a non-parametric analogue of d', this was computed using hit rate and false alarm rate from the present/absent task response (Stanislaw & Todoroff, 1999; Zhang & Mueller 2005). A' ranges from .5, which indicates that a signal cannot be distinguished from noise, to 1, which corresponds to perfect performance. In order to determine whether there was any significant difference in A' across conditions, each individual study was initially analysed using a 2×3 repeated measures ANOVA, using current goal type (alcohol / non-alcohol) and distractor type (alcohol/ goal-congruent non-alcohol/ irrelevant non-alcohol) as the factors.

To follow up these comparisons, and to determine the consistency of the effect, we conducted pairwise comparisons across the three studies using an internal meta-analysis. Four pairwise comparisons were computed, these were between the goal-congruent distractors and the non-alcohol distractor, in both search goal conditions. Metafor statistical package for R was used to conduct the meta-analysis (Viechtbauer 2010). In all Experiments, the A' scores were significantly skewed; therefore, a DerSimonian-Laird random effects model was used to compute the cumulative effects (Hedges' g; Lakens, 2013) and confidence intervals, which is robust to violations of normality and is suitable for calculating cumulative effects from a small number of studies (DerSimonian & Laird, 2014; Kontopantelis & Reeves, 2012). Each study's contribution to the cumulative effect was weighted by sample size.

Bayes factors were calculated for all pair-wise comparisons across Experiments, as well as the cumulative effect. A Bayes factor compares evidence for the *experimental hypothesis* (positive attentional capture by alcohol versus an irrelevant distractor) and the *null hypothesis* (zero capture by alcohol versus an irrelevant distractor). The Bayes factor ranges from 0 to infinity. The strength of this evidence is indicated by the magnitude of the Bayes Factor; values greater than three or less than .33 indicate substantial evidence for either the experimental or

null hypothesis, respectively. A value closer to 1 suggests that the data are insensitive and any difference is 'anecdotal' (Dienes 2008, 2011, 2014, 2016).

The Bayes factor was computed using a modified version of Baguley and Kaye's (2010) R code (retrieved from Dienes 2008). To compute the factor, we used a half-normal distribution with a mean of zero to reflect the null hypothesis. The standard deviation of the distribution for all pairwise comparisons was set to .10, which is the plausible raw effect size for a difference between goal-congruent distractor and irrelevant distractor [9]. For meta-Bayes factors, used for the overall population mean, the effect was computed sequentially using Zoltan Dienes online calculator; first, combining the raw effect sizes and standard error of Experiment 1a and 1b, then combining this cumulative posterior value with the mean and standard error of Experiment 1c (Dienes 2008; Rouder and Morey 2011).

Results and Discussion

See Table 7 for the means and standard deviations from each condition across all experiments, and see Figure 16 for the distractor effects, which show the subtraction of A' scores when the distractor is goal relevant from the distractor which is never congruent with the search goal.

Experiments 1a and 1b both showed a significant effect of search goal, p's < .007, thus revealing that the pot target was harder to detect than the alcohol target (Experiment 1a: Alcohol $M = .81$, $SD = .07$ vs Pots/pans $M = .73$, $SD = .1$; $F(1,11) = 17.42$, $p = .002$; Experiment 1b: Alcohol $M = .80$, $SD = .10$ vs Pots/pans $M = .73$, $SD = .15$; $F(1,15) = 9.76$, $p = .007$). The effect of search goal was however non-significant for Experiment 1c, confirming that my adjustments to the task were successful in equating the accuracy level for detection of shoes versus alcohol targets, $M = .80$, $SD = .09$ vs $M = .80$ $SD = .09$; $F(1,59) = 1.34$, $p = .252$.

	Search goal	Distractor type		
		Alcohol	Pots	Shoes
Experiment 1a	Alcohol	.76 (.10)	.83 (.04)	.84 (.05)
($n = 12$)	Pots/pans	.74 (.10)	.71 (.11)	.73 (.10)
Experiment 1b	Alcohol	.73 (.14)	.83 (.05)	.84 (.03)
($n = 16$)	Pots/pans	.74 (.16)	.68 (.16)	.75 (.11)
Experiment 1c	Alcohol	.74 (.14)	.83 (.04)	.83 (.04)
($n = 60$)	Shoes	.82 (.06)	.82 (.05)	.76 (.13)
Experiment 2	Alcohol	.82 (.07)	.82 (.07)	.82 (.08)
($n = 43$)	Pots/pans	.83 (.06)	81 (.08)	.83 (.07)

Table 7. The mean A' scores and standard deviations from across all conditions in the 4 experiments. A' was computed from the frequency of hits and false alarms made during the present/absent judgement. A' is a detection sensitivity index which ranges from .5 to 1, with .5 reflecting chance detection and 1 reflecting perfect detection of the target.

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[9] The prior was based on a previous investigation in my previous research which investigated capture effects by emotional faces in an identical RSVP task (Brown, Berggren and Forster, under review – Chapter 2).
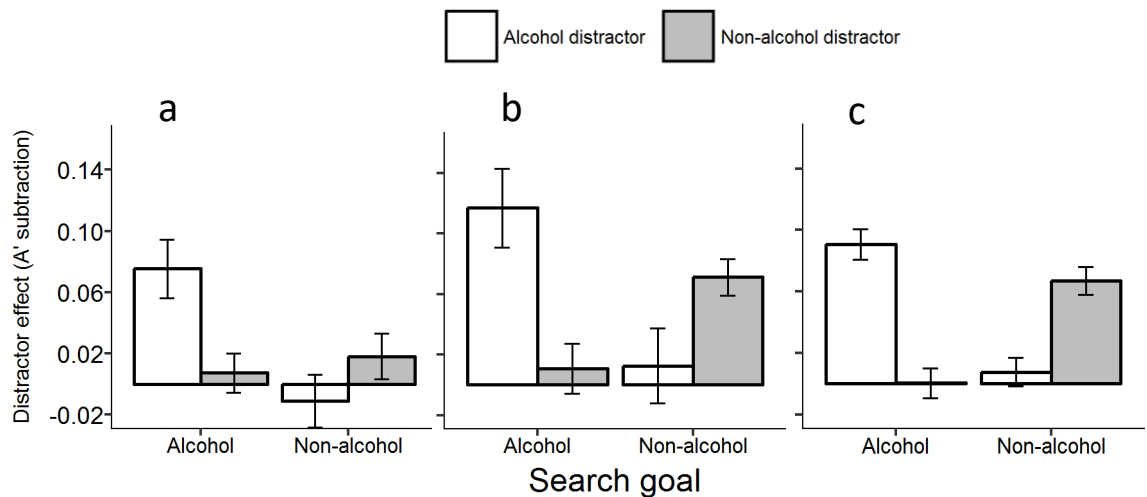
Figure 16. Graph depicting the mean distractor effects across Experiments 1a, 1b, and 1c. The distractor effect reflects the subtraction of the A' detection sensitivity score when the distractor was of the same category as one of the search goals, from the distractor which is never searched for. This distractor effect was calculated for both search goal conditions. Error bars reflect within-participants' standard error.

Regardless of any main effect of search goal, the pattern of results concerning the distractors was identical across all three experiments. In each, the distractor effect was significant, showing that some distractors had reduced detection sensitivity of the targets (Experiment 1a: $F(2,22) = 5.22$, $p = .014$; Experiment 1b: $F(2,30) = 11.09$, $p = .001$ (Huynh-Feldt corrected); Experiment 1c: $F(1,118) = 26.59$, $p < .001$). Critically, all three experiments revealed the main effect of distractor to be qualified by a significant interaction between search goal and distractor type, thus suggesting that some distractors interfered more with the task when participants were searching for a congruent target (Experiment 1a: $F(2,22) = 5.79$, $p = .019$; Experiment 1b: $F(2,30) = 12.47$, $p = .001$ (Huynh-Feldt corrected); Experiment 1c: $F(1,118) = 25.12$, $p < .001$). Specifically, as can be seen in Figure 16, and as predicted by a goal-driven account of alcohol-related attentional capture, distractor interference was observed only during search conditions that involved a goal for that distractor type.

Internal Meta-Analysis. To further delineate these distractor effects, and their interactions with search goal, we computed pairwise comparisons between goal-congruent and goal-incongruent distractors meta-analytically (see Figure 17). For this analysis Hedges' g effect size (Lakens, 2013) and confidence intervals, as well as Bayes factors, were computed. As hypothesised, when comparing the alcohol distractor effect versus the completely task-irrelevant distractor, there was a consistent and large effect size (Hedges' $g = .95$) across all three experiments, with Bayes factors also showing very strong evidence in favour of the experimental hypothesis. Similarly, when the non-alcohol distractor was congruent with the contents of the current non-alcohol search goal there was a medium sized decrement (Hedges' $g = .56$) in detection sensitivity versus the completely task-irrelevant non-alcohol distractor. The Bayes factors revealed that overall there was strong evidence favouring the experimental

hypothesis, although this was not true across all experiments, with evidence favouring the null in Experiment 1a.
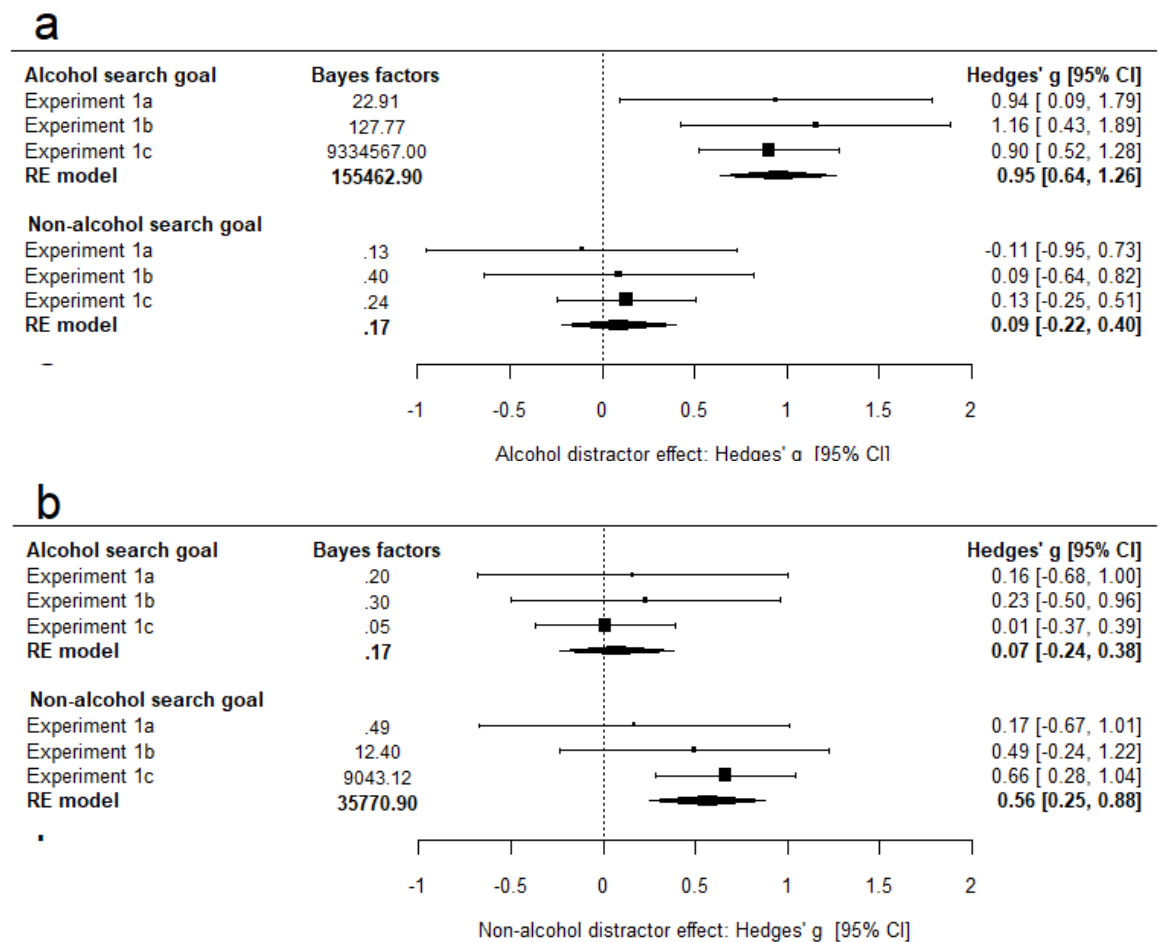
Figure 17. Forest plots presenting the random effect model of the cumulative Hedges' *g* effect sizes, confidence intervals, and Bayes factors. Values for each individual study are also presented. 2a reflects the distractor effect for the goal-congruent alcohol distractor versus a completely irrelevant non-alcoholic distractor, when searching for alcohol (top), and when searching for a non-alcoholic object category (bottom). 2b reflects the distractor effect for a goal-congruent non-alcohol distractor versus a completely irrelevant non-alcohol distractor, whilst searching for alcohol (top) a non-alcoholic object category (bottom).

Interestingly, the goal-congruent alcohol distraction was larger than the non-alcoholic goal-congruent distraction: Experiment 1a: $t(11) = 2.44$, $p = .031$; Experiment 1b: $t(15) = 1.96$, $p = .068$; Experiment 1c: $t(59) = 2.97$, $p = .004$. There are multiple potential causes for this difference, though it could hint at an interaction between the qualities of stimulus features and participants' current goals (see General Discussion).

In contrast to the large and consistent goal-congruent distractor effect, when the alcohol distractor was incongruent with the current search goal there was a non-significant and negligible effect size, when comparing it to the goal-incongruent non-alcohol distractor (Hedges' *g* = .09). Overall, the Bayes factors showed evidence for the null hypothesis (B < .33). When the non-alcohol distractor was incongruent with the current search goal there was also a

negligible and non-significant effect size, when compared to the completely task-irrelevant distractor (Hedges' g = .07). The Bayes factor also showed evidence favouring the null hypothesis (B < .33). The evidence, therefore, suggests that a distractor only resulted in interference when it was congruent with the current search goal, regardless of whether it was an alcohol or a neutral category. The same distractors which capture attention under these conditions had no effect upon performance when they were incongruent with the current search goal. This was true for both non-alcohol stimuli and alcohol stimuli.

Exploratory Correlations. An exploratory correlational analysis was conducted using the alcohol relevant questionnaire measures and the subtraction of detection sensitivity when the distractor was alcohol from when it was neutral category, from Experiment 1c. Pearson's correlation coefficients between alcohol related self-report measures and both goal-congruent and goal-incongruent alcohol distractor effects were calculated. Bayes factors were computed to test whether the results favoured the null or the experimental hypothesis. The prior for all correlational analysis was set as .27 as the upper-limit of the expected effect size based on the Fisher's Z transformed effect size (r = .26) taken from a meta-analysis of the correlation between attentional capture by addictive substances and substance use (Rooke et al., 2008). This relatively small expected effect size was selected based on the relationship being taken from multiple types of experiment, and should therefore generalise to the current novel task.

	Goal-congruent alcohol distraction			Goal-incongruent alcohol distraction		
	Pearson's r	p-value	Bayes factor	Pearson's r	p-value	Bayes factor
Units	-.1	.44	.27	.15	.245	1.32
Binge score	.06	.643	.63	.03	.811	.53
AUDIT	.03	.852	.51	.16	.213	1.42
AEAS – positive arousal	-.05	.698	.34	-.05	.7	.34

Table 8. Pearson's r correlation coefficient, p-values, and Bayes factors for the relationship between distractor effects when congruent or incongruent with the current search goal, and alcohol related self-report measures. These measures include the number of units drank per week and the binge score derived from the AUQ (Mehrabian & Russell, 1978). The AUDIT (Sanders et al., 1993), and the positive high arousal subscale of the AEAS (Morean et al., 2012).

The alcohol relevant self-report measures included the number of units drank per week and the binge score, derived from the Alcohol Use Questionnaire (AUQ; Mehrabian & Russell, 1978), the Alcohol Use Disorders Identification Test (AUDIT; Sanders et al., 1993), and the positive high arousal subscale of the Anticipated Effects of Alcohol Scale (AEAS; Morean et al., 2012). All p-values showed a non-significant effect, which the Bayes factors revealed to be an inconclusive null effect, being neither lower than .33 nor higher than 3, and can only be described as a weak anecdotal relationship (see Table 8).

Experiment 2

The internal meta-analysis across the first experiment suggests that attentional capture by alcohol stimuli in the current task can be accounted for by a goal-driven mechanism. Experiment 2 sought to further clarify the precise mechanism underlying these effects. Note that my manipulation of goal-driven attention in Experiment 1 is also likely to have manipulated the contents of visual working memory (VWM), in that participants may have maintained a representation of their search target throughout the search. Previous research suggests that merely holding information in VWM can bias attention (for review see Soto, Hodsoll, Rotshtein & Humphreys, 2005). For example, when participants were instructed to hold an image of palatable food active in VWM, task-irrelevant food images which matched this representation captured attention during a concurrent visual task (Higgs, Rutters, Thomas, Naish & Humphreys, 2012; Kumar, Higgs, Rutters & Humphreys, 2016). As such, it was important to consider whether the results of Experiment 1 might reflect the role of more passive top-down VWM maintenance rather than resulting from a deliberate top down attentional goal.

To address this, Experiment 2 modified the original paradigm so that the contents of VWM were manipulated while the primary search goal remained constant. Participants performed the RSVP task searching for an alcohol irrelevant category (cars), while also maintaining either alcohol-related or alcohol-unrelated (pots/pans) imagery in VWM as part of a separate memory task. If VWM maintenance alone can explain the findings of Experiment 1, similar results would be expected in this new experiment.

Methods

Participants. 48 participants were initially recruited, though 5 were excluded from the analysis due to performing at chance on either the pots/pans or alcohol condition of the memory task. Sample size was based on the maximum number of participants that could be recruited over a two-month period (see participant details in Table 6). A post hoc power analysis using Gpower revealed that on the basis of size of the interaction effect between VWM contents and distractor type observed in the present study ($\eta^2_p = .015$) the power was at adequate levels to detect an effect, $1-\beta = .8$ (Faul et al., 2009; Cohen, 1988).

Stimuli and procedure. The task and stimuli were identical to Experiment 1b, with the following exceptions. At the start of each trial a 1000ms fixation cross was presented, which was followed by a 500ms memory cue, measuring 5.14°×3.35°, which participants were instructed to hold in memory throughout the RSVP search task. This was followed by a 400ms ISI that preceded the RSVP stream. The RSVP task was similar to previous studies, except that the search target was a car (selected from one of 24 different car images). After the participant had responded to the present/absent judgement, a memory probe was presented from the same category as the memory cue. Participants had to judge whether the memory probe was the same or different from the memory cue they held in memory, they responded with 's' for same and

'd' for different. On half the trials the cue and probe matched. After this second response, participants were presented with feedback for the memory task, which appeared for 600ms. Trials were separated with 100ms of white noise filling the screen. All within participants' variables were counterbalanced within each block, there were two blocks which were made up of 96 trials.

In one block, the memory cue was one of 24 alcohol images, on the other block the memory cue was one of 24 pots/pans images. Each image consisted of different alcohol types or different pots/pans in a single scene[10]. All additional images in this task were sourced from Google images. The order of these blocks was counterbalanced between participants. At the beginning of the task participants were given a 16-trial practice block without any distractors. Half the participants completed the questionnaires prior to the task, half after.

Results and Discussion

In order to ensure that a VWM representation was active in the trials analysed, we removed all trials (10%) where participants incorrectly reported whether the probe was same/different from the cue. Rerunning the analyses with all trials included did not change the pattern or significance of the results. The RSVP target detection sensitivity (A') was entered as the dependent variable in a 2×3 ANOVA, with active memory type (pots/pans, alcohol) and distractor (pots/pans, alcohol, shoes) as factors. For means and standard deviations see Table 7. The main effect of memory contents was non-significant, $F(1,42) = .36$, $p = .55$, $\eta^2_p = .01$, as was the main effect of distractor type, $F(1,84) = 1.17$, $p = .316$, $\eta^2_p = .03$. Importantly for my hypothesis, the interaction between memory contents and distractor type was also non-significant, $F(2,84) = .64$, $p = .529$, $\eta^2_p = .02$, thus suggesting that there was no difference between the distractor type when it was congruent with the contents of VWM compared to when it was incongruent. To further test the sensitivity of this analysis we conducted Bayesian pairwise comparisons. The data were significantly skewed; therefore, follow-up analyses were supplemented with bootstrapped confidence intervals which are robust to violations of normality (Field, 2013).

Follow-up Bayesian comparisons revealed no evidence of interference from alcohol (vs shoe) distractors, regardless of whether VWM contained alcohol images, $t(42) = .21$, $p = .838$, 95% CI [-.02, .2], $B_{H[0, .10]} = .10$; or pots and pans, $t(42) = .04$, $p = 859$, 95% CI [-.02, .02], $B_{H[0, .10]} = .11$. Note that this result meets the $< .33$ criteria for a sensitive null result (Dienes 2008). It therefore appears that despite the alcohol imagery being active in working memory, there was no biasing effect towards visually similar alcohol distractors. There was also no evidence of

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[10] In order to match the pots/pans to the alcohol memory images, which had a greater variety of colours within each image, the selected exemplar within each image were colourised to another colour that was suitable for a pot or pan. For example, with an array of stainless steel pans, several pans were changed to a copper colour; nine images were changed in this way.

interference from pot (versus shoe) distractors either during the alcohol VWM condition, $t(42) = .18$, $p = .859$, 95% CI [-.01, .01], $B_{H[0, .10]} = .09$, or the pot search condition, $t(42) = 1.71$, $p = .094$, 95% CI [> -.01, .03], $B_{H[0, .01]} = .62$.

General Discussion

Across three experiments the findings demonstrated that when participants held a search goal for alcohol related targets there was a consistent attentional capture by alcohol distractors. This occurred at presentations as brief as 83ms and when the distractors were completely task-irrelevant, thus suggesting that an early and automatic bias was induced by the search goal. Furthermore, Bayesian analyses revealed that this capture effect was absent when participants were searching for a non-alcoholic category of objects. Additionally, a null effect was found when participants held the alcohol features in VWM but did not prioritise them as a search goal. Taken together, these results provide a clear demonstration that an involuntary attentional capture by alcohol stimuli can be induced by the deliberate prioritisation of alcohol as a top-down search goal.

Our results are inconsistent with a stimulus-driven effect independent of the current search goal, as predicted by IST (Berridge & Robinson, 2016). The present series of experiments cannot rule out the possibility that purely stimulus-driven effects might be observed in certain contexts (e.g. less perceptually difficult tasks, cf. Lavie, 2005), although the present data provide an alternate suggestion, that a seemingly stimulus-driven effect may in fact be dependent on search goals driven by the individual's desire to consume alcohol. Note, alcohol capture effects have exclusively been found among a group of individuals (i.e. drinkers) known to find alcohol imagery to be pleasant and personally relevant, who might hence reasonably choose to attend to these images. Furthermore, previous evidence for the alcohol capture effect is derived from tasks such as the dot-probe, in which not only is there little motivation to follow the instruction to ignore the alcohol (in that there is no performance cost to doing so), but in which the task instructions necessitate the allocation of attention to the location of the images (effectively making them impossible to completely ignore). Taken together with the demonstration that the bias can be induced by manipulating goal-driven mechanisms, it appears that the stimulus-driven account should be questioned.

A goal-driven account of attentional capture by alcohol stimuli could explain some previous inconsistencies in the literature. Overall attentional biases are found towards alcohol (Field & Cox, 2008), although more recently the attentional bias towards alcohol has been found to fluctuate over the duration of a dot-probe task (Gladwin, 2017). Such a fluctuation effect could potentially be explained by the ebb and flow of goal priority, as individuals may switch between searching for alcohol cues and following the instruction to detect the dot-probe, which does not require much attentional engagement.

Integrating the current results into IST, it appears that the incentive value may not directly influence early attentional selection of the stimuli, independent of the current search goal. Rather, it may be that the incentive associations of a stimulus increase the likelihood that that object will be searched for. It would make sense that a person who values alcohol would be likely to intentionally search for alcohol in their environment.

An interesting but unexpected feature of the results is that while my manipulation of search goal induced attentional capture by alcohol and non-alcohol stimuli alike, the alcohol attentional capture effect was consistently stronger than the non-alcoholic goal-driven effect. This finding cannot reflect a purely stimulus-driven effect, because there was no evidence of distraction by the same stimuli when they were incongruent with the search goal, however, it may still indicate that high incentive salience of the stimuli interacts with the search goal, amplifying the goal-driven effect. Alternatively, perhaps the attentional capture was goal-driven, but the level of disruption was magnified due to craving induced by the alcohol stimuli. Future research could adopt the current paradigm to follow up this intriguing possibility, for example by comparing non-drinkers and heavy drinkers, by manipulating the level of craving, or by using eye tracking to disentangle initial capture from delayed disengagement.

The term 'goal-driven attention' is often discussed primarily in terms of the voluntary direction of attention in line with the task instructions (e.g. Theeuwes, 2010). The results, however, highlight that goal-driven attention is more complex, and should not be conflated with voluntary attention. A voluntary attentional goal can have involuntary attentional consequences. the current results are a clear demonstration of this; when participants searched for alcohol in one location they could not ignore alcohol in another (irrelevant) location, despite clear instructions to do so, and despite an obvious performance cost to attending to the irrelevant alcohol. It therefore appears that there is a distinction between declarative task rules and goal-driven attention which is often ignored in models of attention and addiction. In relation to alcohol, a heavy drinker may declare that they want to reduce their intake of alcohol when visiting the doctors, but they would likely exhibit different behaviour when in a bar where alcohol is present and the incentive value more apparent, leading them to prioritise the goal to search for alcohol in their environment.

In the current investigation, we found attentional capture only when the alcohol image was the primary search goal, but not when it was held in VWM. This finding appears to somewhat conflict with previous results that holding imagery in VWM can involuntarily bias external attention (e.g., Kumar et al., 2016). One reason for this could be that the current task required participants to search for a complex category of images in a perceptually demanding RSVP task. It has recently been found that a secondary stimulus active in VWM only biases attention when the primary task is simple, such as when the target is a simple shape repeated across trials (Gunseli, Olivers & Meeter, 2016). What this does reveal is that alcohol cues are

not automatically prioritised in attention, and if an individual is sufficiently engaged with a competing goal, this individual would not orient attention to congruent alcohol cues despite those being active in memory.

In terms of applications, the current results suggest that attentional capture by alcohol was eliminated when the individual was searching for a non-alcoholic object, even when they held an alcohol image in memory. This therefore suggests that interventions which encourage problem drinkers to pursue a competing attentional goal could be effective in disrupting attentional capture by alcohol, and hence preventing this attentional bias from leading to the escalation of craving (Field & Eastwood, 2005). This idea is consistent with evidence that individuals who were more satisfied with their non-alcohol related life goals were less prone to hazardous drinking, when compared to those who found their non-alcohol related goals unsatisfying (Cox et al., 2002). Further, the absence of a goal-incongruent distraction by alcohol suggests that attentional bias retraining might be improved by training participants to search for a single competing pleasant category (i.e. training participants to search for smiling faces in the presence of alcohol cues), rather than attempting to train avoidance of alcohol (i.e. training participants to search for a target away from an alcohol image and towards random non-alcoholic objects; Schoenmakers et al., 2007).

In summary, we have demonstrated that a consistent involuntary attentional capture by alcohol in social drinkers can be induced, or blocked, through a goal-driven mechanism. The present study is not definitive evidence of a goal-driven mechanism as the *only* driver of involuntary attention to alcohol cues; however, the clear demonstration of goal-driven alcohol attentional capture raises the possibility that effects previously assumed to be stimulus-driven could actually occur as an unintended outcome of voluntary top-down processes.

Chapter 5: Goal-Driven Attentional Capture by Appetitive and Aversive Smoking-Related Cues in Nicotine Dependent Smokers

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Abstract

Conventionally, automatic attentional capture by tobacco cues in smokers are seen as an implicit bias, operating independently of an individual's current search goals. Mainstream attention research, however, has suggested that current search goals can actually induce an involuntary attentional capture. In the current investigation, we tested whether appetitive and aversive smoking images affected attention through such a mechanism, and whether there were any group differences based on nicotine dependence. we instructed non-smokers, occasional smokers (low dependence), and nicotine dependent smokers (moderate-high dependence), to hold search goals for either an aversive smoking category, appetitive smoking category, or a category of non-smoking images. These images were presented in a stream of briefly appearing filler images, whilst task-irrelevant distractors were presented outside the stream. Distractors could be aversive or appetitive smoking images, or a category of non-smoking images. Therefore, in some conditions, the distractors matched the current category being searched for, whilst in others it was incongruent. Task-irrelevant smoking distractors, compared to the non-smoking distractors, reduced target detection only when they were congruent with the specific category being searched for. There was no effect on performance from either aversive or appetitive smoking distractors when participants were searching for the non-smoking targets. Distractor interference did not differ between smokers and non-smokers. The results support a goal-driven mechanism underpinning involuntary attentional capture by smoking cues. These findings can be used to inform models of addiction and attention, as well as the display of graphic health warnings on tobacco packaging.

Attentional theories of Pavlovian associative learning suggest that drug-related cues, including smoking-related cues, command the focus of selective attention (Mackintosh 1975; Pearce and Hall 1980). Several studies have provided evidence that smoking-related cues attract attention. Smokers but not non-smokers show greater interference on a primary task when a secondary task includes the presentation of a smoking cue vs control cue (e.g. Cepeda-Benito and Tiffany, 1996; Jarvik, Gross, Rosenblatt & Stein, 1995). Furthermore, smokers but not non-smokers show slower detection latencies for targets that appear in a different location from a smoking image compared to a control image (Mogg, Bradley, Field & De Houwer, 2003; Field,

Mogg & Bradley, 2008; Field, Mogg & Bradley, 2004). In recent years, such attentional capture by drug related cues have been thought to perpetuate maladaptive behaviours which underpin substance dependence (Stacy & Wiers, 2010).

It has often been assumed that the attention to cues which are associated with drug use is under the control of an automatic mechanism, which operates independent of the current goals of the individual (Berridge & Robinson, 2016; Robinson & Berridge, 1993). In smokers, evidence would initially appear to support a stimulus-driven account of attention to smoking related cues. For instance, in a dot-probe task, smokers show an attentional capture by the smoking image (i.e. automatic orienting of attention to a stimulus) even when the smoking stimuli are only briefly presented (e.g. 200ms; Bradley, Field, Mogg & De Houwer, 2004).

There is, however, the alternative possibility that smokers may voluntarily choose to search for smoking cues, and this is why they are distracted by them. It has been found that when some individuals search for a specific feature in their environment, attention is automatically allocated to all stimuli which match that feature, despite interfering with the individual's current task (cf. Folk, Remington & Johnson, 1992). For instance, when participants were instructed to search for a specific colour in a rapid serial visual presentation (RSVP task) stream of images, task-irrelevant distractors only caused participants to miss the subsequent target when they matched the current search goal (Folk, Leber & Egeth, 2002). This phenomenon, known as *contingent capture,* reveals that the current goals of an individual can actually induce an involuntary attentional capture by specific cues. It may be that because smokers consider smoking images rewarding and explicitly rate them as pleasant, they may choose to voluntarily attend to these images (Mogg et al., 2003).

Previous research investigating attentional capture by smoking cues has not yet directly tested whether the capture occurs through a stimulus-driven mechanism, or a goal-driven mechanism. Furthermore, certain features of the paradigms typically used to demonstrate attentional capture by smoking cues mean that a goal-driven account of prior findings cannot be ruled out. For instance, in one investigation, Chanon, Sours and Boettiger (2010) used an RSVP task to investigate attentional capture to smoking images, this task required participants to identify two separate alphanumeric characters embedded in an RSVP stream. It was found that when the first character was embedded in a smoking image, smokers missed the second character more frequently than non-smokers. It is not clear whether this finding shows a stimulus-driven or a goal-driven effect on attention, because the smoking image was task-relevant; participants had to voluntarily attend to the smoking relevant features in order to process the target character. Similarly, in the dot-probe task (e.g. Bradley et al., 2004), the distractor always appears in a potential target location, meaning that in order to process the dot-probe, participants cannot avoid intentionally attending to the smoking images that appear in

this location. Under these conditions, it is impossible to disentangle which mechanism is driving attention.

For this reason, in the current investigation, we tested whether a goal-driven mechanism, activated by an instruction to search for a target, could account for distraction by completely task-irrelevant smoking images. Smoking distractors were task-irrelevant as they were presented in parafoveal locations to the RSVP stream, where the target never appears. If these images interfere with task performance, then it would be evidence of an involuntary attentional capture. A goal-driven account would predict that attention would be captured by these images only when the distractor features matched the features currently being searched for, whilst a stimulus-driven account would predict that smoking stimuli should capture attention regardless of the current search goal.

As well as using cigarette smoking cues, we took the opportunity to investigate attentional capture by aversive smoking cues, to compare the mechanisms of attentional capture for smoking images with differing motivational outcomes (avoidance versus approach). Examining this would have practical importance, because in an effort to curb smokers' cigarette intake, UK tobacco packaging has been labelled with a graphic health warning (e.g. respiratory disease), and cigarette branding has been removed (see Department of Health, 2016 for current guidelines). Recent evidence suggests that pictorial graphic warnings increase intentions and attempts to quit smoking, as well as the reported number of occasions forgoing a cigarette (Brewer et al., 2016; Noar et al., 2015; 2016).

Research seems to suggest that these unbranded packets with graphic aversive smoking images are highly salient to some smokers, as indexed by greater activation of the visual cortex and higher number of eye-movements towards the images during free-viewing (Maynard, Brooks, Munafo & Leonards, 2017; Munafo, Roberts, Bauld & Leonards, 2011). However, free-viewing tasks cannot determine whether participants automatically orient attention to these cues because of a goal-driven or stimulus-driven mechanism. The mechanism by which these images capture attention would have a bearing on how to improve the effectiveness of this intervention (see Applications). We therefore presented task-irrelevant aversive smoking images alongside appetitive smoking images, which could be congruent or incongruent with the content of the participants' current search goal.

Methods

Participants

Participants were recruited based on their level of dependence and self-reported smoking status. Non-smokers ($n = 25$) were individuals who reported never having previously smoked. Occasional smokers ($n = 25$) were individuals who were active smokers but scored below three on the Fagerstrom nicotine dependence test (FNDT) thus showing very low nicotine

dependence. Dependent smokers ($n = 20$) were participants who scored 3 and above on the FNDT. Cut-offs were based on those reported by Fagerstrom, Heatherton & Kozlowski (1991).

One participant was excluded for using inconsistent responses on the irrelevant distractor RSVP task. All the groups' demographic, trait, and state variables are reported in Table 9. The sample size was based on that of Chanon et al. (2010) who found significant smoker versus non-smoker differences in an RSVP task with a sample of 23 participants within each condition.

	NS ($n = 25$)	OS ($n = 25$)	NDS ($n = 20$)	Group differences (p-values)
Gender	19 females	21 females	11 females	.085
Age	20.20 (1.58)	20.84 (1.77)	23.15 (5.67)	.013
FNDT	0	.72 (.79)	4.72 (.75)	< .001
Craving	< 1 (1.06)	27.48 (21.39)	45.75 (33.05)	< .001
SPQ-PR	1.71 (1.06)	4.88 (2.14)	6.05 (2.50)	< .001
SPQ-NR	2.74 (2.32)	5.73 (1.95)	6.01 (2.21)	< .001
SPQ-NC	7.59 (2.17)	7.39 (1.96)	7.85 (1.41)	.721
Impulsivity	62.04 (11.38)	71.40 (11.66)	80.20 (8.40)	< .001
AUDIT	13.68 (5.98)	13.96 (7.94)	14.50 (7.49)	.929

Table 9. Participant demographic information, as well as state and trait measures across three experimental groups. Numbers reported are the mean with standard deviations in brackets. FNDT = Fagerstrom Nicotine Dependence Test; Craving = current craving prior to the task measured on a visual analogue scale ranging 0 – 100; SPQ – PR = Smoking Consequences Questionnaire average expectancy of positive reinforcement, ranging from 1 – 9; SPQ –NR= Smoking Consequences Questionnaire average expectancy of negative reinforcement, ranging from 1 – 9; SPQ-NC = Smoking Consequences Questionnaire average expectancy of negative consequences, ranging from 1 – 9; Impulsivity was measured with the Barratt impulsiveness scale; AUDIT = Alcohol Use Disorders Identification Test. Group differences were measured with a one-way ANOVA, or Chi-squared test for gender differences.

Questionnaires

Barrett Impulsiveness Scale (BIS-11; Patton & Stanford, 1995). Trait impulsivity has been linked to attentional biases towards addictive substances (for meta analyses see Coskunpinar & Cyders, 2013). We, therefore, measured trait impulsivity using the 30 item BIS-11 scale.

Fagerstrom Nicotine Dependence Test (FNDT; Heatherton, Kozlowski, Frecker & Fagerstrom, 1991). The FNDT is a six-item questionnaire which measures different aspects of nicotine dependence. The total dependence score is 10, with a score below 3 suggesting very low nicotine dependence.

Short Form Smoking Consequences Questionnaire (S-SCQ; Myers, MacPherson, McCarthy & Brown, 2003). The S-SCQ is a 21-item measure that records participants expectancy of positive reinforcement, negative reinforcement, aversive outcomes, and appetite suppression from smoking. Responses range from very unlikely to very likely on a nine-point scale.

Craving visual analogue scale (VAS). The task was programmed in E-prime, and require participants to select, using the mouse, a position on a visual analogue scale ranging from "No craving what so ever" to "Highest possible craving imaginable". The scores ranged between 0 and 100.

Other measures. Thirty-two of the participants completed the Profile of Mood States (POMS; McNair, Lorr & Droppleman, 1971) and the behavioural activation and inhibition scales (BIS/BAS; Carver & White, 1994). However, due to time constraints these measures were dropped from the procedure.

Stimuli

The experiment was run using E-prime 2.0 on a Dell Optiplex 7010 PC, and was displayed on a 13inch monitor with a screen resolution of 1280 x 1024. Participants viewed the screen at a distance of 59cm, maintained using a chin rest.

A total of 396 images were sourced for the task from the IAPS image database and Google images (Lang, Bradley, & Cuthbert, 2001). The task required a total of 18 appetitive smoking images, six as the targets and 12 as the distractors. These images showed individuals or groups enjoying cigarettes. A total of 18 aversive smoking outcome images were collected, again six as the target in the central stream and 12 as the distractors. These depicted images often included on graphic health warnings on tobacco products (i.e. gangrene, mouth or throat cancer, and tooth damage). A neutral category of six targets was also collected, which depicted individuals and groups reading books. A group of 12 distractor images were also collected which showed individuals and groups gardening, these were selected due to them depicting non-aversive or appetitive situations and so that none of their features overlapped with the other smoking and non-smoking target features.

The filler images presented in the central RSVP stream included 81 images of neutral everyday scenes (e.g. people on the bus). In order to prevent participants from searching purely for generally positive and negative information in the RSVP and neglect the smoking related features, 72 positive scenes (e.g. people smiling), and 72 general negative scenes (e.g. people arguing), were sourced. In order to prevent participants in the negative search condition simply searching for close-ups of body parts, which constituted the majority of the negative smoking image category, 72 close-up images of healthy body parts (e.g. close-ups of healthy limbs) were also sourced. Alongside the smoking or gardening related distractor images which appeared on each trial, a neutral filler image was selected to appear in the opposite distractor location. For

this purpose, 18 additional neutral everyday scenes and 18 additional close-ups of healthy body parts were selected to appear in distractor locations. From all categories, no image which appeared in the central RSVP stream appeared in a parafoveal distractor location.

All images in the central RSVP stream measured 3.44°×2.29° visual angle and the distractors measured 4.58°×2.98° at a 59cm viewing distance. Distractors appear above and below the central stream with a gap of .5° from the central images.

RSVP Task

See Figure 18 for a diagram of a single trial of the RSVP task. Each trial began with a 400ms cue for upcoming target category: 'POSITIVE SMOKING', 'NEGATIVE SMOKING', or 'READING'. This was followed by a nine image RSVP stream, with each image appearing for 100ms without an interval. The filler images were made up of two neutral, two positive, two negative, and two healthy body part images. The order of these different filler images was randomised for each trial. The target image appeared equally at positions five, six, seven and eight in the RSVP stream. The distractor frame always appeared 2 frames prior to the target (i.e. Lag 2). There were three types of distractor image, appetitive smoking scenes, aversive smoking outcome scenes, and gardening scenes, these appeared in equal number of times across the block. The distractors appeared above and below the RSVP stream, with one of the distractor positions being occupied by the appetitive smoking, aversive smoking, or gardening distractor and the other by a neutral filler distractor. At the end of the trial a screen appeared with a question mark prompting participants to report whether they thought the target category was present or absent on the trial, using the 'c' and 'm' keys, with the response-answer assignment counterbalanced between participants. In total there were three blocks of 120 trials. In half of the trials the target was present. In the other half it was replaced by another neutral filler image. Each search category was presented in an individual block which was preceded by a 4s warning of what the target category would be. All within-participants variables were counterbalanced, and the order of blocks was counterbalanced between participants. The task was preceded by a twelve-trial practice block. Within the practice block participants were instructed to search for houses, and distractor were two black rectangles. No practice block images were repeated in the main task.

Image Arousal and Valence Ratings

All distractor and target images were rated along dimensions of valence and arousal using a nine-point self-assessment manikin, which presents the scale alongside a human figure which depicts each level of valence and arousal (see Bradley & Lang, 1994). The images were presented using Inquisit 5 presentation software, and appeared in a random order.

Procedure

Participants were given the opportunity to view an example aversive image (severed hand) prior to consent, which was in accordance with the declaration of Helsinki. This specific

image was never presented in the task. Half the participants completed the questionnaires prior to the task, in a random order. All participants completed the craving VAS before the RSVP task. All participants were supervised through the instructions and practice trials, before they completed the task on their own. Those that had not completed the questionnaires completed them after the task. 32 of the participants completed the questionnaires using pen and paper, whilst 39 completed a computerised version programmed on Inquisit 5 software in order to fully automate the random presentation order. Finally, all participants rated the images for valence
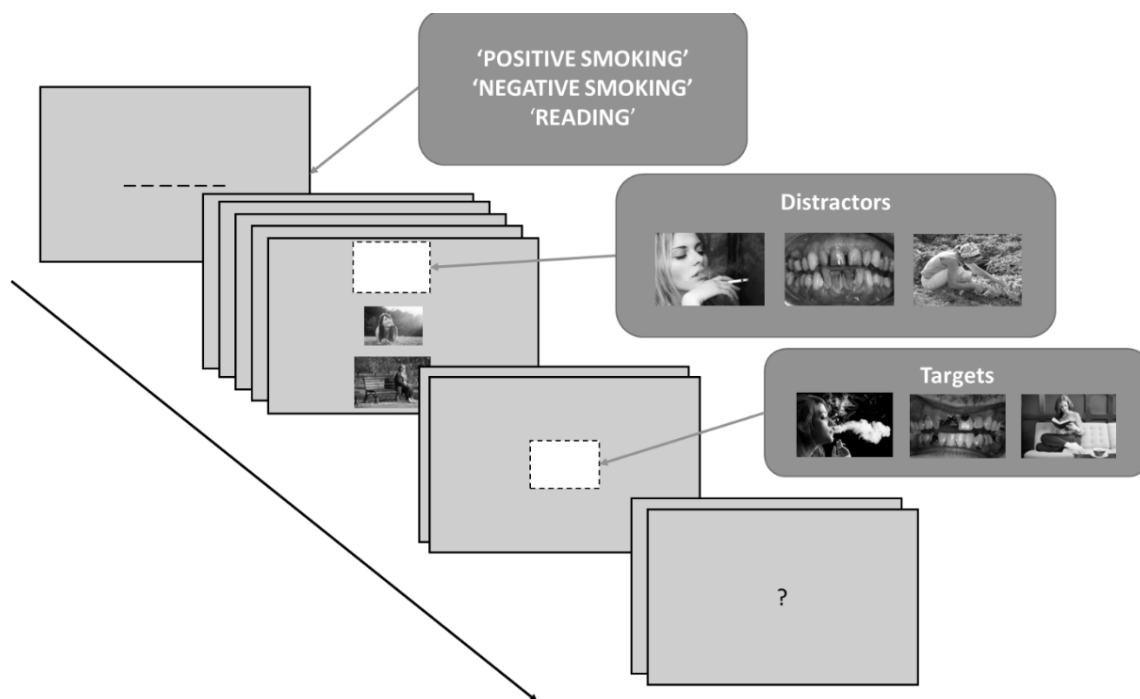
Figure 18. Structure of a single RSVP trial and stimuli used in the RSVP task. At the start of each trial participants were presented with a 400ms prompt, with the target type for that block. Each of the subsequent 9 images in the RSVP appeared for 100ms without inter-stimulus interval. At the end of each trial participants identified whether a target had been present or absent. The distractors consisted of appetitive smoking images, aversive smoking images, and gardening images. The targets consisted of appetitive and aversive smoking images, and reading images. Images' sizes are not proportional to how they appeared in the task.

and arousal, before being debriefed.

Results and General Discussion

Image Ratings

One-way ANOVA's revealed that there was a significant linear effect across groups of valence ratings for appetitive smoking stimuli, $F(1,69) = 13.64$, $p < .001$ (see Table 10 for ratings data), with non-smokers viewing them as unpleasant (< 4.5), occasional smokers neutrally (~ 4.5), and dependent smokers pleasantly (> 4.5). Arousal ratings of these stimuli also showed a significant linear effect in the same direction, $F(1,69) = 11.34$, $p = .001$. There were no group differences in either valence or arousal ratings of aversive smoking images (valence: $F(2,69) = .96$, $p = .386$; arousal: $F(2,69) = .61$, $p = .549$). Also, there were no group differences in either valence or arousal ratings of the non-smoking images (valence: $F(2,69) = .14$, $p = .873$;

arousal: $F(2,69) = .61$, $p = .325$). The image ratings did reveal that the non-smoking distractors were seen as more pleasant than the appetitive smoking images. Importantly, however, these non-smoking images were rated lower on arousal, versus the smoking related images, which is the affective dimension previously associated with attentional capture (Vogt, De Houwer, Koster, Van Damme & Crombez, 2008).

	Image type	Non-smokers	Occasional smokers	Dependent smokers	Total
Valence	Negative smoking	1.14 (.25)	1.16 (.24)	1.34 (.9)	1.21 (.52)
	Appetitive smoking *	3.22 (1.69)	4.69 (1.24)	5.21 (2.41)	4.31 (1.96)
	Non-smoking	6.33 (1.16)	6.24 (1.18)	6.43 (1.31)	6.33 (1.19)
Arousal	Negative smoking	3.86 (2.56)	4.69 (2.57)	4.46 (3.12)	4.33 (2.72)
	Appetitive smoking **	2.25 (1.31)	3.26 (1.28)	3.91 (2.27)	3.08 (1.74)
	Non-smoking	2.31 (1.48)	2.50 (1.13)	3.01 (2.11)	2.58 (1.58)

Table 10. Mean valence and arousal ratings across the three experimental groups, standard deviations are reported in brackets. Valence and arousal range from 1 – 9, ranging from unpleasant to pleasant, and calm to high arousal. Asterisks denote a significant one-way ANOVA linear effect across groups, * = $p < .05$; ** = $p < .001$.

RSVP Task

Using the number of hits and false alarms from the RSVP task, we computed A prime (A') detection sensitivity index (Zhang & Mueller, 2005; Table 11). This measure compares the proportion of 'hits' to the number of 'false alarms' when the target is absent. A 3×3×3 mixed ANOVA was conducted with A' as the dependent variable. Within-participants factors were search goal (appetitive smoking/ aversive smoking/ reading), and distractor type (appetitive smoking, aversive smoking, gardening). Smoking status was the between participants factor (non-smoker, occasional, dependent).

	Aversive smoking search goal			Appetitive smoking search goal			Reading search goal		
	Aversive distractor	Appetitive distractor	Gardening distractor	Aversive distractor	Appetitive distractor	Gardening distractor	Aversive distractor	Appetitive distractor	Gardening distractor
NS	.69 (.14)	.79 (.08)	.81 (.04)	.72 (.09)	.69 (.10)	.73 (.09)	.70 (.10)	.71 (.10)	.71 (.08)
OS	.64 (.14)	.76 (.08)	.77 (.07)	.70 (.15)	.67 (.13)	.70 (.14)	.73 (.06)	.72 (.07)	.71 (.07)
NDS	.68 (.12)	.79 (.05)	.79 (.04)	.71 (.14)	.68 (.13)	.71 (.07)	.71 (.09)	.72 (.09)	.71 (.10)

Table 11. Mean A' scores across all target and distractor conditions for the three difference experimental groups. Standard deviations are presented in brackets. A' ranges from .5 (chance detection) to 1 (perfect hit rate and no false alarms).

Target type was significant, $F(2, 134) = 5.7$, $p = .005$ (Huynh-Feldt corrected), $\eta^2_p = .08$, with negative smoking targets resulting in the highest A'. Distractor type also showed a

significant main effect, $F(2,134) = 24.55$, $p < .001$, $\eta^2_p = .27$. Importantly, this was qualified by a significant interaction between search goal and distractor type, $F(4,134) = 34.53$, $p < .001$ (Greenhouse-Geiser corrected), $\eta^2_p = .34$, with an apparent decrement in detection sensitivity when the distractors were congruent with the current search goal. Interestingly, there was no difference between the smoking groups at any level of the analysis, all F's $< .86$, p's $> .49$, $\eta^2_p < .03$.

We, therefore, collapsed across the different smoking groups in order to compare between the smoking related distractor condition and the non-smoking distractor condition, across each search goal condition. A positive effect would show significant interference in a given search condition. For these pair-wise comparisons p-values were computed, along with bootstrapped confidence intervals to counter violations of normality (1000 samples; Field 2013).

To supplement the main analysis, we computed Bayes factors, which compare evidence for the *experimental hypothesis* (smoking stimuli will result in reduced target detection) and the *null hypothesis* (smoking stimuli will not reduce target detection). The Bayes factor ranges from 0 to infinity, values less than 1 indicate that there is support for the null hypothesis, whilst values of greater than 1 indicate that there is support for the experimental hypothesis. The strength of this evidence is indicated by the magnitude of the Bayes Factor; values greater than three or less than .33 indicate substantial evidence for either the experimental or null hypothesis, however, these are guidelines not definitive cut-offs as with p-values. A value closer to 1 suggests that any nonsignificant result is due to insensitivity and any difference is 'anecdotal' (Dienes, 2008; 2011; 2014; 2016). The Bayes factor was computed using a modified version of Baguley and Kaye's (2010) R code (retrieved from Dienes, 2008). To compute the factor, we used a half-normal distribution which estimates that smaller differences are more probable than larger differences. This half-normal was centred on the null hypothesis: zero difference. The prior used was a plausible effect size of $A' = .12$, based on my previous research using alcohol distractors (Brown, Duka & Forster., under review – Chapter 4).

Search goal	Smoking distractor vs irrelevant distractor	p-value	Bayes factor	95% CI Lower bound	95% CI Upper bound
Aversive smoking	Aversive	< .001	4837128×10^9	.10	.15
	Appetitive	.059	.61	>-.01	.02
Appetitive smoking	Aversive	.392	.15	-.01	.02
	Appetitive	< .001	4918.46	.02	.06
Reading	Aversive	.739	.05	-.02	.02
	Appetitive	.739	.06	-.02	.02

Table 12. statistical results from the pairwise comparisons between A' in in the irrelevant gardening distractor condition and the A' in the aversive or positive smoking distractor condition, across all search conditions.

These comparisons revealed that there was substantial evidence of attentional capture when both appetitive and aversive smoking cues were congruent with the current search goal (Table 12). However, when these distractors were incongruent with the current search goal there was no significant attentional capture relative to the non-smoking distractor. Bayes factors revealed that many of these differences were sensitive null effects with one exception. The appetitive smoking distractor effect was marginally significant in the aversive smoking goal condition and the Bayes factor suggested an inconclusive result (> .33).
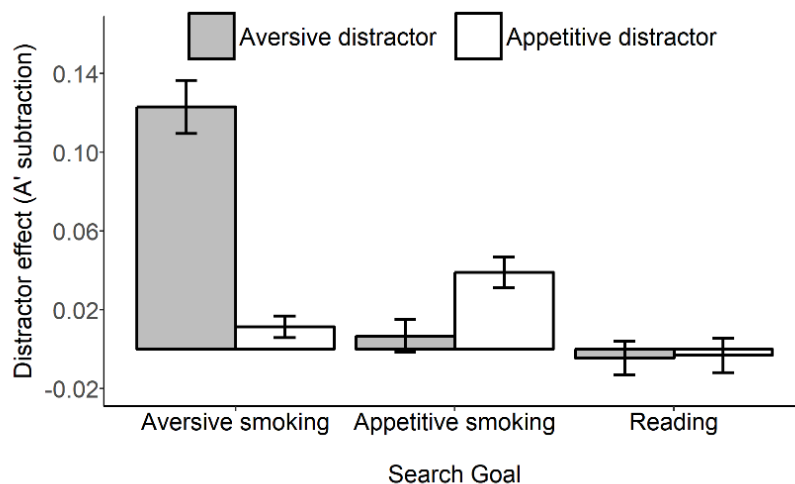
Figure 19. Mean distractor effects for aversive and appetitive smoking distractors across all search goal conditions. Distractor effects were calculated by subtracting the *A'* detection sensitivity index when the distractor was either an appetitive aversive smoking related image from the *A'* when the distractor was a gardening image. An appetitive distractor effect reflects a decrement in target detection versus the completely irrelevant distractor. Standard error represents within-participants standard error.

Examining the mean values across groups reveals that this marginal effect was driven almost entirely by non-smokers (see Table 11), who rated the appetitive smoking images as unpleasant, which indicates that they were congruent with the current negative smoking search goal. There was no difference between these distractors in the nicotine dependent group. Thus, this marginal effect appears to be goal-driven rather than due to any stimulus-driven capture.

Interestingly, the aversive goal-driven effect (plotted in Figure 19) was larger than the appetitive goal-driven effect, $t(69) = 5.77$, $p < .001$. This could have been due to the stronger arousal ratings (see Table 10) or it could have been due to the low-level salience, because the aversive images were less visually complex and contained larger features.

In order to determine whether there was truly no difference between the smoking groups, we conducted Bayesian pairwise comparisons between non-smokers and occasional smokers, and non-smokers and dependent smokers. Based on the logic that smokers would show the largest mean distractor effect found in the current task, whilst non-smokers should

show no smoking distractor effect, the prior expected effect was set as $A' = .12$ with a half-normal distribution. Across almost all conditions, we found evidence which strongly favoured the null hypothesis, suggesting that there truly were no group differences (see Table 13).

It should be noted that there were differences between the smoking groups on age, proportion of males, and impulsivity, with these characteristics being higher in the nicotine dependent group (see Table 9). These are all factors that have been implicated in a *larger* attentional capture by smoking cues, and would actually predict a larger effect, not a null effect (Perlato, Santandrea, Della Libera & Chelazzi, 2014; Coskunpinar & Cyders, 2013).

Search goal	Smoking distractor effect	Occasional smokers vs Non-smokers		Dependent smokers vs Non-smokers	
		p-value	Bayes factor	p-value	Bayes factor
Aversive	Aversive	.682	.37	.872	.27
	Appetitive	.621	.09	.373	.07
Appetitive	Aversive	.514	.11	.622	.19
	Appetitive	.441	.08	.838	.23
Reading	Aversive	.388	.11	.918	.20
	Appetitive	.889	.17	.983	.19

Table 13. p-values and Bayes factors from the pairwise comparisons of distractor effects between occasional smokers and non-smokers, and non-smokers and nicotine dependent smokers. Distractor effects are computed by subtracting the A' when the distractor is a smoking related distractor from the A' when the distractor was a completely irrelevant gardening distractor. Bayes factors were computed based on the largest expected difference between groups being $A' = .12$, with smokers exhibiting larger smoking distractor effects than non-smokers.

The sensitive null results suggest that differences in attentional capture isn't due to the strength of the search goal for smoking images in smokers, which would predict group differences in the goal-congruent effect. It is also inconsistent with the hypothesis that smokers are sensitive to a stimulus-driven capture, which would predict differences in the goal-incongruent effect. Instead, the current results are consistent with a group difference occurring due to the increased likelihood that smokers voluntarily search for a smoking image across the task; however, in the current investigation, instructing all participants to search for smoking cues obscured the group differences. This account could accommodate Zvielli, Bernstein and Koster's (2015) finding that the temporal variability in attentional bias found in the dot-probe was most predictive of smoking related individual differences, rather than the conventional attentional bias score. This temporal variability could be explained in terms of fluctuation of the smoker's search goals across the task period – during some parts of the task they may have focused on the instructed task goals, while in other parts adopted goals for smoking stimuli.

Some features of previous tasks like the dot-probe may have also increased the probability that participants favoured searching for smoking related stimuli over the task goals. The dot-probe and similar tasks only require participants to assume a non-specific search goal (i.e. respond to location of dot). This task does not require participants to hold a specific feature in memory, and can be completed by reacting to *any* stimulus onset, thus allowing competing visual representations to guide attention (see Gunseli, Olivers & Meeter, 2016, for discussion of competing memory guidance). Additionally, the probability that participants may prioritise attending to smoking cues would have been increased because they appeared in target locations (e.g. Mogg et al., 2003).

Applications

In the current task, searching for a specific category with consistent features resulted in no interference from smoking cues. This null effect suggests that searching for non-smoking features prevents distraction by smoking cues. In support of this, Donohue et al. (2016) found that when nicotine deprived smokers were instructed to respond to the location of a specific colour target, they were able to avoid attentional capture by smoking cues. It may be that by occupying the search goal with a specific pre-defined feature, this prevents the formation of a competing search goal for smoking stimuli. This points to a potential avenue for attentional bias retraining, which has shown promising, albeit inconsistent effects (Christiansen, Schoenmakers & Field, 2015); instead of training attention away from smoking stimuli, training participants to search for a healthy competing outcome (e.g. smiling faces) could be more effective in preventing attentional capture by tobacco products.

Our finding that automatic orienting occurred only in goal-congruent conditions could also point to how graphic health warnings could be made more salient, and why unbranded packaging appears to increase the salience of the graphic warnings (Munafo et al. 2017). We found that searching for anything but an aversive image blocked interference from these aversive images. It may be that the branding information provides smokers with a non-aversive target feature to search for when they desire a cigarette, thus allowing avoidance of the graphic

Figure 20. Current unbranded tobacco packaging on the left (Department of Health, 2016), and proposed changes to packaging on the right. The graphic warning has been enlarged to cover the whole front of the packet, the salient competing coloured warning has been made less salient, and the text warning which provides information about the image content has been embedded in the image. These modifications were made in order to increase the need for smokers to tune attention to the aversive features of the graphic warning in order to detect the cigarettes.

warning (Maynard et al., 2014). Removing this non-aversive feature makes the graphic warning the main identifying feature of the packaging. Thus, the only way to intentionally detect the cigarette packaging is to voluntarily search for the graphic health warning, leading to greater exposure. A recommendation based on my findings would be to make the aversive cue the only salient identifying feature on the packaging, removing any other coloured warning labels which constitute a competing salient feature (see Figure 20 for example).

Conclusion

The current results suggest that top-down goals constitute a powerful driver of involuntary attention, which may account for previous findings of automatic orienting to both appetitive and aversive smoking cues. The magnitude of this effect does not appear to vary with smoking dependence; if a goal-driven mechanism underpins attentional capture by smoking images, then the differences may emerge under conditions in which participants are freer to select their own search goals, or when the distractors are task-relevant. Delineating the role of goal-driven mechanisms underpinning attentional capture by addictive substances allows the advancement of models of attention and addiction, but also the refinement and creation of health interventions.

Chapter 6: Testing an Importance-Expectancy model of attentional goal selection

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Abstract

There has been extensive research exploring how goal-driven attention operates, however the process determining the initial selection of attentional goals is understudied. I, therefore, propose a novel Importance-Expectancy account of attentional goal selection, in which the top-down prioritization of a particular object is jointly, but independently, predicted by the perceived importance of detecting the object as well as the expectancy of the object appearing in the current context. To test this model, we created a novel Concurrent Attentional Goal Task (CAGT), which forces participants to choose between two competing objects in order to rate relative importance, expectancy and priority. Experiment 1 revealed that individuals generally believe that both threat and reward associated images are attentionally important. Experiment 2 demonstrated that, consistent with the Importance-Expectancy model, the extent to which individuals rated threatening objects as being relatively important and expected jointly predicted the priority that the individual placed on searching for threat, in a given context. Follow-up analysis revealed that importance and expectancy similarly predicted other reward and neutral objects. A significant effect of context was found on both expectancy and priority: participants reported expecting threat objects more, and reported prioritising these objects more in a threatening context, versus a safe context. By contrast, there was no effect of context on perceived detection importance. The current results provide support for the hypothesised Importance-Expectancy model of attentional goal selection, and reveals how this model may operate in real-world contexts, through a contextual cueing mechanism.

In order to detect objects which are important to our current desires, concerns and intentions, we must be able to selectively attend to certain objects in our environment, whilst ignoring less important objects. For instance, if we are hungry then we should be able to detect food in our environment and ignore other less relevant objects in the background. Alternatively, if we feel unsafe we might wish to prioritise detection of any potential threats, and ignore other objects which could cause us to miss the potential danger. For this reason, we require a goal-driven attentional mechanism which directs attention to goal-relevant objects.

Typically, in cognitive experimental investigations, goal-driven attention is operationalised as the mechanism which results in the correct execution of the task instructions. For instance, when instructed to search for a coloured shape, the allocation of attention which results in the detection of this shape is often considered goal-driven; whilst any interference in

detection of this image is often considered independent of the current goal of the individual, and more reliant on bottom-up stimulus features (e.g. Theeuwes, 1992). This operational definition, however, may not be fully representative of how individuals would select attentional goals in real-world settings. As the examples above illustrate, attentional goals may often be internally generated without explicit external instruction. Curiously, despite decades of research elucidating how goal-driven attention operates when a goal is active (Folk, Remington & Johnson, 1992; Folk, Remington & Wright, 1994; Leber & Egeth, 2006; Eimer & Kiss, 2008; Eimer, 2015), the process by which attentional goals are selected has, to my knowledge, received no prior empirical consideration.

Importance – Expectancy Models of Motivation

One potential approach to exploring how attentional goals may be selected is to draw upon other areas of research. Specifically, research in social and motivational psychology has explored the factors which influence whether an individual pursues a behavioural goal; that is, what variables make an individual work to achieve one outcome over another competing outcome (see Braver et al., 2014 for review). For instance, in areas of social psychology, goal setting is often believed to be determined by the combined effect of expectancy of the goal's outcome and the value or importance of this outcome (Lewin, Dembo, Festinger & Sears, 1944; Gollwitzer, 1990; Locke & Latham, 2002; 2006). These models state that if an outcome is important to an individual, and the outcome is expected to be attainable, then an individual will select to pursue that goal over another competing goal, and will then take action in order to achieve that outcome.

This literature suggests that if a goal's outcome is not deemed important by the individual, then they are unlikely to pursue it. For instance, if a person finds an activity inherently rewarding then they will pursue that goal more than one which has been given to them by an external agent (Deci & Ryan, 2000). Additionally, if a desired outcome is unlikely to be achieved then the goal will be neglected in favour of a competing goal, for instance if an individual has repeated failures in completing a task they may select an easier goal (Locke & Latham, 2002; 2006). Broadly, these models have focused mainly on the social factors which influence the level of importance and perceived attainability (i.e. expectancy). Neurocognitive research further supports the notion that the value of a particular outcome is determined by a combination of importance and expectancy. Regions of the reward network, which encode the value of an outcome, are sensitive to manipulations not only of value magnitude (amount of financial reward) but also to the expectancy of the outcome (probability of the rewarding outcome; Knutson, Taylor, Kaufman, Peterson & Glover, 2005).

Despite the Importance-Expectancy model of goal setting being pervasive in other literatures (Braver et al., 2014), it has never yet been applied to explain how participants choose to search for goal-relevant objects. I, therefore, investigated whether this model could be applied

to *attentional* goal selection. Given the key role of expectancy and importance in the valuation of outcomes and behavioural goal pursuit, it appears plausible that these factors could also be implicated in setting top-down attention to search for the features which are associated with these outcomes.

The Importance-Expectancy model of attentional goal selection (see Figure 21) would suggest that the category of object which an individual voluntarily searches for is determined by its relation to the most important outcome that is expected in a situation. Specifically, if a goal outcome is very important to an individual, and this outcome is expected to occur imminently, then individuals will search for the features associated with this outcome. Also, based on existing models of expectancy and its interaction with attention, we suggest that expectancy is strongly related to the current context that the individual is in (Bar, 2004; Summerfield & Egner, 2009). We shall now review previous research which demonstrates these relationships in support of the Importance-Expectancy model.
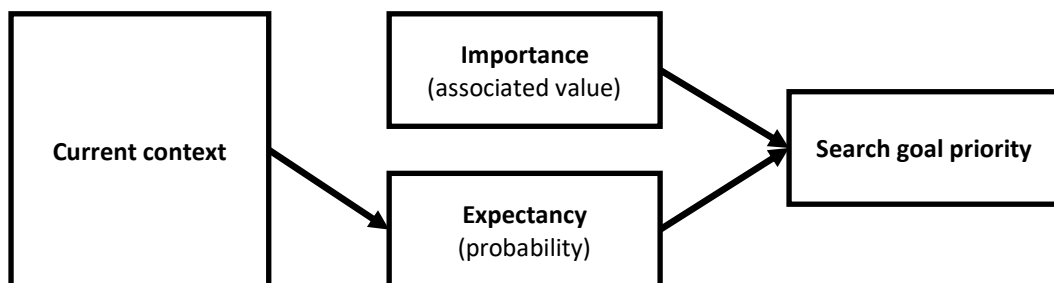
Figure 21. A hypothesised model between the variables measured within Experiment 1 and 2. It is predicted that context will increase the expectancy of objects which appear in that context appearing, and that this will increase the chance that participants will assume a search goal for them. I predict that importance of an object will not vary across contexts, and that the importance of an object will positively predict the chance that participants will prioritise that object as a search goal.

Importance and Attention

There is some existing evidence which could suggest that importance of an outcome could be implicated in the selection of a top-down search goal. First, attention is often directed towards stimuli which are associated with a valued or motivationally important outcome. For instance, in a visual search task, when participants are searching an array for an odd-one-out stimulus, threatening stimuli such as fearful faces, or stimuli previously associated with electric shock, grab attention and slow target detection (Hodsoll, Viding & Lavie, 2011; Schmidt, Beloposky & Theeuwes, 2015; for reviews see, Anderson, 2016; Chelazzi, Perlato, Santandrea & Della Libera, 2013). Additionally, a similar effect has been found for images which predict reward, such as food or smiling faces, or images which are associated with financial gain (see Pool et al., 2016 for meta-analysis).

Therefore, there is some level of allocation of attention to motivationally salient stimuli, such as these, despite no instructions to attend to them. Motivational salience in this context

refers to the attention-grabbing properties of a stimulus due to its affective, rewarding, or threatening associations. Some theories of attention suggest that this occurs in a stimulus-driven manner, whereby the motivational salience of the stimulus captures attention independent of the current intentions of the participant (Carretie, 2014; Öhman, 2005). Alternatively, recent research suggests that top-down factors such as task-relevance modulate this effect. Whereby if the motivational content of the stimuli is irrelevant to the task it no longer captures attention (Hahn & Gronlund, 2007; Everaert, Spruyt & De Houwer, 2013; Everaert, Spruyt, Rossi, Pourtois & De Houwer, 2014; Stein, Zwickel, Ritter, Kitzmantel & Schneider, 2009; Vogt, De Houwer, Crombez, & Van Damme, 2013; Lichtenstein-Vidne, Henik & Safadi, 2012; Vogt, Koster & De Houwer, 2017). This suggests that top-down factors may play a role in attentional capture by both threat and reward stimuli. More recently, it has been found within my own research that when individuals are instructed to search for a category of motivationally salient stimuli, such as alcohol in social drinkers, distractors which are congruent with this goal capture attention despite being irrelevant to the task (Brown, Duka & Forster, under review – Chapter 4). This is direct evidence that individuals' attention is involuntarily drawn to the features which are congruent with what the individual is currently searching for.

Interestingly, involuntary attentional capture by motivationally salient stimuli are larger in individuals who are more likely to regard these categories of stimuli as important. For instance, participants who report being trait anxious have been found to attend to threat more than low anxious individuals (Bar-Haim et al., 2007). Additionally, this effect is greatest for threatening stimuli which are relevant to their personal concerns, such as spiders in spider phobic individuals, or emotional faces in socially anxious individuals (Pergamin-Hight et al., 2015). It is plausible that an individual's current concerns could result in a goal to search for these stimuli, based on their importance to this individual.

Further evidence of this comes from associative learning research, in which individuals who have a history of consuming addictive substances preferentially attend towards stimuli which are associated with receiving drug reward; individuals who have not learned the association between these stimuli, and do not consider them important or valued do not preferentially attend to them (Field & Cox, 2008; Field et al., 2016). Furthermore, there is direct evidence that personal relevance leads to attentional prioritisation; telling an individual that a shape is associated with themselves leads to this shape capturing attention more than a shape which they are told is associated with a stranger (Sui & Humphrey's, 2012). In the current investigation, we generally characterise this personal relevance, learned value, or associated threat as importance. we suggest that these different factors converge and imbue a goal with 'importance' but are influenced by separate factors.

I note that traditionally, attentional capture by reward and threat has been seen as stimulus-driven, mainly due to the effect appearing involuntarily and interfering with task

instructions (Öhman, 2005; Öhman, Flykt & Esteves, 2001; Carretie, 2014; Bishop, 2008). There is evidence, however, that involuntary attentional capture can paradoxically occur as a consequence of voluntary top-down goals, not just stimulus-driven effects. For instance, it has been found across multiple investigations that when individuals are instructed to search for a feature of a target or a general category of stimuli in a relevant location, then stimuli in irrelevant locations which match this feature capture attention, as indexed by participants being slower to respond to a target, or make more errors in detecting a target. This occurs despite the distractors being irrelevant to the current task (Folk, Remington & Johnson, 1992; Folk, Leber & Egeth, 2002; Wyble, Folk & Potter, 2013; Eimer, 2015). Further, we have recently found that task-irrelevant motivationally salient distractors (i.e. threatening animals and emotional faces) only captured attention in an involuntary fashion when participants were searching for that category of image in a task-relevant location (Brown, Berggren & Forster, under review – Chapter 2). It, therefore, appears that the current goals of the individual could account for an involuntary attentional capture by motivationally salient stimuli.

In these previous tasks, participants were given an instructed goal, though it is also plausible that individuals would wish to deliberately search for these stimuli without instruction to do so, because they signal important outcomes which are relevant to current concerns. This importance could then lead the individuals to tune attention towards features which are associated with this important outcome. In the current investigation we shall aim to demonstrate that individuals perceive motivationally salient stimuli as important to detect.

Expectancy and Attention

Reviewing the previous literature, it appears that expectancy can influence the allocation of voluntary attention in response to an instructed search goal. For instance, there are several theoretical models which suggest that goal-driven attention is influenced by the expectancy of a target appearing (Corbetta & Schulman, 2000; Summerfield & Egner, 2009). These models suggest that prior expectations influence what goal-relevant features are searched for, where to search for these features, as well as making decisions regarding ambiguous perceptual information (Summerfield & Egner, 2009). These models, however, do not address how a search goal may be initially set, and instead focus on how an individual may use learned expectancies to guide an already active goal. In the current investigation, We focus on the novel idea that expectancy could be implicated in the motivation to begin searching for a particular object in the first place.

Predictive coding models' or 'Bayesian inference models' posit that through statistical learning, participants acquire expectancies of where to search for certain stimuli in order to respond to them (Rauss, Schwartz & Pourtois, 2011; Rauss & Pourtois, 2013; Chikkerur, Serre, Tan & Poggio, 2010). If a target consistently appears in one location over another, then participants are more likely to attend to that location in order to detect the target, and are slower

to detect it if it appears in an unexpected location (Geng & Behrmann, 2005). Further, if a symbolic cue signals the correct location of a target on a high proportion of trials then participants are likely to attend to the signalled location, but not when the same cue is an unreliable predictor of the target location (Posner, 1980). Therefore, it appears that individuals can learn probabilities in order to guide their top-down goals through their prior expectations.

Despite the main-stream attention literature not including the influence of expectancy on attentional goal-selection, the individual differences literature does appear to provide some indirect evidence that expectancy is implicated in attentional goal selection. Within the anxiety literature, it is well established that anxious individuals selectively attend to threat more than low anxious individuals (Bar-Haim et al., 2007). Interestingly, participants who report high levels of anxiety also exhibit a threat expectancy bias, whereby anxious individuals over-estimate the likelihood of a threatening outcome (Reiss, 1991). For instance, in children, those who exhibited anxious symptoms reported expecting negative outcomes to be more likely to happen, compared to children with fewer anxious symptoms (Suarez & Bell-Dolan, 2001). Additionally, spider phobic individuals reported expecting a spider to appear more in an imagined situation relative to other animals, whilst non-phobic individuals did not show this difference (Aue & Hoeppli, 2012). This raises the question of whether this heightened expectancy might contribute to the attentional capture effects.

Such expectancy biases are also influential in models of reward seeking behaviours; for instance, heavier drinkers reported expecting greater pleasurable outcomes and tension reduction compared to light drinkers (Rohsenow, 1983). Additionally, an expectancy bias has been implicated in risky gambling behaviour, where heavier gamblers expect to win more often in a gambling task compared to non-gamblers, and this resulted in riskier betting behaviour (van Holst et al., 2012b). Importantly, both heavy drinkers and problem gamblers have been found in separate investigations to exhibit involuntary attentional capture by disorder related imagery versus control images (Townshend & Duka, 2001; van Holst et al., 2012a), again raising the possibility that expectancy might be (partially) driving these biases.

More recently, the link between expectancy and the attentional capture has been directly explored (Aue & Okon-Singer, 2015; Sussman, Jin & Mohanty, 2016), but these studies failed to reveal any effect of expectancy on attentional capture. For instance, it was found that participants were no faster at detecting a spider target in a visual search task when they were given the instruction that the target was 90% likely to be a spider (or a bird), compared to a 50% chance that it would be a spider (or a bird; Aue, Chauvigne, Bristle, Okon-Singer & Guex, 2016). One reason for the lack of evidence of the association between expectancy and attentional capture may be that expectancy does not have a direct effect upon attentional selection. It may be, instead, that expectancy effects are mediated by top-down search goals. Meaning that expectancy may be related to attentional capture by threat, or other motivationally

relevant objects, but this only occurs because it prioritises the goal to search for the object. It could have been that in the previous investigation, both the 50% and 90% expectancy condition were sufficient to activate an equivalent search goal for the spider, versus the bird (Aue et al., 2016, see General Discussion for further explanation of this point).

Context and Expectancy

Models of attention which outline how expectancy could influence goal-driven attention cite the role of context in how participants deploy an already active search goal (Bar, 2004; Summerfield & Egner, 2009). For instance, when a search array is repeated across trials, participants learn the target location relative to the other non-target stimuli (Chun & Jiang, 1998). Thus, participants quickly learn relational information between a target and the context. This is true when using real-world scenes as well, for instance, participants searched the sky before the ground when instructed to search for aircraft despite appearing in both locations across the task (Neider & Zelinksy, 2006; see also Bar, 2004). Additionally, influential computational models of attention suggest that participants use a combination of stimulus salience and learned scene regularities to detect a target (Itti & Koch, 2000). It therefore appears that the context can encode the probabilities of what appears in a particular location, and that participants use this information to efficiently detect a specific target.

There has thus far been no direct evidence of contextual cueing of search goal selection within the attention literature. However, the relation between context, expectancy and goal setting is well established in other literatures. For instance, goal-priming research has revealed that health related cues in an environment can increase the chance that an individual will pursue health goals and reduce consumption of unhealthy food (Papies, 2016). Additionally, in both animal and human studies, drug seeking behaviour is greatest in environments which have been previously associated with receiving drug reward; and this occurs because the contextual cues in the environment increase the expectancy of receiving drug reward (Hogarth, Dickinson, Wright, Kouvaraki & Duka, 2007).

In the present investigation, we therefore predict that the context that participants imagine themselves in will increase the expectancy that a context related object will appear; and that the search goal for this object will also be greater in this congruent context, compared to when it is presented alongside an incongruent context. Specifically, we predict that in a threat associated context, participants will expect and prioritise dangerous objects more than rewarding or neutral objects. If supported then this contextual cueing model would provide a parsimonious mechanism that could explain how individuals can use top-down search goals for specific stimuli, in order to maximise automatic detection of relevant targets, but minimise the cost of missing another important stimulus in the environment.

The Present Study

In the current investigation, we shall explore how individuals may voluntarily choose to prioritise different stimuli of varying motivational relevance (threatening, rewarding or neutral), based on a proposed Importance-Expectancy theory of attentional goal selection. As in real life, in which attending to one object necessarily means attending less to other objects, we devised a forced choice rating task to establish goal-driven attentional priority. My first experiment tested whether the categories of motivationally relevant objects typically associated with attentional capture are rated as attentionally important. Specifically, participants were presented with pairs of objects and asked which object they would want to notice first if they encountered both objects in a room, simultaneously. To foreshadow the results, objects which posed an immediate threat were ranked as the most important to detect, whilst potential threat and rewarding stimuli were seen as less important to detect, but more important than neutral stimuli.

In a second preregistered experiment (osf.io/vxkc2), we tested whether the Importance-Expectancy model could predict the search goal priority of a specific object. We also wanted to determine the role of contextual cueing in this model. To test this, we instructed participants to rate the detection importance, expectancy, and search goal priority in two imagined contexts. It is expected that when a motivationally salient object is relevant to a context, then individuals will expect it more compared to a context where it is unrelated, and will prioritise it more as a search goal in the related versus unrelated context, but (based on the findings of Experiment 1) will not perceive it as more important to detect in the related context versus unrelated context. To do this we focused on threatening objects, due to their simple association with certain contexts. Specifically, the threatening objects should be prioritised as a search goal and expected more in the threat related context, and be less prioritised and less expected in the safe context.

Due to the previous evidence that there was individual variation in goal-driven behaviour for reward seeking and threat avoidance, we also measured two personality variables related to these behaviours. Primarily we were interested in the relationship between trait anxiety and the search goal for threatening objects, due to the evidence that these highly anxious individuals would find these stimuli important and/or expect them more in the environment (Bar-Haim et al., 2007). We also measured the behaviour activation system scale (BAS; Carver & White, 1994). This scale measures an individual's general reward seeking behaviour, and has previously been found to positively correlate with attentional capture by reward associated stimuli (Hickey, Chelazzi & Theeuwes, 2010). We therefore expected this variable to correlate positively with the search goal for rewarding objects, as well as the importance or expectancy of these objects.

Experiment 1

In Experiment 1wefocused on establishing the perceived attentional importance of various objects which may be encountered in daily life. We selected objects from different categories of affective stimuli which have been associated with attentional capture (see Pool et al., 2016; Bar-Haim et al., 2007). These categories were imminent threat (i.e. attacking dog, man with knife), potential threat (i.e. broken glass, warning sign), reward (i.e. phone, smiling face, money, food), and a control category of stimuli which were neutral (i.e. towel, chair).

The main aim of this task was to determine whether the affective categories which had previously been found to capture attention would also be reported as important to detect. we also hypothesised that some individuals would report some stimuli more important to detect than others; specifically, we expected that trait anxious individuals would report that imminent threat and potential threat were more important to detect than other objects, and that participants scoring high on the BAS subscale would report that detecting rewarding objects was more important than detecting other objects.

Methods

Participants. 239 participants responded to the online advert through the University of Sussex subject pool, of whom 213 participants completed the questionnaire. 28 participants were excluded for answering over half (> 5/11) reversed scored items with the previous unreversed item response. Of the remaining 185 participants, 150 were female and 35 were male. The average age of the participants was 19.86 ($SD = 4.52$). The sample size was determined by the number of participants who could be recruited over two academic terms. Participants were remunerated with partial course credit. Post-hoc power analysis using Gpower revealed that we had sufficient power to detect an effect of $\eta^2_p < .01$ with power at .80 (Faul, Erdfelder, Buchner & Lang, 2009).

Stimuli and procedure. Participants accessed the experiment using their own computer on campus or at home using Inquisit online testing software. They first read the consent page before completing the Concurrent Attentional Goal Task (CAGT). The CAGT was designed to test the relative importance individuals would place on detecting different motivationally salient objects, by placing them in opposition to each other. This simulates the competitive nature of the allocation of attention, where some objects must be suppressed in order to focus on a prioritised object. An example trial and all image types are presented in Figure 22. The different motivationally salient objects were selected so that they formed five specific categories. The categories were imminent threat (man with knife, attacking dog), potential threat (broken glass, flammable warning), neutral (chair, towel), and potentially rewarding object, in order to get a range of rewarding stimuli, four reward related images selected were selected desserts, money, smiling people, mobile phone). Four images were chosen instead of two, as with the other categories, in order to provide sufficient variety of reward related objects to

mimic the complexity of a real-world context. All images were the same across participants except for the smiling people, which varied depending on which gender participants reported being attracted to. Along with the age and gender demographic questions, participants were asked to say which gender they were most attracted to; the smiling face was the gender which they selected. Participants who responded with "I'd prefer not to answer" were shown a picture of a smiling man and woman.

All of these images were sourced from Google images, and were resized to 200 x 300 pixels. All tasks and images are available via the Open Science Framework (osf.io/vxkc2). As shown in Figure 22, these images were presented in pairs, one to the left, the other to the right; between the images was a visual analogue scale (VAS), and immediately below each image was an anchor phrase "I would want to notice this first". At the centre of the VAS is a phrase "no preference", whilst at the top of the screen was the question: "Which thing would you want to notice first in your environment?". All the possible combinations of the object pairs were presented (e.g. man with knife versus towel), this led to 45 different combinations of the 10 objects. The object pairs were presented in a random order, and the position of each of the objects in the pair was randomised.
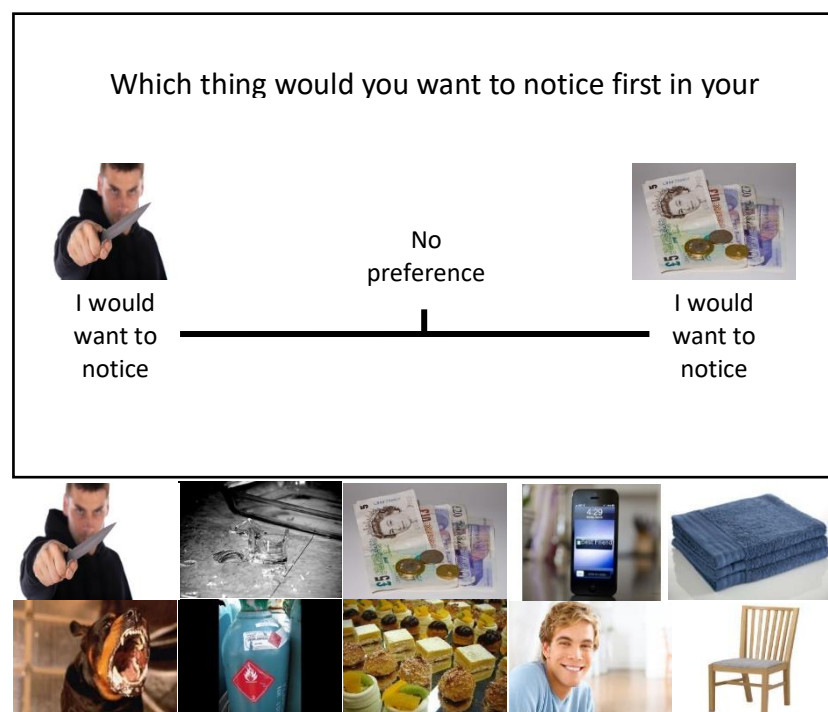
Figure 22. An example trial from the (CAGT) and all images presented in the task. The size and positioning of stimuli is approximate to how they appeared in the task. The images are ordered from left to right in their categories: imminent threat (knife, dog), potential threat (glass, warning), reward (money, food, phone, face), and neutral (towel, chair).

Prior to the CAGT, participants were given the following instructions: *"In this task, you will rate the priority of several objects which you could encounter in your environment. During the task, you will be shown two images on the left and the right of the screen. The images will be*

of things which could be important to your everyday goals and could be beneficial for you to notice quickly so you could respond to them. For each question, you should imagine that you are entering a room in which the two objects are present. You must compare these objects based on which you would want to notice first on entering the room, you do this by clicking along the continuous scale presented in the middle of the screen; if you would want to notice one object first then you would click on the scale closer to the image of that object. If you have no preference you would click in the middle of the scale. Please think carefully about how much you value each object and respond accordingly. You are encouraged to respond along the continuum, rather than responding just at the extreme ends of the scale. i.e. if you wanted to notice one object only slightly more than the other, you would click on the line closer to the middle, compared to if you wanted to notice one object a lot more than the other, in which case you would click closer to the preferred object."

CAGT Scoring. The dependent variable derived from the CAGT was the preference score for each category of object relative to each other category. This was computed based on how close the participant responded to an object, relative to the other objects, across trials. The closer the participant clicked to an object, the higher the preference score was on that trial for that object, and the lower the score was for the competing object; the score on each trial ranged from zero to 100. Across all trials the average relative score was computed for each individual object versus every other object. These scores were then averaged to form the overall category preference score. The intra-category comparisons were excluded from the category's average, e.g. the knife versus attacking dog comparison was excluded from the overall imminent threat average.

Image ratings. In order to confirm the intended valence of the images use in the CAGT, participants next rated each of the ten images presented in the CAGT along dimensions of attractiveness, positive, threatening, and negative. These four scales ranged from one to ten on a Likert scale. The images were presented in a random order.

Questionnaires. Finally, the participants completed two questionnaires, the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983) and the Behavioural Inhibition System/ Behavioural Activation System questionnaire (BIS/BAS; Carver & White, 1994). The STAI is a 40-item state and trait anxiety questionnaire, 20 items for state, and 20 items for trait anxiety (e.g. "I feel safe"). For state anxiety items, participants indicated how they were "feeling right now at this moment" in relation to these items. Whilst for trait anxiety items, participants indicated "how they generally feel" in relation to the items. Participants indicated how they felt along a four-point scale. The BIS/BAS is a 24-item scale measuring trait differences in general approach motivation and avoidance of punishment motivation. Participants had to indicate how relevant each of the items were to them, along a four-point scale. The activation system subscale was of interest in this investigation (e.g. "I

crave excitement and new sensations."). The order in which these two questionnaires were presented was randomised between participants.

Bayes factors. As well as using traditional significance testing methods, we also conducted Bayesian analyses in order to compare the strength of evidence in favour of the experimental hypothesis or the null hypothesis. A Bayes factor compares evidence for the *experimental hypothesis* and the *null hypothesis,* relative to the prior expected effect. The Bayes factor ranges from 0 to infinity, values less than 1 indicate that there is support for the null hypothesis, whilst values of greater than 1 indicate that there is support for the experimental hypothesis. The strength of this evidence is indicated by the magnitude of the Bayes Factor; values greater than three or less than .33 indicate substantial evidence for either the experimental or null hypothesis, respectively. A value closer to 1 suggests that the data is insensitive and that any result is due to insensitivity and is 'anecdotal' (Dienes 2008, 2011, 2014, 2016). The Bayes factor was computed using a modified version of Baguley and Kaye's (2010) R code (retrieved from Dienes 2008). The Bayesian priors are listed with each individual analysis.

Results and Discussion

Image ratings. Initial examination of image ratings confirmed that the categories were perceived as intended (see Table 14). A repeated measures ANOVA comparing the threat score across the four categories, revealed that there was a significant difference across the categories of stimuli, $F(2.19, 403.45) = 1942.83$, $p < .001$, $\eta^2_p = .91$ (Huynh-Feldt corrected). Imminent threat was perceived as more threatening than potential threat, $t(184) = 22.01$, $p < .001$. Potential threat was also rated as more threatening than neutral stimuli, $t(184) = 34.27$, $p < .001$. Thus, the threatening stimuli were perceived as intended. Additionally, the reward images were rated as more attractive and positive relative to the neutral images, $t(184) = 22.15$, $p < .001$; $t(184) = 18.78$, $p < .001$, respectively.

	Image ratings			
	Threatening	Negative	Attractiveness	Positive
Imminent threat	8.73 (1.25)	8.45 (1.5)	1.68 (1.41)	1.48 (.91)
Potential threat	5.75 (1.82)	5.95 (1.85)	1.73 (1.21)	1.69 (1.03)
Neutral	1.19 (.64)	1.4 (.91)	3.61 (2.16)	4.26 (2.26)
Reward	1.53 (.79)	1.82 (.97)	6.96 (1.55)	7.26 (1.39)

Table 14. Mean ratings of the different categories of images along dimensions of how threatening, negative, attractive, and positive the images were perceived. Ratings were along a ten-point likert scale. Standard deviations are presented in brackets.

Overall CAGT results. An initial repeated measures ANOVA with imminent threat, potential threat, reward, and neutral categories as the levels was conducted. This revealed a highly significant effect across the categories, $F(1.49, 274.28) = 186.4$, $p < .001$ (Greenhouse-

Geisser corrected), 95% CI [25, 29.54], $\eta^2_p = .5$. As can be seen in Figure 23, the overall pattern of results reflected different levels of importance in detecting each of the four categories, with imminent threat receiving the most preference and neutral stimuli being preferred the least.

Comparisons between different object importance. Bayesian pairwise comparisons between imminent threat, potential threat, or reward versus the neutral objects were computed. Due to the lack of prior knowledge regarding the size of this effect uniform prior was set (signified as B_U), a plausible effect size of 80 was selected to compare imminent threat to neutral object, this was judged by myself to be a large effect on this scale, lower bound set to zero. Whilst comparisons between potential threat versus neutral, and reward versus neutral, were set to a plausible effect size of 50 which is a smaller but still substantial effect based on the current scale, with the lower bound set to zero. we were uncertain of the direction of the difference between potential threat and reward, We therefore set a two-tailed hypothesis with the lower bound set to -20 and the upper bound set to 20. These effect sizes were selected by myself based on what was judged to be a suitable effect, the data and script are available to the reader for potential reanalyses with different priors.
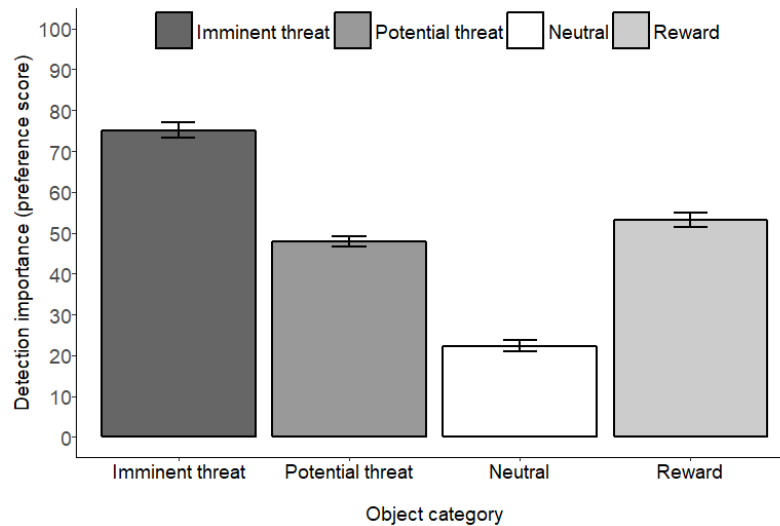
Figure 23. Plot displaying the mean detection importance scores for each of the four categories of stimuli. The scores are centred on zero which signifies no preference or avoidance. Error bars depict within-participants standard error.

Follow-up t-tests revealed that imminent threat was rated as more important to detect in the environment than neutral objects or potentially threatening objects, $t(184) = 19.15$, $p < .001$, $B_{U[0,80]} = 3423814 \times 72$; $t(184) = 18.07$, $p < .001$, $B_{U[0,50]} = 5964428 \times 63$, respectively. It was also rated as more important to detect than the reward associated objects, $t(184) = 27.88$, $p < .001$, $B_{U[0,50]} = 121240512901$. Therefore, imminent threat was the category clearly seen as the most important to detect. Potential threat was also rated as more important to detect than neutral stimuli, $t(185) = 12.35$, $p < .001$, $B_{U[0,80]} = 8927185 \times 25$, as was the reward associated category, $t(185) = 27.88$, $p < .001$, $B_{U[0,80]} = 1916186 \times 161$. Therefore, the motivationally salient objects

were still seen as more important to detect than objects which were not strongly linked to a motivational outcome (i.e. towel, chair). The difference between potential threat and the reward category was the smallest, though reward was seen as slightly more important to detect than potential threat, $t(185) = 2.14$, $p = 034$, $B_{U[-20, 20]} = 1.51$, however the Bayes factor suggested an inconclusive effect, despite being consistent enough to reach significance.

Relationships between importance and individual differences. In order to investigate whether there was any relationship between anxiety, or reward seeking behaviour, and the importance in detecting threatening objects, we correlated trait anxiety and the overall BAS score with each of the detection importance scores. To determine whether these relationships favoured the experimental hypothesis or the null hypothesis, we computed Bayes factors using a uniform distribution where small effects are equally likely as large effects. Based on guidelines for the magnitude of effect size reported by Cohen (1988), we expected a effect size ($r = .5$), therefore, we used an upper expected effect of .55 which was the fisher transformed effect size.

	Imminent threat	Potential threat	Neutral	Reward
Trait anxiety	-.07	.03	-.03	.07
BAS	.04	.1	-.02	-.09
Imminent threat	-	.56**	-.83**	-.83**
Potential threat		-	-.56**	-.86**
Neutral			-	.58**
Reward				-
	Bayes factors			
Trait anxiety	.09	.23	.13	.41
BAS	.29	.72	.14	.08

Table 15. Correlation coefficients between the different detection importance scores. p < .05 = *; p < .001 = **. Bayes factors are also presented. Bayes factors above 3 signifies substantial evidence favouring the experimental hypothesis, a Bayes factor below .33 denotes substantial evidence favouring the null hypothesis.

As can be seen in Table 15, and contrary to my predictions, the correlations suggest that there was strong evidence for the null hypothesis signifying no relationship between trait anxiety and self-rated attentional importance of imminent threat and potential threat. To conclude, trait anxiety did not correlate with detection importance of either potential or imminent threat, and there was evidence favouring the null hypothesis across all correlations; therefore, against expectations, trait anxious individuals do not consider threat as more important to detect than low trait anxious individuals in the current task. Similarly, there was no significant relationship between reward detection importance and BAS score, and Bayes factors favoured the null hypothesis for this relationship.

The inter-dependent nature of the current dependent variable means that an increase in priority of one variable results in the inherent de-prioritisation of another variable; thus, strong

correlations are unavoidable. What these correlations do show is the direction of the competition between the categories. The data suggests that there is a divide between the categories, with both threat related categories positively correlating, and both non-threatening categories positively correlating. These relationships suggest that some groups of objects were rated according to their affective associations, although the exact pattern is too complex to draw strong conclusions.

Experiment 2

The results from Experiment 1 indicate that, overall, individuals' self-reported voluntary attentional goals generally corresponded to the same stimuli that are known to capture attention in experimental tasks (Carretie, 2014; Pool et al., 2016). More specifically, potential threat and reward received a moderate level of prioritisation, suggesting that participants did believe these objects to be important to detect. However, relative to imminent threat, these objects were considered substantially less important to detect.

The result of Experiment 1 is unsurprising; however, it was important to confirm this result as it is a necessary piece of evidence for the goal-driven account of attentional capture by motivationally salient stimuli; individuals would have to consider these stimuli important to detect in order to adopt an intentional search goal for them. However, a model of attentional goal selection, based purely upon importance, would predict that individuals would search for imminent threat across all contexts and potentially miss other important motivationally salient stimuli. For instance, if an individual was always searching for an attacking dog across every situation, even known safe situations such as home, then this would reduce the ability to focus on work or leisure.

Unlike the task in Experiment 1, in daily life individuals do not typically know exactly what objects are in an environment and must rely on prior expectations of what may appear there; therefore, based on previous evidence, individuals may select a search goal based on both the importance and the expectancy of an outcome (see Figure 21). In Experiment 2, we therefore pre-registered and tested this Importance-Expectancy model of attentional goal selection (osf.io/vxkc2). In order to test it we adapted the CAGT to include forced choice response questions to measure expectancy and search goal priority, not just detection importance. we also added a contextual element to the task, thus resulting in the Contextual-CAGT (C-CAGT). This adapted version of the task required participants to make the ratings whilst imagining themselves within two separate contexts, one a threat associated context (dark alley) and another a safe context (safe office).

I believe that the imagined context would be influential over whether a specific goal would be prioritised, such that if a goal was associated with the current context then it would be more likely to be prioritised than in the context less related to the goal. This contextual cueing effect would provide a suitable mechanism that would allow participants to effectively search

for the most likely outcome in a given context, thus allowing them to effectively pursue a single goal at a time without having to divide attention across multiple important objects.

In Experiment 1,we found that there was evidence suggesting an absence of individual differences in the importance rating of the objects. It may be, that individual differences in anxiety or reward seeking are correlated with expectancy, rather than importance. For instance, all individuals may believe that threat is equally important to detect, but trait anxious individuals may expect it to appear more. Indeed, anxious individuals do appear to exhibit an expectancy bias for threat, thus making this a good candidate for explaining individual differences in search goal priority (Reiss, 1991; Sussman et al., 2016). I, therefore, expect that high trait anxious individuals will show a positive relationship with the expectancy that threat will appear and search goal priority of threatening objects. It is unclear whether this will occur across both contexts, in which case this would suggest that anxious individuals have a general top-down goal for threat. It could appear just in the threat associated context, in which case it would suggest that anxious individuals are sensitive to cueing effects from threat cues; or alternatively, trait anxiety could positively correlate with threat prioritisation and expectancy just in the safe context, which would suggest that anxious individuals are poorer at learning safety context cues.

Methods

Participants. In total, 265 participants responded to the online advert. 220 participants completed the whole experiment. The total time spent on the instruction pages was recorded, based on the distribution of these times, 9 participants were excluded for being over 2 SD's on this measure which suggests poor attention or comprehension. An additional 11 participants were excluded for answering over 5/11 reversed scored items with the previous unreversed item response on the STAI (Spielberger et al., 1983). Testing was continued until a total of 200 usable participants were recruited. A total of 109 participants were female, 88 were male, and 3 reported 'other' as their gender. The average age of the participants was 36.99 ($SD = 11.97$). Post-hoc power analyses revealed the final sample size had sufficient power to detect a minimum effect of $\eta^2_p = .01$ within the interaction term, with a power of $1-\beta = .80$ (Faul et al., 2009). Participants were asked their demographic details at the start of the task, after the consent procedure. In addition to age and gender, participants were asked their level of education, employment, and nationality; they were no longer asked which gender they were attracted to most.

Stimuli and procedure.

Contextual – CAGT (C-CAGT). All trials of the C-CAGT were similar to Experiment 1, with the following exceptions, see Figure 24 for an example trial and the selected stimuli. As in Experiment 1, all images were presented either side of the screen in pairs, with the VAS presented in between them. we selected five images from the ten presented in Experiment 1, in

order to avoid an excessively long task duration. The images selected from the range of categories of threat, reward, and neutral, specifically, broken glass, man with knife, towel, money, and phone. Image selection was based primarily on the threat and attractiveness ratings in Experiment 1. The man with a knife and the broken glass were selected because they were rated the most threatening from the imminent and potential threat categories. The phone and money images were selected because they were less reliant upon subjective judgments or current state, whilst the perception of facial attractiveness and food would be more variable. Objects which were actually present in the context scenes weren't selected, meaning that faces and chairs were excluded because they were visible in the scene. In this version of the task, a contextual cue was presented at the top of the screen – this could either be a threatening context or a safe context. For the threat context we selected an image of a dark alleyway at night, for the
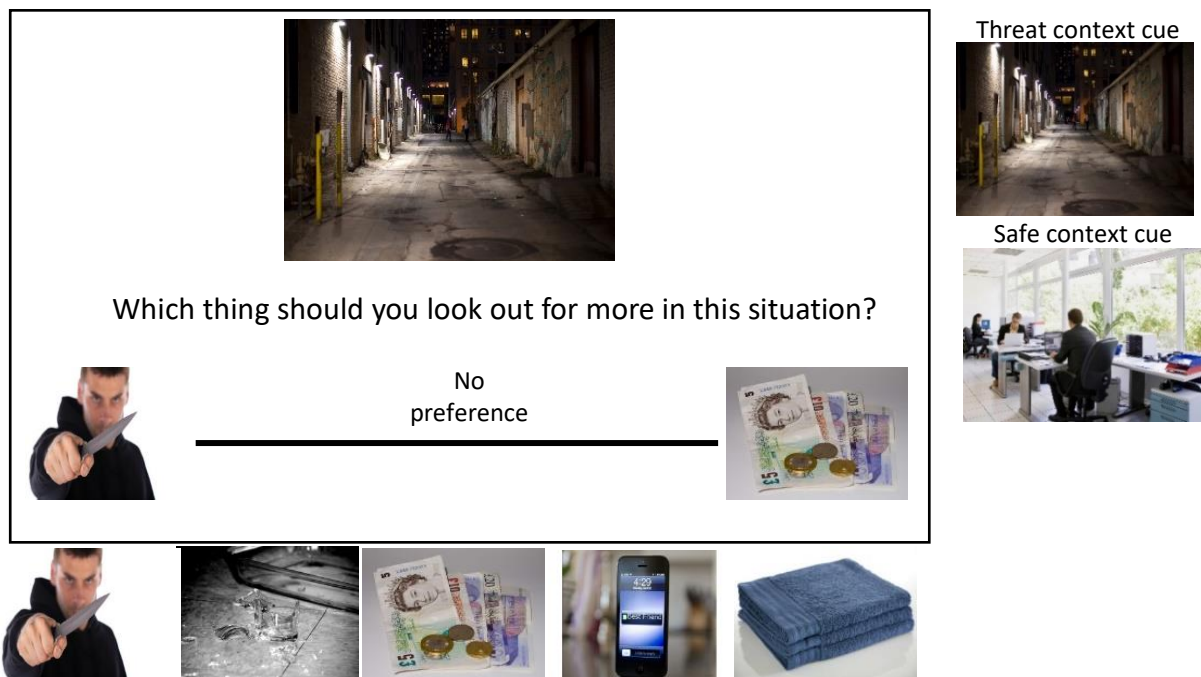
Figure 24. An example trial from the Contextual-Concurrent attentional goal task (C-CAGT) and all images presented in the task. The two possible context images are presented to the right of the trial frame and depict the threat alley context (above) and the safe office context (below). The contextual cue in this situation is a threatening context (dark alley). The size and positioning of stimuli is approximate to how they appeared in the task. The object images are ordered from left to right in their categories: imminent threat (knife), potential threat (glass), reward (money, phone), and neutral (towel). On the example trial participants are asked to rate their search goal priority. The other questions which were presented were expectancy: "Which thing would you most expected to find in this situation?"; and importance: "If both things were present in this situation which thing would you want to notice first?". These were presented in the same location as the search goal priority question.

safe context we selected an office with people working. The question for that block was presented in the centre of the screen.

There were three different blocks presented across the task each measuring a different aspect of attention. These blocks measured search goal priority, expectancy, and detection

importance; each block only differed in the question which was asked, see below. The threat and safe context cues appeared in each block, sequentially, their order was randomised within the block. Within each context there were ten trials, one for each combination of the object pairs (e.g. broken glass vs money). Therefore, there were 20 trials per block, and 60 trials overall. The order of these blocks was randomised between participants.

C-CAGT-Priority. The block began with an instruction of what the question for that block would be: *"In this block you must imagine yourself in the situation presented at the top of the screen. You will be asked: 'WHICH THING SHOULD YOU LOOK OUT FOR MORE IN THIS SITUATION?'"*

Below this instruction was an image of an example trial, in which the context was a park, the image pair was a growling dog and an ice cream van. Further details of the question and response were given below this: *"Your task in this block is to imagine yourself in the situation depicted at the top of the screen, and then answer the onscreen question with respect to the images on the left and right. Use your experience and knowledge of each situation in relation to the two things to make your decision. In this case, you must report which object you think you should be vigilant for in the specific situation when neither object is guaranteed to be there.*

Participants were also given more general information about the possible range of responses, using the example context and image pair as guide: *You must use your beliefs and experiences of the situation and both objects to answer this question. For instance, for the example screen above you would imagine yourself in a park and judge whether you should look out for ice cream van or a scary dog more. If you think you should look out for the scary dog more than an ice-cream van when you are in the park then you would click on the line closer to that image; the closer you respond, the greater preference you are showing for that object. If you think both things should be looked out for equally in the specific situation then you would respond in the middle of the line. You are encouraged to use the whole of the line to indicate the extent to which you should look out for one object over the other".* Following the instructions, participant completed the concurrent choice for each combination of the 5 images presented once, in a random order.

C-CAGT-Expectancy. The expectancy block began with the instruction: *"In this block you must imagine yourself in the situation presented at the top of the screen. You will be asked: 'WHICH THING WOULD YOU BE MORE LIKELY TO FIND IN THIS SITUATION?'"*. The same example trial image was presented again (i.e. park context). Below which another set of detailed instructions was presented: *"Your task in this block is to imagine yourself in the situation depicted at the top of the screen, and then answer the onscreen question with respect to the images on the left and right. Use your experience and knowledge of each situation in relation to the two things to make your decision. In this case you must report which object you*

think is more likely to appear in the specific situation, based on your beliefs and experiences of that situation." Participants were given near identical instructions on how to respond in the example context, before continuing to the concurrent choice stage for that block.

C-CAGT-Importance. The importance block began with the instruction: "*In this block you must imagine yourself in the situation presented at the top of the screen. You will be asked: IF BOTH THINGS WERE PRESENT IN THIS SITUATION, WHICH WOULD YOU WANT TO NOTICE FIRST?"*. Again, the same example image appeared, and below more detailed instructions were given: *"Your task in this block is to imagine yourself in the situation depicted at the top of the screen, then to answer the onscreen question with respect to the images on the left and right. Use your experience and knowledge of each situation in relation to the two things to make your decision. In this case you must report which object you think is more important to notice first when they appear at the same time and at a similar distance. This does NOT refer to which one you would prefer to be present, because both object simultaneously appear in the situation."* Participants were given near identical instructions on how to respond in the example context, before continuing to the concurrent choice stage for that block.

Image ratings. The image rating was completed after the C-CAGT task, and was identical to Experiment 1, with the exception that only the five objects and two context cues were rated on how attractive, positive, threatening, and negative they were.

Questionnaires. The questionnaires were presented after the image rating task. Due to the BIS/BAS being a secondary hypothesis, we presented this measure second to the STAI in order to decrease any between subject noise due to possible questionnaire order effects.

C-CAGT scoring. The dependent variable derived from the C-CAGT was very similar to the measure in the CAGT. In this version, however, participants completed the relative response for each of the three different questions (importance, expectancy, priority) in the safe and threat contexts. The scores for the threatening objects were created from the average of the comparison scores between man with knife versus every other non-threatening object, and broken glass versus every other object; the comparison between the knife and broken glass was not included in this average. The average threat score was created by averaging the knife and broken glass scores together.

Results and Discussion

Pre-registration. We pre-registered all analyses prior to data collection, further, all analyses scripts and datasets are available online via the OSF (osf.io/vxkc2). In order to avoid over-testing, we focused specifically on the threatening objects, these being the man with a knife and the broken glass. Further, focusing on the dangerous objects allowed me to manipulate the contextual cueing, with threat congruent contexts providing a clear signal of danger. All analyses which were not pre-registered are reported as *exploratory*. Additionally,

Bayes factors for correlations and regression analyses were not pre-registered, though we provide detailed information regarding the computation of these values.

Bayes factors. Bayes factors were calculated for all pair-wise comparisons, correlations, and regression analyses, in order to determine whether any non-significant effects were true null effects. To compute the Bayes factor for pairwise comparisons, we used a half-normal distribution (signified by B_H), with a mean of zero difference, which estimates a directional hypothesis with in which a smaller difference is more probable than a large difference. The standard deviation of this distribution is reported a long with the results, and was set according to the highest plausible effect size based on existing evidence taken from Experiment 1 and pilot data conducted on a small sample of participants (n = 38; see OSF for data osf.io/vxkc2). Conversely, due to the lack of knowledge about the size of the expected relationship between variables, we computed Bayes factors for correlations and regression analyses using a uniform distribution. All Bayes factors were one tailed, that is, expecting that a threatening object would be to be preferred in a threatening context versus a safe context, and expecting a positive relationship between the priority, expectancy, and importance preference scores, and also expecting a positive relationship between trait anxiety and these variables. The selection of the prior expected effect for these Bayes factors is outlined within the specific analyses.

Manipulation check. There was a significant difference between the threat ratings of the office context and the threatening alley context $M = 1.58$, $SD = 1.1$ vs $M = 7.38$, $SD = 2.24$ on threat rating, $t(196) = 33.76$, $p < .001$. In fact, only one participant reported the alley being less threatening than the office. Thus, the ratings confirmed that the contexts were perceived as intended.

Context effects on threat priority. See Figure 25 for a plot of mean values. we conducted a 2x2 repeated measures ANOVA with context (office/ alley) and object (knife/ broken glass) as factors. The relative priority of the objects was the dependent variable. This revealed, as pre-registered, that the alley context resulted in higher relative priority of threatening stimuli than when they were presented in the safer office context, $F(1,199) = 614.52$, $p < .001$, $\eta^2_p = .76$. Participants reported a higher relative priority score of the knife compared to the broken glass, $F(1,199) = 359.63$, $p < .001$, $\eta^2_p = .64$. Additionally, there was a significant interaction between the context and the object, $F(1,199) = 964.24$, $p < .001$, $\eta^2_p = .83$, whereby the increase in the priority of the knife was greater than the broken glass in the threatening alley. Planned comparisons revealed that the interaction was driven by a significant increase in priority of the knife in the threatening alley, relative to the safe office, $t(199) = 34.32$, $p < .001$, $B_{H[0, 50]} = 1682524 \times 10^{247}$. As well as the broken glass, $t(199) = 9.94$, $p < .001$, $B_{H[0, 50]} = 2219491 \times 10^{13}$.

Figure 25. Plot displaying the mean search goal priority for both the knife and the broken glass, relative to other objects, across the threatening context and safe context. Positive scores signify priority of searching for that object, negative scores signify avoidance. Error bars represent within-subjects standard error.

Context effects on threat expectancy. See Figure 26 for plot of mean values. The same analysis was conducted on the relative expectancy of the broken glass and knife across both contexts. This revealed that the relative expectancy of the objects appearing increased in the threatening alley context, $F(1, 199) = 833.03$, $p < .001$, $\eta^2_p = .81$. Additionally, participants reporting a higher relative expectancy for broken glass compared to the knife, $F(1, 199) = 88.03$, $p < .001$, $\eta^2_p = .31$. Though this did not differ between contexts, $F(1, 199) = .61$, $p = .440$, $\eta^2_p < .01$, with the difference in expectancy across contexts being approximately equal for both knife and glass.

There was a significant increase in relative expectancy in the threat context versus the safe context for both the broken glass, $t(199) = 25.78$, $p < .001$, $B_{H[0, 50]} = 9504816 \times 10^{117}$ and the knife, $t(199) = 24.12$, $p < .001$, $B_{H[0, 50]} = 1031107 \times 10^{136}$.

Figure 26. Plot displaying the mean expectancy that a man with a knife and the broken glass would appear in the threatening context and safe contexts, relative to the other objects. Positive scores signify that the object was expected more than other objects, negative scores signify that the object was expected less than other objects. Error bars represent within-subjects standard error.

Context effects on threat importance. See Figure 27 for plot of mean values. As predicted by my hypotheses, participants reported no significant difference between the relative importance of the objects in the threatening alley relative to the safe office, $F(1, 199) = .07$, $p = .79$, $\eta^2_p < .001$. Though the knife was reported to have greater relative importance than the broken glass, $F(1, 199) = 163.44$, $p < .001$, $\eta^2_p = .45$. Against expectations, there was a significant interaction between object and the context, $F(1, 199) = 8.35$, $p = .004$, $\eta^2_p = .04$, with the knife having slightly higher importance in the threatening alley context, relative to safe office context. Whilst the opposite was true for broken glass which had slightly higher importance in the safe office context. The η^2_p suggested that this reflected only a small effect, further, planned comparisons revealed that the importance rating for the broken glass did not significantly differ between the two contexts, $t(199) = 1.59$, $p = .112$, $B_{H[0, 50]} = .01$. Additionally, there was no significant difference between the two contexts for the knife rating, $t(199) = 1.62$, $p = .107$, $B_{H[0, 50]} = .19$. Due to testing for a null hypothesis, rather than for a known effect, we repeated the Bayesian pairwise comparison for importance ratings with a uniform distribution. This did not change the interpretations of the results for either the knife or the glass object, $B_{U[0, 50]} = .02$, $B_{U[0, 50]} = .18$, respectively. It therefore appears that context had only a very weak effect upon the importance of the objects.

Figure 27. Plot displaying the mean detection importance of the knife and the broken glass in the threatening context and safe context, relative to the other objects. Positive scores signify that the object was important to detect relative to other objects. Error bars represent within-subjects standard error.

Testing the Importance-Expectancy model of attentional goal selection. To investigate the relationship between priority, expectancy and importance, we conducted a linear regression using the average relative priority, expectancy, and importance scores of both the knife and the broken glass. This allowed us to investigate the general relationship of these variables across the threatening stimuli. We predicted that the priority of searching for threat would be jointly, and independently, predicted by both the importance and expectancy of threat in a given context. we therefore entered the priority of threat as the outcome variable, and expectancy and importance as predictor variables. This model was computed separately for each context. This revealed that in the threatening alley context, the hypothesised model was significant, $R^2 = .10$, $F(2, 199) = 11.34$, $p < .001$, with the expectancy of a threatening object appearing predicting an increase in priority of searching for threatening object, $\beta = .22$, $t(199) = 3.23$, $p = .001$, CI 95% [.07, .32] (see Figure 28 for scatterplots). Further, the reported importance of detecting threatening objects also predicted an increase in the prioritisation of searching for threatening object, $\beta = .26$, $t(199) = 3.8$, $p < .001$, CI 95% [.04, .37]. In the neutral context, however, the hypothesised model was non-significant $R^2 < .01$, $F(2, 199) = .41$, $p = .668$. It therefore suggests that expecting a threatening object to appear and the importance in detecting threatening objects only predicted attentional priority for threatening objects when participants imagined being in a threat associated context.

In order to further test the predictive ability of detection importance and expectancy on search goal priority, across all objects, we conducted exploratory linear regressions for each object in each condition, this produced ten regression models (Table 16). Each object's score was the average of all the comparisons between that object and every other object for a
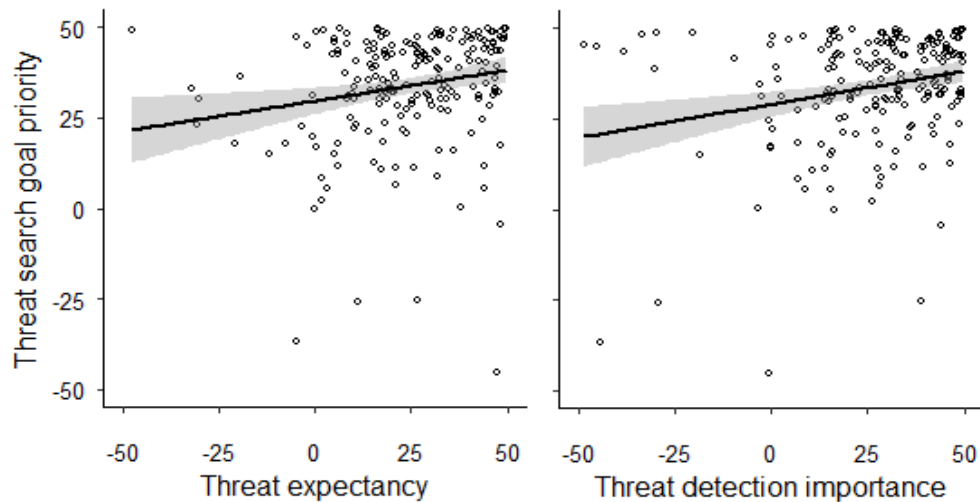
Figure 28. Scatterplots present the relationship between threat search goal priority and threat expectancy ($r = .20$), and priority and threat detection importance ($r = .24$), both in the threatening alley context. Standard error is presented in as error bands.

particular question in a context. This meant that the glass and knife scores were re-scored so that the average included the competition between these two objects. To supplement these analyses, we computed Bayes factors to determine the strength of evidence in favour of a positive predictive relationship between expectancy and search priority, and importance and search priority, versus a null effect. Further, the Bayesian analyses are less susceptible to effects of over testing, due to

the interpretation being based on the magnitude of evidence, rather than an absolute significance value (Dienes, 2014). The Bayes factors were computed using the unstandardized coefficients as the raw effect size, and the standard error of these coefficients. Due to the lack of prior knowledge of the exact effect size, we used a uniform distribution with the lower bound set to zero, and the upper limit set to the plausible effect size of 1. This effect would indicate that a single unit increase in either expectancy or detection importance would directly predict a single unit increase in search goal priority, this is a suitable selection due to the variables using the same scale.

Eight out of ten of these exploratory regression models were significant (seven out of ten after a conservative Bonferroni correction for ten tests), with both expectancy and detection importance significantly predicting search priority in all of the significant models (Table 16). Bayes factors revealed evidence in favour of the experimental hypothesis in all of these cases (B > 1). This occurred across both contexts, though interestingly, the only non-significant regression models were for the broken glass and man with knife images in the safe context. Bayesian analyses suggested that for the knife image importance was not predictive of search priority, but expectancy favoured a positive association, although this was inconclusive. Whilst for the broken glass, expectancy wasn't predictive of search priority, and importance was inconclusive. The pattern of results therefore suggests that the Importance-Expectancy model is

highly predictive of search goal priority across multiple contexts for both rewarding, neutral, and threatening objects; but that in a safe context the relationship is altered for threatening objects, and that it may potentially vary between potential threatening objects, and objects which pose an imminent threat.

		Threat context				Safe context			
		R^2	β	p-value	Bayes Factor	R^2	β	p-value	Bayes Factor
Knife	E	.08**	.22	.001	23.00	.02	.14	.053	2.17
	I		.19	.006	7.23		.02	.803	.16
Glass	E	.15**	.21	< .001	81.60	.02	-.02	.804	.09
	I		.26	< .001	6848.30		.13	.071	.96
Towel	E	.18**	.27	< .001	541.25	.08**	.18	.013	4.33
	I		.28	< .001	1184.89		.18	.013	4.11
Money	E	.09**	.21	.002	23.71	.07**	.17	.018	3.81
	I		.20	.003	11.96		.20	.005	10.47
Phone	E	.10**	.19	.005	9.70	.05*	.14	.043	1.87
	I		.24	< .001	86.72		.17	.015	4.74

Table 16. The regression analyses for each of the objects across both contexts. R^2, Standardised coefficients, p-values, and Bayes factors are presented from each linear regression. Search goal priority was the dependent variable, and was predicted by detection importance (I), and expectancy (E). $p < .001$ = **, $p < .05$ = *. Bayes factors above 3 signifies substantial evidence favouring the experimental hypothesis, a Bayes factor below .33 denotes substantial evidence favouring the null hypothesis.

Individual differences in contextual cueing effects. In order to investigate whether an increase in prioritisation of searching for threat in the threatening alley, relative to the safe office context, was predicted by an increase in expectancy or importance, we repeated the regression but with the subtraction score between the contexts. That is, we subtracted the priority, expectancy, and importance scores in the safe context from the same scores in the threatening context. A higher score from this subtraction denotes a greater increase in threat preference in the threatening alley context versus safe office context. A linear regression with expectancy and importance predicting priority revealed an overall null effect, $R^2 = .01$, $F(2,199) = .62$, $p = .539$. Rather, the strong within-subject effect of context on expectancy and priority appeared consistent across individuals.

The role of anxiety in goal selection. In order to determine whether there was any influence of anxiety on expectancy, importance, or priority of threatening objects, we correlated these variables with trait anxiety, in both threatening and neutral contexts. This revealed null effects across the threat associated condition as well as the neutral condition. Bayes factors were computed to determine the sensitivity of any null effects that were found. Based on the absence of effects in Experiment 1, wereduced the prior to a moderate effect size ($r_z = .31$; Cohen, 1988) with a uniform distribution centred on zero effect.

As can be seen in Table 17, the correlation coefficients between trait anxiety and priority, expectancy and importance variables were all small and non-significant. Additionally,

the Bayes factors revealed that the majority of the correlations favoured the null hypothesis. There was a near sensitive null finding for the relationship between anxiety and attentional goal priority in the threatening context, and a sensitive null for priority in the safe context. For expectancy, there was a sensitive null finding in the threatening context, and an insensitive Bayes factor in the safe context, this was the only effect to favour the experimental hypothesis (Bayes factor > 1). For detection importance there was a sensitive null finding in both the threatening and safe contexts, thus replicating Experiment 1.wenote there were also no correlations between trait anxiety and any measure of the effect of context on priority, importance or expectancy (see Table 17).

	Threatening alley context			Safe office context			Difference between contexts		
	Priority	Expectancy	Importance	Priority	Expectancy	Importance	Priority	Expectancy	Importance
Trait anxiety	.02	-.04	-.03	-.03	.11	-.03	.04	-.1	< .01
Priority	-	.19**	.24**	-	.03	.05	-	.08	.02
Expectancy	-	-	-.1	-	-	-.05	-	-	-.04
Importance	-	-	-	-	-	-	-	-	-
Trait anxiety	.36	.19	.22	.22	1.73	.22	.48	.12	.3

Table 17. correlation coefficients for the relationships between trait anxiety, detection importance, expectancy, and search goal priority, in the threatening alley context, safe office context, and the difference between these two contexts (threat minus safe scores). $p < .001 = **$, $p < .05 = *$. Bayes factors are reported for the relationship between Trait anxiety and the different preference measures, the prior for this effect was a moderate effect size of $r_z = .31$. Bayes factors above 3 signifies substantial evidence favouring the experimental hypothesis, a Bayes factor below .33 denotes substantial evidence favouring the null hypothesis.

General Discussion

The present findings represent the first empirical exploration, to my knowledge, of the factors determining attentional goal selection. The aim of the current investigation was to determine whether a specific Importance-Expectancy model of attentional goal selection can account for how a top-down search goal could be selected. Until now, the actual question of search goal selection has not been investigated. The current results supported the proposed model and indicated that the explicit search goal priority for various motivationally salient and neutral objects could be accounted for by the independent effects of the perceived importance of detecting an object, and the expectancy that the object would appear in a specific setting.

I also revealed a highly significant effect of contextual cues on both priority and expectancy of threat objects. This effect of cues on expectancy is somewhat consistent with other models of attention which suggest that participants quickly learn the association between contextual cues and targets (Chun & Jiang, 1998). In these previous models of attention, it is suggested that when participants are searching for an object within a scene they search in locations where the object has previously been presented, and search for features which are strongly associated with that object (Bar, 2004; Summerfield & Egner, 2009). The current

evidence extends these models by demonstrating that the contextual cues could actually prime what to expect within the context as well as which goal participants choose to search for in the first place, based on the motivational relevance of that object in that situation.

In the present dataset, the effect of threat contextual cues on both threat object expectancy and threat search goal priority appeared consistent across participants. However, we note that the two contexts used in the present study were relatively unambiguous and hence left little room for differences in interpretation. It may be that in a more ambiguous context, where there is more uncertainty about the presence of a threatening object, there would be greater inter-individual variation in the contextual cueing effect, thus this could reveal a correlation between measures.

In contrast to the striking effects of context on expectancy and priority, there was very little variation in the perceived threat importance across contexts. Additionally, on this measure, there was a difference between specific categories of motivationally salient stimuli, with imminent threat being reported as the most important to detect. This is consistent with evolutionary models of attention to threat which suggest that detecting threat is vital in order to survive – it could also explain why early models of attention posited that there was an innate and unconditional 'threat detection module' (Öhman & Minneka, 2001; Amaral, Price, Pitkanen, & Carmichael, 1992; LeDoux, 2000; LoBue & DeLoache, 2009). If threat detection is always prioritised over other neutral goals, then it would likely appear to be an innate and unconditional bias because it would be active the majority of the time, at least when a threatening stimulus was expected to appear in the presence of a less motivationally salient target.

The primary focus of the current investigation was whether the Importance-Expectancy model could account for the search goal priority of threatening objects. we selected these objects because it was simple to manipulate their congruence with the threat and safe contexts; further focusing on these two objects reduced the number of hypothesised comparisons. Interestingly, though, exploratory analyses conducted for all objects revealed that the importance and expectancy variables both predicted an increase in search goal priority. This therefore provided support for the idea that both importance and expectancy are pervasive factors which universally influence the current goals of the individual.

When interpreting these exploratory regression models, it should be noted that these analyses are not entirely independent of each other: The importance, expectancy, and goal priority variables were rated separately; however, the ratings of different objects within each context are internally predictive (in that higher priority of one object in a given context necessarily means lower priority for another object, and so forth). This was a necessary feature of the design, given the competitive nature of attentional priority (cf. Fecteau & Munoz, 2006; Bisley & Goldberg, 2010). In other words, the intentional prioritisation of attention to a specific

real word object would result in a reduction in priority of other objects. Given this non-independence of object-ratings in the CAGT the ten exploratory regression models cannot be considered as separate replications of the model, but rather, different views of the same data. However, the fact that seven out of ten of these models survived a conservative Bonferroni correction for multiple tests provides promising convergent support for the Importance-Expectancy model.

Only two of the ten possible regression models did not find support for the Importance-Expectancy model. Interestingly, the two exceptions were the two threatening objects in the safe office context. This might simply reflect the very low expectancy of these objects in this context, meaning that individual differences in expectancy ratings in this context may have been driven more by the less cohesive contribution of expectancy of the three non-threat competitor objects. On the other hand, it is also possible that there may be exceptions to the predictive relationship of importance and expectancy on search goal priority (e.g. perhaps due to factors such as threat-avoidance goals). Future examination of such exception could be a useful avenue for future research.

Across the study we found no evidence of any correlation between individual differences or trait anxiety with any of the variables. This could be evidence that variation across individuals in reward seeking and threat avoidance does not influence attention via a deliberate goal-driven route. This could suggest that a goal-independent mechanism underpins attentional capture in some individuals. For instance, as suggested in some models of anxiety, trait anxious individuals may have weaker top-down control and greater stimulus-driven input from threat, thus leading to a larger attentional capture effect through this route (Bishop, 2009).

Alternatively, the current results could be due to the types of contextual cues which were selected. It has been found that the expectancy bias found in anxiety emerges within uncertain contexts. For instance, within a previous investigation, participants learned that two visually different shapes predicted a safe and an aversive outcome. Participants then had to rate the expectancy of an aversive outcome when presented with these shapes, along with stimuli which were visually similar to both safe and aversive shapes. When participants were presented with the unambiguously safe or threat predictive shapes there was no variation across anxiety in expectancy ratings of threat; however, it was found that anxious participants reported expecting an aversive outcome more than low anxious individual when rating the more ambiguous shapes (Lissek et al., 2014). It may be that when the context is more ambiguous then individual differences may emerge in expectancy ratings, and potentially goal priority ratings.

The novel Importance-Expectancy model of attentional goal selection provides a potentially universal model of how individuals select what motivationally salient stimuli to search for in the environment. This model could explain previous results from past research which have explored top-down factors in attention to motivationally salient stimuli. Aue et al.

(2016) found that manipulating the probability that a target would be a spider did not alter the speed of detection of the spider target between conditions. Participants were just as fast to detect a spider when there was a 50% probability that the target would be a spider (or bird) versus 90% probability it was a spider (or bird), thus suggesting that expectancy did not alter goal-driven attention. This result did not, however, factor in search goal priority as a mediating mechanism of the effect of expectancy on attention. Prior evidence suggests that individuals can only tune attention to a small set of target features at any one time (van Moorselaar, Theeuwes & Olivers, 2014). Indeed, evidence from my own research suggests that involuntary attentional capture by threat only occurs when individuals are searching for a single category of threatening stimuli, rather than multiple categories (Brown, Berggren & Forster, in preparation – Chapter 3). Due to the competitive nature of the bird and spider search goals, only one would become prioritised and searched for. Due to the cued expectancy being the same for both the spider and the bird, the only factor which would increase search goal priority would be the importance. In Aue and colleagues (2016) investigation, participants were told that there is 50% chance that a bird would appear and 50% chance a spider would appear. Due to the spider's affective associations it would have a greater detection importance, meaning that the spider search goal would then outcompete the bird search goal. In the other condition, the 90% spider cue condition would be prioritised as the search goal as well. Therefore, in both conditions the spider would be prioritised, and this could explain why there was no difference between the 50% and 90% spider cueing conditions. Thus, the novel model can account for previous results which appear to contradict its predictions.

The current evidence reveals that importance and expectancy correlate with what participants report they would search for; however, it does not confirm whether these variables actually directly influence attentional search goals in an experimental task. If the Importance-Expectancy model of attentional goal selection can account for actual deployment of attention, then it would be expected that when participants are given two competing search goals with motivationally relevant outcomes, then stimuli related to the goal which is most expected and important will capture attention more than the competing goal.

In conclusion, we have provided the first evidence that the current search goals of an individual are selected based on the magnitude of the motivational outcome (importance) and the expectancy of this outcome occurring. Further, we have demonstrated that this model operates in tight association with the current contextual cues an individual finds themselves exposed to. This finding allows us, for the first time, a view into the factors driving a general attentional goal selection of motivationally salient stimuli.

Chapter 7: The Influence of Self-Selected Motivationally Relevant Goals on Goal-Driven Attentional Capture

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Abstract

Recent evidence has raised the possibility that involuntary attentional capture by motivationally salient (e.g. reward or threat associated) stimuli may not reflect stimulus-driven mechanisms, as was previously thought, but rather may be an involuntary consequence of goal-driven attention. However, this previous research has only examined the effects of single instructed attentional goals, which may not fully represent real-world goal selection. In applying this goal-driven account to real-world situations, an important remaining question is whether the involuntary capture seen previously in response to instructed goals could also be induced by self-selected goals. To test this question, a novel goal-competition task was created in which participants responded to two different coloured targets; one which resulted in winning financial reward, and another which resulted in avoiding an aversive outcome. Task-irrelevant distractors were presented prior to the target, these could be congruent with the reward seeking target feature, or the threat avoidance target feature. At the end of the task, participants were asked to indicate the relative priority they had assigned to the threat avoidance versus the reward associated target. As predicted, the self-reported pursuit of the reward seeking goal positively predicted distraction by the reward related distractor, although only for reward targets. Unexpectedly, there was also a strong cueing effect when the distractor was incongruent with the target type. This preliminary evidence is consistent with the suggestion that attentional capture by motivationally salient stimuli could be influenced by self-selected search goals, but also highlights the powerful role of contextual cues in goal-selection.

It has long been established that stimuli associated with an aversive or rewarding outcome can involuntarily capture attention, apparently due to their motivationally relevant associations rather than any physical properties (for reviews, Carretie, 2014; Pool, Brosch, Delplanque, & Sander, 2016). For this reason, we term these stimuli *motivationally salient.* This attentional capture by motivationally salient stimuli has often been argued to reflect a stimulus-driven mechanism (Schmidt et al., 2015; Anderson et al., 2011). Recent evidence, however, suggests that this capture effect might alternatively reflect goal-driven attention, with an individual's current search goals inducing 'contingent capture'. Specifically, when participants are asked to adopt a goal to detect a category of motivationally salient stimuli (i.e.

alcohol in social drinkers, fearful faces, dangerous animals), task-irrelevant distractors from the same category capture attention and result in a decrement in target identification or detection (Brown, Berggren & Forster, under review – Chapter 2; Brown, Berggren & Forster, in preparation – Chapter 3; Brown, Duka & Forster, under review – Chapter 4; Brown, Forster & Duka, under review – Chapter 5). Consistent with the goal-driven account, but not the stimulus-driven account, these same motivationally salient distractors were no more distracting than a neutral image when participants were given a different search goal.

It appears plausible that individuals would adopt a voluntary goal to detect motivationally salient stimuli, because detecting objects which could signal harm or possible reward would allow individuals to respond quickly to them. However, the goal-driven attentional capture demonstrated in my previous research, and all other clear examples of goal-driven capture to my knowledge, have occurred as a consequence of a single instructed experimental search goal (e.g. for a particular colour, or for a category of stimuli such as scary animals, Folk, Leber & Egeth, 2002; Wyble, Folk & Potter, 2013; Brown et al., under review – Chapter 2). This may not be fully representative of the manner in which goal-driven attention operates in daily life. There is currently little research into the factors determining attentional goal selection, although evidence from beyond the attention literature suggests that individuals rarely follow an instructed goal which is only based on external motivation for any amount of time, and instead select to pursue more intrinsically rewarding goals (Deci & Ryan, 2000). It therefore appears likely that many real-world attentional goals are not externally instructed, but rather selected on the basis of an individual's own judgements of which goal would produce the most beneficial motivational outcome at that given time. An important question for any goal-driven account of attentional capture by motivationally salient stimuli is, therefore, whether self-selected goals could also induce involuntary attentional capture. It might be argued, for example, that the mental representation of self-determined attentional settings might be weaker than those of instructed experimental goals, perhaps to allow greater flexibility in unpredictable situations, and hence be less likely to cause goal-driven involuntary attentional capture.

In order to investigate this, we designed a novel goal-competition task, to allow participants to self-select their search goals and measure the effects on the degree of motivational distractor interference (our index of attentional capture). Forced choice, or concurrent choice, paradigms have been used in other areas of research, such as animal behaviour, to isolate the perceived value of an outcome by making individuals select between competing outcomes (Dickinson & Balleine, 1998; Mackillop et al., 2010; Chase, Mackillop & Hogarth, 2013). If self-selected goals could induce attentional capture by motivationally salient stimuli in the same way that instructed search goals can, then it would be expected that interference by a specific motivationally salient distractor would be greater for individuals who prioritise searching for that type of stimulus, over another competing search goal. This should

be revealed by a significant relationship between the motivationally salient distraction and the measure of priority that the individual gave for searching for that type of stimulus, versus another stimulus.

Recently, we have used the principle of concurrent choice between motivationally salient stimuli to isolate the priority that a motivationally salient object had as a search goal, versus other objects; as well as the factors which predict this attentional prioritisation. This revealed that a two-factor Importance-Expectancy model predicted the search goal priority; whereby the expectancy that a motivationally salient object would appear in a specific context, as well as the importance in detecting this object, predicted its attentional priority versus other objects (Brown & Forster, in preparation – Chapter 6). Therefore, the notion of competition has been found to effectively isolate the self-reported attentional priority that an object has. In the current task we shall explore whether this competition can be used to isolate the influence of self-reported search goal priority upon attentional capture in an experimental task.

In order for the concurrent choice to reveal competition, the two competing outcomes must be roughly equivalent and reflect opposing motivations. For this reason, the two goals we selected were avoiding an aversive outcome in the form of a loud noise and unpleasant image, and seeking a rewarding outcome in the form of financial reward. Importantly, both these types of outcomes (i.e. financial reward, aversive noise) have been found to capture attention (Austin & Duka, 2010). Further, evidence has revealed that attention is directed towards threat at the cost of reward associated stimuli, and vice versa, thus suggesting that these two motivational outcomes compete for limited attentional resources (Frewen, Dozois, Joanisse & Neufeld, 2008; Schechner et al., 2011). Neuroimaging evidence also suggests that reward and threat have been found to be processed in distinct locations in the brain, and that greater attention to a reward associated target was related to attenuated threat processing (Hu, Padmala & Pessoa, 2013; Padmala, Spechler & Pessoa, 2013). Thus, reward seeking and threat avoidance appear to compete rather than act in concert, and should be appropriate competing goals to determine which goal is prioritised versus the other.

The novel task was designed to produce several indices of priority. The primary one was an explicit self-reported search goal priority. This required participants to respond along a Visual Analogue scale (VAS) with the reward/threat associated target at each end, participants responded closer to the target they had been pursuing over the course of the task. In order to confirm the validity of this subjective measure of goal priority, we also computed an objective measure of attentional priority to corroborate the self-report. This was computed by subtracting the average accuracy for the threat target from the average accuracy of the reward target. A higher score on this subtraction measure would indicate greater accuracy in identifying reward targets, which suggests a greater prioritisation of this goal, versus the other threat avoidance goal.

The central hypothesis of the current investigation is that self-reported prioritisation of reward over threat will positively correlate with attentional capture by reward-related distractors, and negatively with threat-related attentional capture. To measure attentional capture by the motivational relatedness of the distractors, we subtracted the accuracy when the distractor colour was associated with a motivational outcome (threat/reward) from accuracy when the distractor colour was not associated with an outcome (neutral), in order to isolate the interference from the motivational associations.

Within this exploratory investigation we also interested in determining whether personality variables were associated with differences in the reward seeking or threat avoidance search goal priority. I, therefore, measured personality variables which have previously been associated with involuntary attentional capture by both threat and reward related stimuli, in order to explore whether these were associated with the preference of searching for one goal over another. These personality variables were impulsiveness, state and trait anxiety, and the BAS (Coskunpinar & Cyders, 2013; Bar-Haim et al., 2007; Hickey, Chelazzi & Theeuwes, 2010). It was predicted that the variables which had previously been linked to attentional capture by reward would be associated with greater reward seeking (BAS, impulsivity). Conversely, variables linked to increased attentional capture by threat would be associated with greater threat avoidance (state - trait anxiety). If these measures predicted self-reported attentional goal priority, this could point to an alternative account of individual differences in attentional capture induced by top-down goals.

Methods

Participants

The sample size was based on the largest number of participants that could be recruited in two academic terms. Originally 90 participants were recruited for the Experiment. In total, 77 participants were carried forward to analyses, with 8 participants excluded for having below chance accuracy (25%) on identification of either one of the target types. This was necessary because the measure of attentional capture was sensitive to floor effects. Two further participants were excluded for incorrect learning of the colour-outcome associations, as shown by rating the aversive stimulus as positive, or the rewarding stimulus as negative at the end of the expectancy rating block.

One further participant was excluded for reporting being aware from experience of prior studies that they would be rewarded with a set amount of money at the end of the task, rather than it being dependent upon performance (this was a requirement of the institutional ethical committee). Two other participants were excluded for skipping instructions and did not respond to the stimuli for most of the task. Participation was in exchange for credits and a fixed amount of financial reward, participants were only informed of the fixed payment after they completed the task which they believed to be performance dependent.

Stimuli and procedure

All stimuli were presented using E-prime 2.0 on a Dell Optiplex 780 PC, displayed on a 16-inch monitor with a screen resolution of 800×600. Participants viewed the stimuli at a distance of 59cm which was maintained using a chinrest. The task began with a consent procedure, where participants where given the opportunity to hear the aversive noise and view an example image of a mutilation which were presented during the task, in order for them to decide whether they wished to continue (see Learning phase section below for exact specification of these stimuli). The example image was not presented in the main task. Participants then had disposable skin conductance electrodes attached to their index and middle fingers of their left hand – the skin conductance data was not used due to problems extracting the data for analysis. There were two phases to the experiment - a learning phase and a goal-competition test phase. Half the participants completed personality and state questionnaire measures prior to the learning phase, the other half after the goal-competition test phase (see Questionnaires section below for more details).

Learning phase. During the learning phase, participants were first instructed that over the duration of the experiment there would be a rewarding outcome and a threatening outcome (see Figure 29a for example trial). The rewarding outcome was winning or being awarded 5 pence on each trial, every time they were awarded this an 8.5°×6.5° colour image of coins was presented for 500ms. There were nine possible images and all were sourced from Google images, and depicted small denominations of UK currency. The threatening outcome was a loud 40ms 102dB burst of white noise delivered through Blaupunkt CN-112 headphones. The loud burst of white noise was accompanied with a 500ms concurrent presentation of one of nine 8.5°×6.5° images of dead bodies and mutilation. These images were sourced from the Affective Image Picture System and were selected based on their high unpleasantness and arousal ratings (IAPS; Bradley, Lang & Cuthbert, 2005).

Participants were then instructed that during the learning phase of the experiment they would be presented with three coloured cues which would be consistently followed by three possible outcomes, and that they would have to learn the consistent pairing of each colour and each outcome whilst passively watching the screen. These outcomes were the rewarding and threatening outcome, previously mentioned, and no outcome, which consisted of 500ms of silence and no image presentation.

In order to determine that all the coloured cues were perceived as neutral prior to the learning stage, participants completed two outcome expectancy ratings blocks. Within one block, participants had to rate the probability that a cue was associated with a positive outcome, the other block they reported the probability it was associated with a negative outcome. The order of these blocks was randomised. On each trial of the ratings blocks, each of the three coloured cues appeared as a 1° square presented in the centre of the screen. Participants then

had to rate along a VAS, ranging from 0% probability to 100% probability that a negative or positive outcome occurring. The colours that were rated were green, purple and orange (RGB colour values – green: 0,180,0; purple: 135,0,220; orange: 255,160,0), the order of these colours was randomised within each block. After completing the initial baseline rating blocks, participants completed the main part of the learning phase.

Throughout the learning stage, four square placeholders appeared on screen. These measured 2.2° with a line thickness of 0.1°. These appeared to the left and right, and above and below the central fixation. Horizontal placeholders were 7.41° eccentricity from fixation, whilst the vertical placeholders were 6.77° from fixation. At the start of each trial four 1° cues appeared on the screen outside of the placeholders, at a diagonal distance of 6.5° from fixation. Each block consisted of six trials, on two trials the cues were green, two purple, and two orange. On half of the trials the cues appeared for 1000ms, the other half 8000ms. The colour-outcome association was consistent across the task and was counterbalanced between participants. At the end of the trial there was a randomly selected inter-trial interval ranging between 10s and 15s.

At the end of each block participants were told how much money they had been awarded over the course of the block. To the left of the participants was a *bank* tin which contained £10 in small change (made up of 5 pence, 10 pence, 20 pence, 50 pence, and £1 coins), participants were told to move the amount that they had won that block into the *winnings* tin to the right of them. Participants were made aware that they would be able to take their winnings home at the end of the task, although in reality they were paid a set amount. Before the next block began, participants completed another block of ratings, identical to initial positive and negative outcome rating blocks. In total there were three blocks of the learning stage, therefore the learning phase structure was thus: baseline ratings – learning block 1 – ratings 1 – learning block 2 – ratings 2 – learning block 3 – ratings 3.

Goal-competition phase. See Figure 29b for example trial of the goal-competition phase. After the learning stage, the skin conductance electrodes were removed. Participants were instructed that they would now have to actively search and respond to win the rewarding outcome and avoid the threatening outcome, rather than passively view the screen. As in the learning stage, the four placeholders remained on screen throughout the task. Each trial began with a fixation cross appearing for 1000ms. This was followed by the four coloured cues that were presented in the learning stage, though they only appeared for 150ms in this stage. Participants were made aware that these coloured cues were now acting as distractors (hereon in referred to as distractors), and should be ignored because they would interfere with the task. There were four different distractor trial types across the goal-competition phase, in these experiments the distractor could be the reward associated colour, threat associated colour,
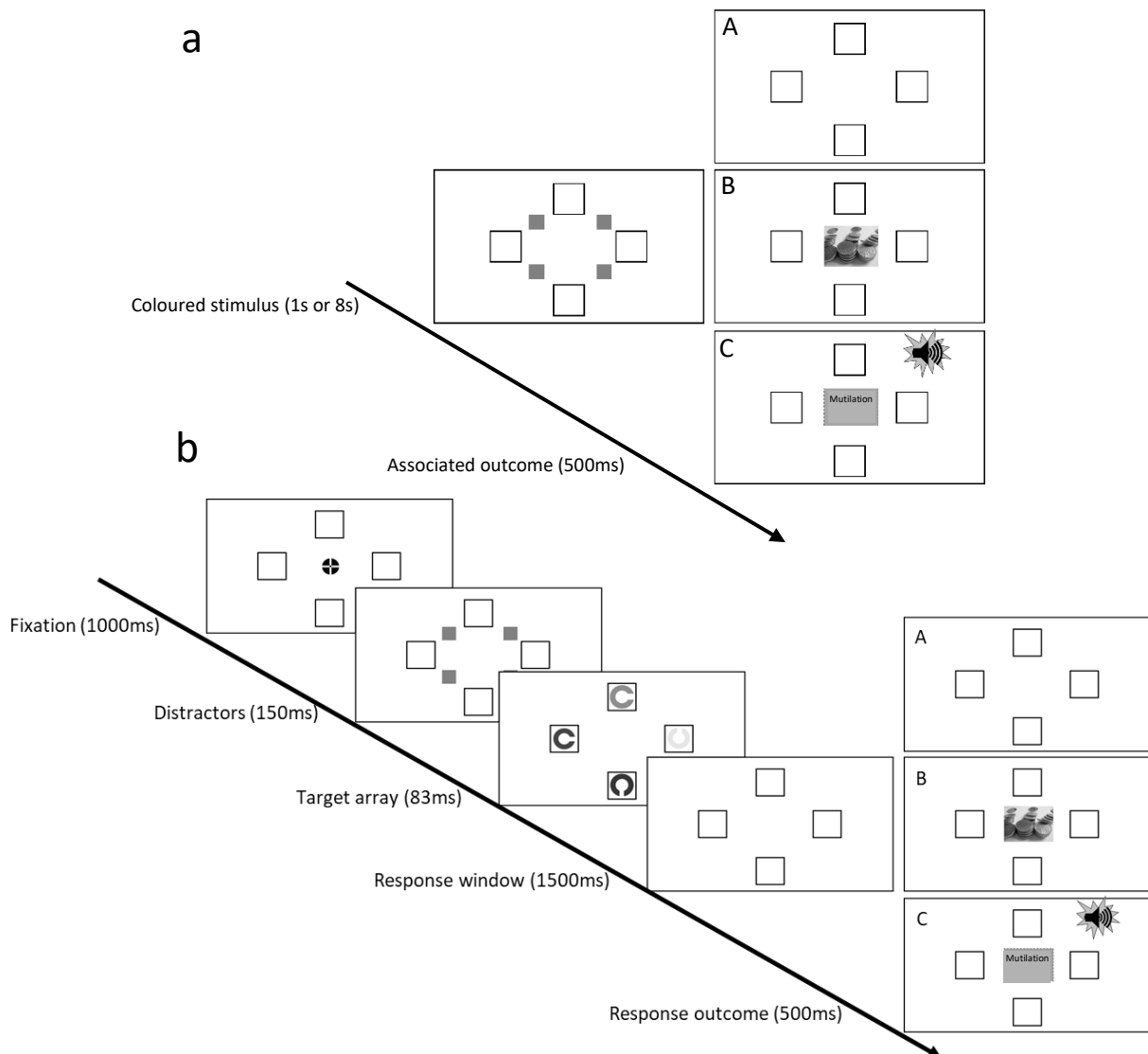
Figure 29a. & 29b. a) Diagram of a single trial during the learning stage of the experiment. Within this stage participants first viewed four coloured square stimuli for either 1 second or 8 seconds, these squares could be one of three colours on a given trial. Immediately after the presentation of these squares an associated outcome was presented for 500ms. There were three possible outcomes, one consistently associated with each of the coloured squares. Outcome A was a 'no outcome', where the placeholders remained on screen. Outcome B was winning 5 pence, this was signalled by an image of money. Outcome C was an aversive outcome which consisted of an image of mutilation and a 40ms 102dB burst of white noise. Each trial was separated by a 10 – 15 second jittered intertrial interval in which the placeholders remained on screen. b) A single trial within the goal-competition stage of the experiment. Within this stage participants first viewed a fixation cross for 1000ms, before the task-irrelevant distractors were briefly presented (150ms). Following this the stimulus array was presented with four Landolt C stimuli appearing in each of the four placeholders, one of these stimuli was the target stimulus. Participants had to respond to the stimulus which was either the colour associated with reward or a colour associated with threat. The reward associated target consistently appeared in two opposing placeholders (e.g. top-bottom/ left-right), whilst the threat associated distractor appeared in the other opposing placeholders (counterbalanced between participants). Following the briefly presented target array (83ms), participants were given 1500ms to respond to what they believed the orientation of the target stimulus had been, using the arrow keys. Participants were then given feedback for 500ms based on the accuracy of their response. If participants incorrectly responded to the reward target, or correctly responded to the threat target then no response was shown (Outcome A), however if they correctly responded to the orientation of the reward target then they presented with the rewarding outcome (Outcome B). If, however, they responded incorrectly to the orientation of the threat target then they were presented with the aversive outcome. Trials were separated by a variable inter-trial interval randomly jittered between 100 and 600ms.

no outcome associated (neutral) colour, and another condition where no distractor was presented at all. Each distractor trial type appeared on 20 trials, meaning that there were 80 trials per block.

Immediately after the appearance of the distractors the placeholders were filled with the target and filler Landolt C's which were presented for 83ms. These C shaped stimuli had a diameter which measured 1.1° with a gap of .2° in one side, this gap could be either on the left, right, top, or bottom of the C. Participants were instructed beforehand that they should respond to the direction the gap in the C using the four corresponding arrow keys, and that they should only respond to the targets which appeared as the threat and reward associated colours to achieve the associated outcome. The filler stimuli were identical to the targets with the exception that they appeared as different colours, these were blue (RGB: 60, 192, 243), yellow (RGB: 255, 240, 0), and red (RGB: 240, 0, 0). The orientation and location of each of these filler stimuli was randomised on each trial. On 32 trials the target was reward related and on another 32 trials the target was threat-related. Across a block there were eight trials for each of the four distractor conditions for each of the two targets. Each target type was presented at each of the four orientations an equal number of times, counterbalanced across distractor conditions and target location.

In order to make it easier to prioritise one target over the other, the reward and threat targets appeared in consistent locations out of the four possible placeholders, with one target type potentially appearing in opposing places holders, and the other target potentially appearing in the other two opposing places. For instance, the reward targets could appear at the top and bottom placeholders, and the threat targets could appear in the left and right placeholders. Participants were made aware that there was a relationship between target type and location, but were not told the specific pairing, instead they had to learn this during the practice block (see below). The target-location pairing was counterbalanced between participants.

Participants were made aware that correctly responding to the orientation of the reward related target resulted in being presented with the rewarding outcome from the previous learning stage, incorrectly responding or not responding to the reward related target resulted in no outcome. They were also made aware that correctly responding to the orientation of the threat-related target would result in the avoidance of the aversive outcome, whilst incorrectly response or not responding would result in the delivery of the aversive noise and image.

Participants were also made aware that on a portion of trials no target may appear, and that they should only respond when the target was present. This was to encourage accurate, rather than impulsive, responding. In total there were 16 no target trials, each distractor type appeared equally within these 16 trials. The location which would usually have presented the target was occupied by a Landolt C which was the colour of the neutral distractor.

After the target and filler array was presented, participants were given a 1500ms response window in which to respond to the orientation of the target C. Only the placeholders remained on screen within this period. Afterwards, the response dependent outcome was presented for 500ms. If participants correctly responded to the threat-related target then participants avoided the threat outcome (noise and image), however, if they incorrectly responded, or did not respond, to this target then the loud noise and unpleasant image were presented. If the participants correctly responded to the reward related target then they received the reward outcome (5 pence and money image), however if they incorrectly responded, or did not respond to this target then they received no outcome. This was followed by a random inter-stimulus interval ranging from 100 to 600ms before the next trial began. At the end of each block, as in the learning phase, participants were told how much money they had won over the course of the block. They were instructed to move this amount from the bank tin to the winnings tin.

Prior to the goal-competition task, participants completed a brief practice block in which they learnt the association between target type and location, as well as practicing the correct responses to the Landolt C shaped stimuli. These trials were identical to the main goal-competition trials with the exception that only the target image without filler stimuli was presented; this appeared for 300ms, instead of 83ms, in order to make the practice easier. In total there were eight trials, four of which were reward relevant and four of which were threat relevant; each orientation of Landolt C was presented once but was randomly selected at each location, and each target appeared in each of the possible locations an equal number of times.

Self-reported goal priority. At the end of the goal-competition task, participants completed a 3-trial goal priority rating task in order to determine their self-reported prioritisation of the reward seeking versus threat avoidance goals. In this task participants were asked *"How did you divide your attention between these stimuli?"*. Below the question, a pair of Landolt C stimuli were presented either end of a VAS. At either end of this scale were two anchors: *"I focused all my attention on this image"*. The image pairs that were presented were a reward associated colour C and a neutral associated colour C, the threat associated colour C versus the neutral associated colour C, and, most importantly, the reward associated colour versus the threat associated colour C. Participants were required to click closer to the image which they were preferentially attending to. The value of this final measure was the main dependent variable from this rating task, with a higher value reflecting greater voluntary reward seeking versus threat avoidance. The target stimuli orientations and the question order were randomly selected for each participant.

Questionnaires. Approximately half the participants completed personality questionnaires after the consent procedure, prior to the learning phase, the other half completed them after the goal-competition task phase, prior to the debrief procedure. All questionnaires

were completed in a randomised order. The questionnaires were the Behavioural Inhibition Scale/ Behavioural Activation Scale (BIS/BAS), the State-Trait Anxiety Inventory (STAI), and the Barratt Impulsiveness Scale (Carver & White, 1994; Spielberger et al., 1983; Patton, Stanform & Barratt, 1995).

The BIS/BAS scale is a 24-item scale which makes up a single BIS subscale which consists of 7 items e.g. *"criticisms or scolding hurt me quite a bit"*; the BAS subscale measures facets of behavioural activation and included items such as *"I go out of my way to get things I want"*. Participants had to rate how relevant each of the statements were to them generally, using a 4-points scale ranging from 'Very true for me' to Very false for me'. The BAS subscale was the main focus of this investigation due to its links to reward seeking behaviour and attentional capture by reward (Hickey et al., 2011).

The STAI is a 40-item measure of both current state and trait level anxiety. The state questionnaire consists of 20 items e.g. *"I am tense"*. Participants had to rate along a 4-point scale how relevant each statement was to how they *'feel right now at this moment'*, ranging from 'Not at all' to 'Very much so'. For the trait subscale participants had to rate how relevant 20 different statements were to how they *'generally feel'*, e.g. *"I feel like a failure"*. Again, this used a 4-point scale, although it ranged from 'Almost never' to 'Almost always'.

The Barratt impulsiveness scale is a 30-item scale designed to measure the construct of impulsiveness, that is responding without proper planning of the consequences. This scale included items such as "*I don't pay attention* or "*I do things without thinking"*. The items required participants to rate along a 4-point scale how relevance the statement was to them, generally. Responses ranged from 'Rarely/never' to 'Always'.

Results and Discussion

Learned Outcome Expectancies

In order to confirm the successful learning of the associations between colour and positive and negative outcome expectancies across the blocks of the learning stage, two 3×4 ANOVAs were performed on both positive and negative outcome expectancy ratings, with stimulus type (reward, threat, neutral) as one factor, and block order as a second factor (baseline/ block 1/ block 2/ block 3). As can be seen in Figure 30, the overall pattern of results reflects the successful learning of the outcome expectancies over the course of the learning stage. The ANOVA revealed a significant main effect of stimulus type on positive outcome, $F(1.69, 128.44) = 410.62$, $p < .001$, (Huynh-Feldt corrected), $\eta^2_p = .84$, with participants reporting a higher probability of a positive

outcome when the stimulus shown was reward associated. There was also a significant
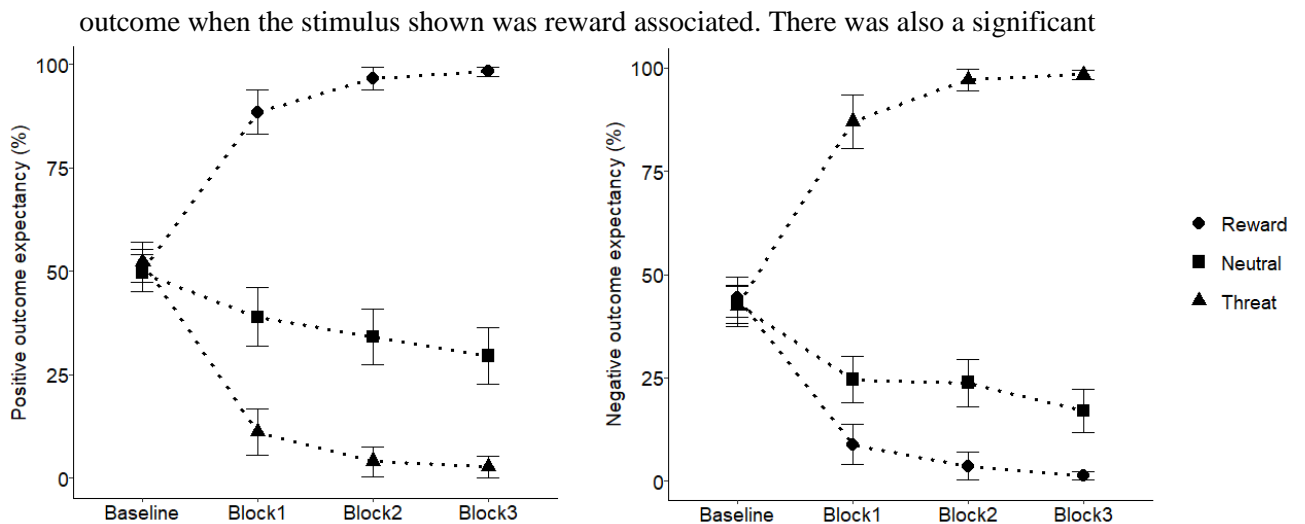

Figure 30. Participants' positive and negative outcome expectancy ratings at baseline and after each of the three learning blocks. Positive and negative ratings were conducted in separate blocks, participants rated their outcome expectancy along a visual analogue scale ranging from 0 – 100. Error bars reflect within-subjects standard error.

difference across blocks, $F(2.61, 234) = 10.09$, $p < .001$ (Huynh-Feldt corrected), $\eta^2_p = .12$, with participants reporting lower expectancy of a positive outcome in later blocks; however, this was qualified by a significant interaction between stimulus type and block, which revealed that only the reward associated colour was rated as more predictive of a positive outcome in later blocks, whilst the neutral associated colour and the threat associated colour were rated as less predictive of a positive outcome in later blocks, $F(4.08, 309.67) = 92.94$, $p < .001$, $\eta^2_p = .55$ (Huynh-Feldt corrected). In order to confirm that participants had indeed correctly learnt the colour-outcome associations, we compared the positive outcome expectancy rating of the reward associated colour in the final block to the rating of the neutral colour in the final block. This confirmed that reward was rated as more positive versus the neutral associated colour, $M = 98.3$, $SD = 4.81$ versus $M = 29.52$, $SD = 30.39$, $t(76) = 18.7$, $p < .001$. Further, comparing the positive outcome expectancy rating in the final block for the threat associated colour to the neutral colour revealed that the threat colour was perceived as less positive, $M = 2.7$, $SD = 11.93$, $t(76) = .25$, $p < .001$.

Similar patterns were revealed with respect to learning for negative outcome expectancy. Here, again, a difference between stimuli was found, $F(1.82, 137.92) = 566.05$, $p < .001$, $\eta^2_p = .88$. (Huynh-Feldt corrected), whereby the threat associated colour was reported as being the most predictive of a negative outcome, whilst the reward associated colour was reported as being the least predictive, below the neutral distractor. Further, the main effect of block was also significant, $F(2.67, 202.55) = 3.68$, $p = .017$, $\eta^2_p = .05$. (Huynh-Feldt corrected), with participants reporting lower expectancy of a negative outcome in later blocks, although the interaction revealed that this effect was driven by participants reporting lower expectancy for

both neutral associated colour and reward associated colour stimuli, and only reported an increase in expectancy of a negative outcome in later blocks for the aversive associated colour stimulus, $F(3.81,289.79) = 130.78$, $p < .001$, $\eta^2_p = .63$. (Huynh-Feldt corrected).

I compared the negative outcome expectancy ratings of the threat associated colour to the negative expectancy ratings of the neutral associated colour in the final block. This revealed that the threat associated colour was rated as having a higher expectancy of a negative outcome versus the neutral associated colour $M = 98.4$, $SD = 4.9$ versus $M = 17.08$, $SD = 22.84$, $t(76) = 29.87$, $p < .001$. Comparing the negative ratings in the final block for the reward associated colour to the ratings of the irrelevant colour revealed that the reward colour was perceived as less negative $M = 2.7$, $SD = 11.93$, $t(76) = 6.12$, $p < .001$. Therefore, participants appeared to quickly learn which colour was associated with each outcome and that these outcomes were perceived as positive and negative as intended. The two participants who did not learn this association were removed prior to the above analyses.

Goal-Competition Task Performance

To investigate the differences in response accuracy across target and distractor conditions (see Table 18), a 2×4 repeated measures ANOVA was conducted with goal target type (reward seeking/ threat avoidance) as one factor, and distractor type as another factor (reward/ threat/ neutral/ absent distractor types). The analysis revealed no significant difference between threat target identification accuracy and reward target identification accuracy, $F(1,76) = 2.51$, $p = .118$, $\eta^2_p = .03$, suggesting that on average across participants reward and threat goals received a similar level of priority. There was, however, a main effect of distractor type, $F(3,228) = 22.74$, $p < .001$, $\eta^2_p = .23$, revealing that all distractor types resulted in lower performance than the absent distractor condition, it also appeared that both reward and threat associated distractors resulted in lower performance than the neutral distractor condition which had not predicted any goal relevant outcomes. Unexpectedly, a highly significant interaction revealed that response accuracy across the different goal targets differed depending on which distractor preceded it, $F(2.58, 196.33) = 29.95$, $p < .001$, $\eta^2_p = .28$ (Huynh-Feldt corrected).

Follow-up t-tests revealed that this interaction was caused by an apparent cueing effect (see Table 18 for means and standard deviations), whereby participants were less accurate when the distractor colour was associated with a different outcome from the target. Specifically, the threat associated distractor caused a decrement in identification for the reward target relative to the neutral distractor, $t(76) = 5.46$, $p < .001$. Similarly, the reward coloured distractor resulted in a decrement in detection of the threat goal target, relative to trials where the distractor was neutral coloured, $t(76) = 5.33$, $p < .001$. It, therefore, appears that the colour of the distractor cued expectancy of the colour associated outcome, with the result that participants directed their attention to the spatial location of the outcome associated target (and hence missing the subsequent target when this was incongruent with the cue). On the other hand the reward

distractor did not result in a significant decrement or boost to reward target identification, $t(76)$ = .31, p = .760. On the other hand, the identification of the detection of the threat goal target was non-significantly different when it was a preceded by a threat coloured distractor, $t(76)$ = 1.41, p = .162.

	Reward distractor	Threat distractor	Neutral distractor	No distractor
Reward target	.65 (.19)	.55 (.21)	.64 (.19)	.68 (.19)
Threat target	.51 (.19)	.61 (.22)	.58 (.20)	.63 (.21)

Table 18. The percentage accuracy of target identification for both reward targets and threat targets across four distractor conditions. Reward and threat targets were intermixed meaning that participants had a dual target search goal. Standard deviations are presented in brackets.

Relationship between self-reported goal priority and distractor effects.

Bayes factors. Bayes factors were calculated for all correlations. A Bayes factor compares evidence for the *experimental hypothesis* and the *null hypothesis*. The Bayes factor ranges from 0 to infinity. The strength of this evidence is indicated by the magnitude of the Bayes Factor; values greater than three or less than .33 indicate substantial evidence for either the experimental or null hypothesis, respectively. A value closer to 1 suggests that the data are insensitive and that any difference is 'anecdotal' (Dienes 2008, 2011, 2014, 2016). The Bayes factor was computed using a modified version of Baguley and Kaye's (2010) R code (retrieved from Dienes, 2008). To compute the factor, we used a uniform distribution, with a mean of zero, due to the lack of prior knowledge of the effect size. We hypothesised that trait and state anxiety would predict the prioritization of threat avoidance over reward seeking in the goal competition task. Conversely, we expected that BAS and impulsiveness would predict prioritization of reward seeking versus threat avoidance.

Unless stated otherwise, the standard deviation of the distribution from the zero mean, for all Bayes factors was a plausible maximum effect size of r_z = .55. This is based on the guidelines set by Cohen (1988) which state that r = .5 reflects a strong relationship, this effect was then Fishers' Z transformed to correct for non-normality. We chose this effect size due to the lack of knowledge of how large the effect would be and therefore set the maximum likely effect.

Goal-driven capture correlations. To first confirm whether self-reported goal priority would predict the performance based index of goal priority, we correlated the priority score for reward seeking versus threat avoidance with the subtraction score between the identification accuracy of the reward target versus the accuracy of the threat target. Higher scores on both these measures denoted greater preference for reward versus threat. This revealed a very strong relationship between the two variables, r = .73, p < .001, $B_{U[0, .55]}$ = 26767125265 (see Figure

31). Therefore, participants were aware of the competition between the two goals and were aware of how they allocated their attention under these conditions.
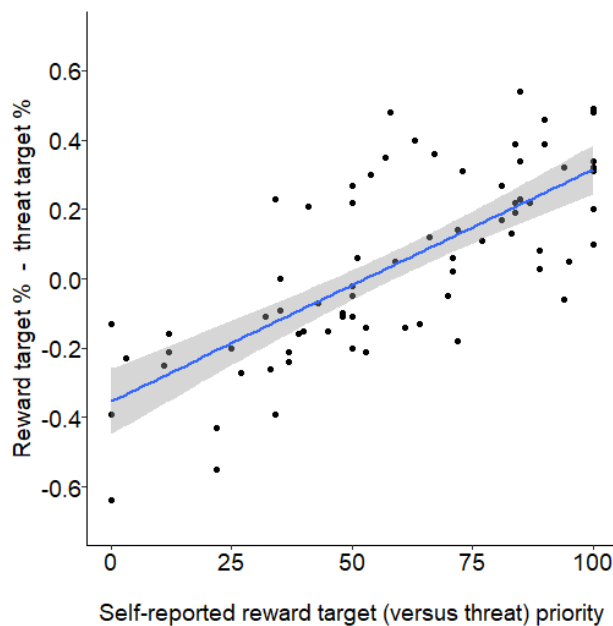

Figure 31. Scatterplot presenting the relationship between self-reported reward search goal priority versus threat search goal priority, and the subtraction of threat target identification accuracy from the reward target identification accuracy, higher scores on this subtraction measure reflect better identification of reward compared to threat. The self-report measure was taken from a VAS, higher scores reflect higher reward seeking. The error band reflects standard error.

	Reward target		Threat target	
	Reward distractor	Threat distractor	Reward distractor	Threat distractor
	.25*	-.01	-.1	-.07
Goal priority	Bayes factors			
	6.2	.29	.15	.17

Table 19. Correlation coefficients of the relationship between the subtraction of the reward and threat distractors from the neutral distractor condition across search conditions, and participants self-reported search goal priority. $p < .05$ = *; $p < .01$ = **. Bayes factors were computed using a prior expected effect of $r_z = .55$, which is the fisher transformed large effect size $r = .5$ (Cohen, 1988).

To test my main research question of whether individual differences in goal priority predicted attentional capture by goal-congruent coloured distractors, we ran four correlations between the distractor effects and the self-reported goal priority (Table 19). Given the unexpected large distractor cueing effect, we analysed the correlations across each target condition in case the distractor cueing effect influenced the relationship between prioritisation and attentional capture. These correlations revealed that when the distractor type was incongruent with the target colour there was evidence which favoured the null hypothesis, both

these small relationships were non-significant. Focusing on the conditions when the distractor was congruent with the target type; the threat distractor effect was negatively correlated with the self-reported reward goal priority, although this was only weak, and the Bayes factors suggested that the evidence favoured the null hypothesis. There was, however, a significant moderate positive relationship between the reward distractor effect and reward goal priority, as predicted (see Figure 32 for scatterplots). Further, the Bayes factor favoured the experimental hypothesis (B > 3).

This correlation is in line with my prediction that participants who reported prioritising reward targets, over threat targets, would be more distracted by the task-irrelevant reward coloured distractor when the reward target was present. This, therefore, provides some initial evidence of goal-driven capture by a selectively prioritised goal. However, we note that this effect would not survive a conservative Bonferroni correction for multiple comparisons ($\alpha =$ .013), and as such this finding should be interpreted with caution pending future replication.
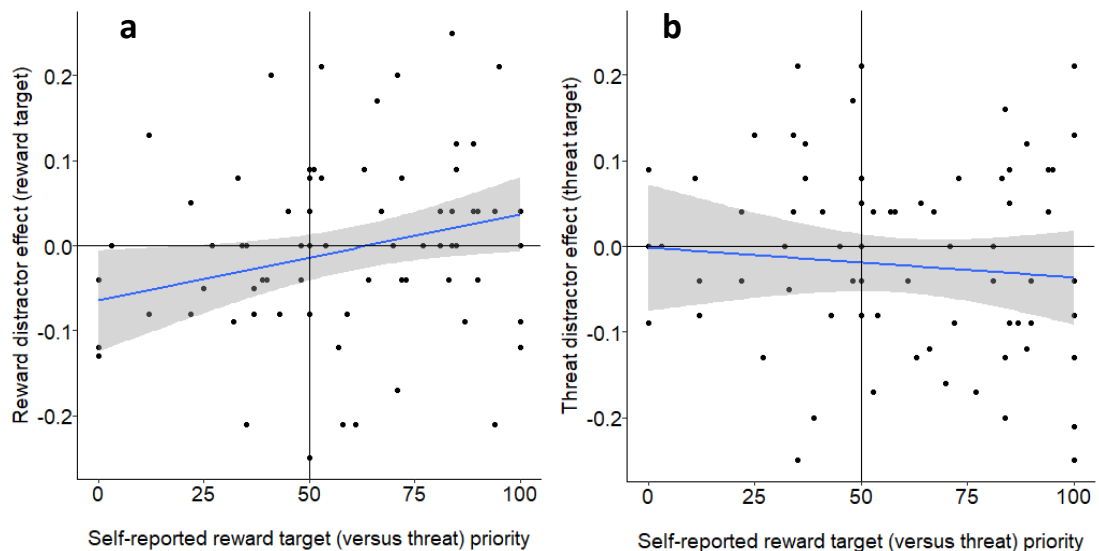

Figure 32a and 32b. Scatterplots depicting the relationship between motivational distractor effects and self-reported goal priority as reported by the VAS. Due to an unexpected incongruent cueing effect I only present the motivational distractor effects from conditions where the target was the same type as the distractor; Figure 32a depicts the relationship when the congruent distractor effect when the target was reward-relevant. Figure 32b depicts the relationship when the congruent distractor effect was threat-relevant. The scatter plots are divided into quadrants. A value in the upper quadrants would indicate greater attentional capture by a motivationally salient distractor versus a neutral distractor, as opposed to a value in the lower quadrants which would indicate a facilitation effect, with the distractor enhancing identification of the target. A value to the left of the line indicates greater self-reported threat avoidance versus reward seeking; whilst a value to the right of the line indicates greater self-reported reward seeking versus threat avoidance. Data values which favour goal-induced capture would be located in the top-right quadrant for plot 4a) and the top-left quadrant for plot 4b). The error band reflects standard error.

Trait and state personality correlations. In order to investigate whether any personality or current state variables predicted the goal priority measure, we ran exploratory correlations between the personality measures and the goal priority measure (see Table 20). Only state anxiety significantly predicted self-reported goal priority, with more anxious

participants reporting that they focused more of their attention to the threat avoidance target than the reward seeking target. Trait anxiety showed a similar but weaker negative relationship with reward goal priority, with the Bayes factor 'anecdotally' supporting the experimental effect, although it remained inconclusive. The evidence of a relationship between the BAS and goal priority favoured the null hypothesis, although it too remained inconclusive. As did the relationship between impulsiveness and goal priority; the Bayes factor for this small positive relationship favoured neither the null nor the experimental hypothesis.

	State anxiety	Trait anxiety	BAS	Impulsiveness
Goal priority	-.34*	-.18	.08	.14
State anxiety	-	.31**	< .01	-.08
Trait anxiety		-	-.25*	.16
BAS			-	.09
Impulsiveness				-
	Bayes factors			
Goal priority	56.78	1.76	.49	1

Table 20. Correlation coefficients of the relationship between the personality questionnaire variables, and participants self-reported search goal priority. $p < .05$ = *; $p < .01$ = **. A significant negative coefficient reflects prioritisation of threat over reward, and a positive coefficient reflects prioritisation of reward over threat. Bayes factors were computed using a prior expected effect of $r^z = .55$, which is the fisher transformed large effect size $r = .5$ (Cohen, 1988).

General Discussion

Evidence from my previous work has suggested that instructing participants to hold a top-down goal can induce an involuntary attentional capture by motivationally salient stimuli (Brown et al., under review – Chapter 2; Brown et al., in preparation – Chapter 3). However, this is unlikely to be how individuals search for motivationally salient stimuli in real-world contexts. Instead, we have recently proposed a framework in which individuals' search goals are jointly determined by the perceived importance and expectancy of a specific stimulus (Brown & Forster, in preparation – Chapter 6). Engrained within this model is the idea that goals compete for priority, and that the prioritised goal can then induce an involuntary attentional capture effect. We will now discuss how the current findings relate to the idea of goal competition, as well as how other findings can be explained by the Importance-Expectancy model of attentional goal selection.

First, the current study introduced a new experimental paradigm which is sensitive to reveal the extent participants choose to intentionally prioritise one attentional goal over another. We found that the self-reported goal priority strongly predicted superior identification of the prioritised target. Therefore, it is clear from the data that participants were aware of what they were searching for across the task, and that this preference transferred into actual task-performance.

Second, we found a powerful but unexpected cueing effect, in which target identification was significantly less accurate when the distractor preceding it shared the colour of the opposing target type. Note that this is not a simple spatial cueing effect because the distractors were not associated with potential target locations. Neither could it reflect response competition, because both targets required the same responses. Finally, it cannot be fully explained through low-level feature priming, whereby the appearance of the stimulus activates these features and enhances processing of them across the visual field in a bottom-up fashion. By this account, because the distractor shared the same colour features as the target, and could have led to the activation of these features without activation of any sort of top-down outcome expectancy (Theeuwes, 2013). However, this would not explain the incongruence effect, and instead would predict a congruence cueing effect, where the distractor facilitated the identification of the target which matched the colour, versus the neutral distractor, rather than the distractor impeding the detection of the contrasting target.

Despite the incongruent cueing effect being unexpected, we propose that the most plausible account is within the proposed Importance-Expectancy model of attentional goal selection. Recently, we found that both the perceived importance and expectancy of a motivationally salient stimulus predicted the extent to which participants rated the stimulus as being deserving of attentional priority. Critically, we also discovered that both expectancy and attentional priority were significantly, and strongly, modulated by contextual cues: When the context was congruent with the motivationally salient stimulus, then both expectancy of the stimulus appearing, and the priority of searching for this stimulus increased. For instance, a dark alley context resulted in participants expecting to find, and prioritising as a search goal, a potential attacker with a knife (Brown & Forster, in preparation – Chapter 6).

It appears plausible that the incongruent cueing effect in the present results may reflect a similar form of contextual cueing of goal selection. The expectancy ratings taken during the learning phase demonstrate that participants had made a strong association between the distractors and the expectation of the aversive and rewarding outcomes. The distractor, presented prior to the target, could therefore have acted as a contextual cue, increasing the expectancy that the outcome associated with the cue would occur, which in turn increased the likelihood that participants would switch to prioritising a search goal for the target feature or location associated with that outcome. In other words, in the same way that entering a dark alley could cue the search goal for a potential attacker, the threat associated distractor could have cued the search goal for the threat-related target. If the distractors cued expectancy of a particular target appearing and hence caused participants to direct attention to that location, this would explain why they were more likely to miss the actual target on incongruent trials. I, therefore, conclude that the incongruent cueing effect is most likely to represent contextual cueing of goal selection from the distractors, whereby the cueing increased the outcome

expectancy, as outlined in the Importance-Expectancy model of attentional goal selection (Brown & Forster, in preparation – Chapter 6). An interesting avenue for future research would be to adapt my task to further study this contextual cueing effect, for example by varying the level of expectancy associated with each cue.

Unfortunately, the powerful within-subject cueing effect undermined the ability of my task to address my main research question, which was whether self-selected goals can induce goal-driven capture. On incongruent trials, participants who had been prioritising the correct target (e.g., due to perceived importance of the competing outcome) would be cued to switch to a goal for the other (incorrect) target. On the other hand, participants who had been already prioritising the other target would be unaffected by the cue. In both cases, the incorrect target was prioritised, thus causing a ceiling effect. On congruent trials, presumably all participants would have been attending to the spatial location of the correct target (either because they already prioritised it, or because they had switched in response to the cue). However, only those participants who were already holding a goal for the target prior to distractor presentation would have been vulnerable to goal-driven attentional capture (i.e. if participants only adopted the goal in response to the distractors, these goals could not affect attentional priority of the distractors). As such, only the congruent condition would be sensitive to reveal individual differences in goal-driven attentional capture.

Within the congruent condition, those participants who self-reported greater prioritisation of the reward targets indeed showed greater goal-driven attentional capture by the reward distractor. The fact that the increase in attentional capture corresponded to the target which participants explicitly reported searching for highlights the involuntary nature of this capture. Additionally, it is clear that participants were motivated to pursue this goal and were not passively searching for it, because selecting it came at the cost of an increased likelihood of an aversive outcome. On the other hand, although the relationship between threat-priority and goal-driven distraction by threat was in the expected direction, it was only weak ($r = -.07$), and the Bayes factor suggested a sensitive null effect (B < .33). Therefore, although the present results are somewhat consistent with the hypothesis that self-selected goals can induce goal-driven attentional capture, further research is required to confirm this. Revising the experiment to contain fewer between subjects counterbalanced variables (e.g. target type location) could help detect the hypothesised effect by removing unaccounted variation from the task, or alternatively provide further evidence for the null hypothesis.

As well as investigating my primary hypothesis, we also conducted exploratory analyses to determine whether any individual differences influenced the search goal priority. We found that state anxiety predicted greater threat avoidance versus reward seeking. This, therefore, introduces the idea that an individual's current state can influence the choice to avoid threat, even at the cost of missing out on a rewarding outcome. It has been found that reward

and threat compete for attention, with attention being biased towards one at the cost of the other when they are presented as competing stimuli in a visual task (Frewen, Dozois, Joanisse & Neufeld, 2008; Choi, Padmala, Spechler & Pessoa, 2014). If my exploratory result were confirmed in future investigations, then it would suggest that this competition could be mediated by deliberate goal-selection.

One possible approach could be to experimentally induce an anxious state by placing participants in stressful conditions (e.g. McHugh, Behar, Gutner, Geem & Otto, 2010) to determine whether this influenced goal-priority, as well as subsequent involuntary capture by the goal-relevant distractors. As well as state measures of personality, we cannot rule out the influence of trait measures on goal-selection (i.e. BIS/BAS, trait anxiety, impulsiveness) because the Bayes factors for the relationship between these variables and goal-priority suggested an inconclusive effect: neither strongly favouring the null nor the experimental hypothesis.

The main contribution of the current investigation is that it points a path forward for future research. Up until now researchers have generally treated top-down goals as either synonymous with following task instructions (Theeuwes, 2010); or have concluded from an experimental manipulation that participants have chosen to adopt a goal for a stimulus, despite there being no explicit evidence of this selection. For instance, Vogt, Lozo, Koster and De Houwer (2011), compared attentional bias scores in a dot-probe task between a group of participants who interacted with disgusting objects versus a group who interacted with neutral objects. They found that the disgust induction group showed an attentional bias towards images depicting cleanliness, while the neutral group did not. This could be interpreted as participants choosing to attend to goal-relevant stimuli when they were not instructed to do so. However, with no explicit measure of choice it is not possible to conclude that this was goal-driven capture, it may have instead been reflective of the activation of low-level associative links between related images, which would influence attention independent of the current top-down goals (Moores, Laiti & Chelazzi, 2003; Bucker & Theeuwes, 2017). Further, because the clean images appeared in a target location, where the dot-probe would appear, it is not clear whether this is truly involuntary capture, because goal-driven attention would already have to be deployed to this location to detect the target.

In the current investigation, however, the distractors were presented in completely task irrelevant locations away from the target, thus ensuring that attention to these stimuli was involuntary. The task also gave an index of explicit self-reported goal preference which was corroborated with an objective measure of task performance (subtraction between the target identification accuracies). This could lead to future tasks incorporating participant choice within their designs, rather than concluding that task instructions are synonymous with the actual

preferred goal of the participants, or that an experimental manipulation is in fact effecting the current goals of the individual.

Chapter 8: Discussion

Traditionally, mainstream models of attention did not explicitly integrate motivationally salient stimuli into their frameworks. Instead, these models of attention focused primarily upon the bottom-up role of low-level stimulus properties such as brightness, and the role of guidance by a top down search goal (Desimone & Duncan, 1995; Theeuwes, 1994; 2010; Itti & Koch, 2001; Buschman & Miller, 2007; Parkhurst, Law & Niebur, 2002; Turatto & Galfano, 2000; Corbetta & Schulman, 2002). Motivational salience is, however, a vital factor which drives much of human attention and behaviour. Work within the attention and emotion literature has argued that the automatic attention to these stimuli is due to a stimulus-driven mechanism (Carretie, 2014; Bishop, 2007; 2009), although this account has been challenged by recent evidence that top-down goals may modulate attention to motivationally salient stimuli (Hahn & Gronlund, 2007; Everaert, Spruyt & De Houwer, 2013; Everaert, Spruyt, Rossi, Pourtois & De Houwer, 2014; Lichtenstein-Vidne et al., 2017; Lichtenstein-Vidne, Henik & Safadi, 2012; Vogt, Koster & De Houwer, 2017). Attempts to accommodate motivationally salient stimuli have also recently led to calls for revisions to mainstream models, adding a third determinant such as selection history (Awh, Belopolsky & Theeuwes, 2012). The present thesis tested an alternative possibility, that motivationally salient stimuli could be accommodated under the existing framework as a (sometimes involuntary) outcome of voluntary goal-driven attention. In order to determine whether a goal-driven mechanism could plausibly account for involuntary attentional capture by motivationally salient stimuli, we identified two essential questions that needed to be answered. In addition to these necessary conditions, we also set a third question in order to explore the precise underlying processes that could provide answers about how such a goal-driven mechanism could operate in real-world settings:

Question 1: Do individuals believe that detecting motivationally salient stimuli is important?

Question 2: Can top-down search goals for motivationally salient stimuli induce an involuntary attentional capture by goal-congruent motivationally salient stimuli? If so does this extend to self-selected goals?

Question 3: How are top-down search goals initially selected?

Do Individuals Believe That Detecting Motivationally Salient Stimuli is Important?

Due to the involuntary nature of attentional capture by motivationally salient stimuli, it is often assumed that they attract attention independent of the current goals of the individual. This assumption neglects the possibility that individuals might want to search for these stimuli because they consider them important to detect. Evolutionarily, it would seem clearly advantageous and obvious for individuals to have a long term aim to avoid danger and seek reward. However, empirically confirming that individuals consider motivationally salient stimuli important to detect is an important and necessary first step to any goal-driven account of attentional capture by these stimuli.

In Chapter 6, two large sample experiments provided clear evidence that individuals consider motivationally salient stimuli important to detect in their surroundings, and hence deserving of voluntary attentional priority. There was a difference between specific categories of motivationally salient stimuli, with imminent threat being reported as the most important to detect. This is consistent with evolutionary models of attention to threat which suggest that detecting threat is vital in order to survive – it could also explain why early models of attention posited that there was an innate and unconditional 'threat detection module' (Öhman & Minneka, 2001; Amaral, Price, Pitkanen, & Carmichael, 1992; LeDoux, 2000); if threat detection is always prioritised over other neutral goals, then at least it would likely appear to be an innate and unconditional bias because it would be active the majority of the time, when a threatening stimulus was expected to appear in the presence of a less motivationally salient target. Despite being seen as less important, potential threat and reward were still seen as important to detect and were rated more important that neutral stimuli, thus suggesting that these objects could effectively compete for attention against the less important neutral objects. To summarize, many of the same categories of stimuli which have been previously argued to capture attention correspond to those which people typically believe to be deserving of voluntary attentional priority.

Can Top-Down Search Goals for Motivationally Salient Stimuli Induce an Involuntary Attentional Capture by Goal-Congruent Motivationally Salient Stimuli? If so Does This Extend to Self-Selected Goals?

While Chapter 2 highlights that individuals may often voluntarily prioritize motivationally salient stimuli, Chapters 2-5 tested whether this voluntary prioritization could explain involuntary attentional capture. Involuntary and voluntary processes are often seen as distinct from one another. However, drawing on contingent capture research (cf. Folk et al., 1992), Chapters 2-5 consistently demonstrated that involuntary attentional capture to a range of motivationally salient stimuli can be induced as a direct, yet unintended, consequence of a voluntary search goal.
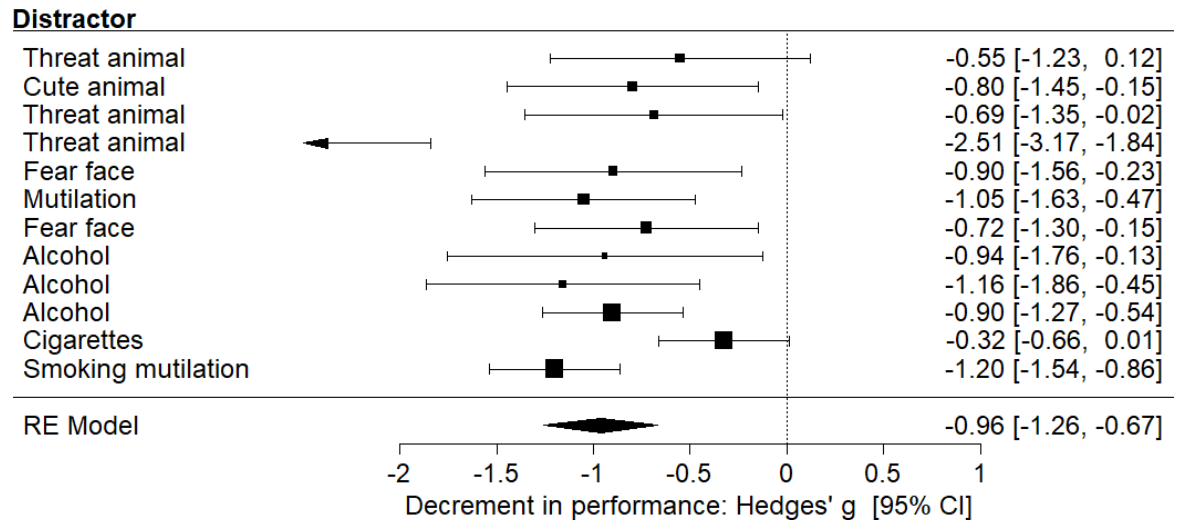
Figure 33. A forest plot depicting hedges' *g* effect size and 95% confidence intervals from a DerSimonian-Laird random effects model. Effects are weighted by sample size. The decrement in performance, versus a neutral distractor, when a motivationally salient distractor was presented in conditions where participants were searching for a target from the same specific category.

In order to illustrate the cumulative evidence for goal-driven involuntary capture by motivationally salient stimuli, we meta-analytically computed effect sizes across experiments from Chapters 2 – 5 (see Figure 33). This produced the standardised Hedges' *g* effect size which revealed the magnitude of the difference between the motivationally salient distractor and a matched neutral distractor under various search goal conditions. The meta-analysis was computed using R's Metafor package. Hedges' *g* and 95% confidence intervals were computed using DerSimonian-Laird random effects model, with each experiments' effects weighted by sample size (as described in Aloe & Becker, 2012; Viechtbauer, 2010). All subsequent meta-analyses within this chapter were computed using the same technique. Across nine experiments in Chapters 2 – 5, when participants were searching for a target from the same category as the distractor, task-irrelevant motivationally salient distractors resulted in lower detection or identification accuracy versus a neutral distractor. The cumulative effect size of this goal-driven effect was large and consistent, Hedges' $g = -.96$, $Z = 6.40$, $p < .001$, 95% CI[-1.26, -.67], with a significant decrement in performance recorded across all goal-congruent conditions. Further, Bayesian comparisons revealed that when participants were not searching for the category of stimuli congruent with the motivationally salient distractor, there was no poorer performance versus the neutral distractor.

The involuntary nature of this goal-driven attentional capture is supported by the fact that it occurred when the distractors were completely task-irrelevant and appeared away from the target, meaning that any attentional allocation to these stimuli would result in a complete inability to detect the target. Participants were also made explicitly aware that these distractors were irrelevant to the task and should be ignored. Additionally, this also occurred for conditions

where participants were searching for rewarding and personally relevant targets, such as in Chapter 5 when smokers were searching for appetitive smoking images. Under these conditions participants should have been especially motivated to pursue the search goal and detect the target and ignore the distractors. This finding, therefore, highlights the involuntary nature of the attentional capture in the current task.

I found this goal induced attentional capture across a multitude of different motivationally salient stimuli – specifically threatening stimuli such as fearful faces (Chapters 2 and 3), threatening animals (Chapter 2), images of mutilation (Chapter 3), and graphic health warnings related to relevant smoking concerns (Chapter 5). Additionally, we found the same goal-induced attentional capture for rewarding stimuli such as alcohol in social drinkers (Chapter 4), and appetitive smoking cues in nicotine dependent and occasional smokers (Chapter 5). It, therefore, appears that a goal-driven account of involuntary attentional capture could potentially explain a wide variety of attentional capture effect. There is the possibility that the motivational salience of the stimuli was not perceived in the experimental context, indeed Chapter 6 revealed that a safe context resulted in the reduced priority of motivationally salient stimuli. We did, however, find that participants rated the stimuli as emotionally arousing in Chapters 2 and 5, thus indicating that the affective associations of the stimuli were perceived by the participants in the experimental context.

In addition to the consistent evidence that a single instructed search goal could induce attentional capture by motivationally salient stimuli, Chapter 7 also found preliminary evidence suggesting that a self-selected goal (which participants were able to explicitly report) could induce a similar involuntary effect.
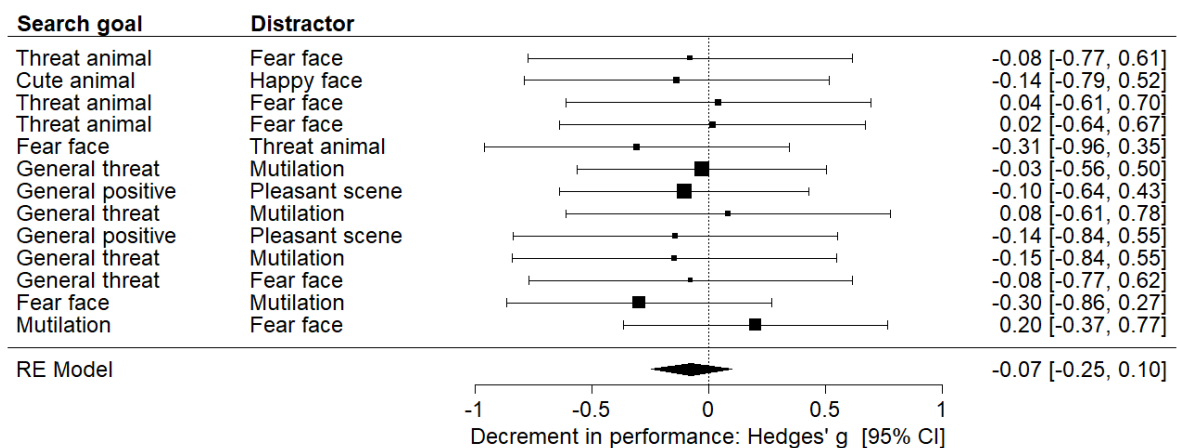

Figure 34. A forest plot depicting hedges' *g* effect size and 95% confidence intervals from a DerSimonian-Laird random effects model. Effects are weighted by sample size. The decrement in performance, versus a neutral distractor, when a motivationally salient distractor was presented in conditions where participants were searching for a target from the same general affective category

As well as revealing that involuntary attentional capture by multiple motivationally salient stimuli could be accounted for by a goal-driven mechanism, we also revealed an important boundary conditions of this mechanism. Goal-driven attentional capture only occurred when stimuli matched the specific semantic category of the goal. Stimuli linked to the goal only by affective content did not appear to capture attention - for example, searching for threatening animals did not induce attentional capture by fearful faces, despite both categories being related to threat. To test whether there was any cumulative evidence that there was a detrimental distractor effect on target detection, in conditions where there was affective but not conceptual overlap between the search goal and the distractor, we meta-analytically computed the Hedges' g effect size across 7 conditions within Chapters 2 and 3 (see Figure 34). We found that the cumulative reduction in task performance, versus a neutral distractor, was very small and non-significant, Hedges' $g = -.07$, $Z = .82$, $p = .412$, 95% CI[-.25, .10]. This suggests that affective similarity to a search goal does not automatically result in attentional capture when searching for a specific category of motivationally salient stimuli. This boundary condition has important implications for any goal-driven account of attentional capture by motivationally salient stimuli – namely, that these capture effects could only result from a goal for the specific semantic category of the stimuli. A broad, cross-category, danger avoidance goal alone would not be enough to induce involuntary attentional capture (cf. Vogt et al., 2013).

How are Top-Down Search Goals Initially Selected?

Having demonstrated that a goal-driven mechanism could plausibly drive attentional capture by motivationally salient distractors, we then questioned how attentional goals are initially selected. Across previous studies, including my own in Chapters 2 – 5, goal-driven attention has typically been operationalised as the following of task instructions. This is unlikely to be how search goals are commonly selected in real life. When a goal is determined by an external agent, individuals rarely follow the goal for a long time, and instead are more motivated to pursue intrinsically valued goals (Deci & Ryan, 2000). It is likely, therefore, that search goals are often internally generated based on personal needs and desires. Drawing upon social models of goal setting, as well as the findings across all six empirical chapters, We have developed a novel Importance-Expectancy model of attentional goal selection (A detailed description and diagram can be seen in Figure 35). This framework was directly tested in Chapter 6, where the data supported the proposed role of both importance and expectancy in predicting voluntary judgements of attentional priority. Specifically, my data supports the notion that voluntary attentional goal setting is jointly determined by a combination of the perceived importance of detecting a particular stimulus, and the expectancy of encountering this stimulus. Expectancy, in turn, varied between individuals but was also strongly cued by the context. Importance, on the other hand, varied between individuals but remained very consistent across contexts.

This framework accommodates the specificity of involuntary goal-driven capture, as revealed within Chapters 2-5. It might be argued that such specificity in a real-world setting would be maladaptive, as it could result in missing important information (e.g. missing an approaching car when we are talking to a friend whilst crossing the road). The strong contextual cueing effect would account for this by suggesting that participants adopt specific goals in response to the relative importance of all stimuli they are likely to encounter in a particular context.

For instance, if individuals were approaching a road, they would have learned from prior experience that cars are both highly likely to be encountered and also highly important to detect, and would hence tune attention to prioritise cars. This contextual cueing mechanism would allow for adaptive allocation of attention given that there is often a consistent association between many motivationally salient objects and their surroundings (e.g. cars-roads; alcohol-bar; spider-basement); and that participants are quickly able to learn these associations through a general Pavlovian learning mechanism, which is widely considered to be universal across organisms (Pearce & Hall, 1980; Rosas, Todd & Bouton, 2013; Shirakawa, Gunji & Miyake, 2011). The contextual cueing mechanism of top-down goal selection, therefore, provides a plausible explanation of how individuals might select specific search goals in order to maximise detection of important objects, but reduce the cost of searching for multiple objects at one time (Eimer & Grubert, 2014).

In summary, top-down search goals appear to be selected based on the importance and expectancy of the goals outcome in a given setting; and this is very specific to the environment that participants are in. Further, the findings of Chapters 6 and 7 suggest that at least in these conditions participants make a conscious choice between pursuing potential search goals.

Theoretical implications for the literature

Mainstream attention literature

The current investigation can provide valuable information for mainstream models of attention. Recently, these models have focused on how involuntary capture by stimuli associated with financial reward and aversive outcomes capture attention (Anderson, 2016; Awh et al., 2012). The conclusion from this research has primarily been that these motivationally salient stimuli constitute a third mechanism which biases attention independent of the current goals of the participant. Within the current investigation, however, we found consistent evidence which suggests that these stimuli may capture attention through an existing goal-driven mechanism, outlined in traditional models (e.g. Folk et al.,1992). Hence, my results allow for a parsimonious accommodation of motivationally salient stimuli within existing dichotomous models.
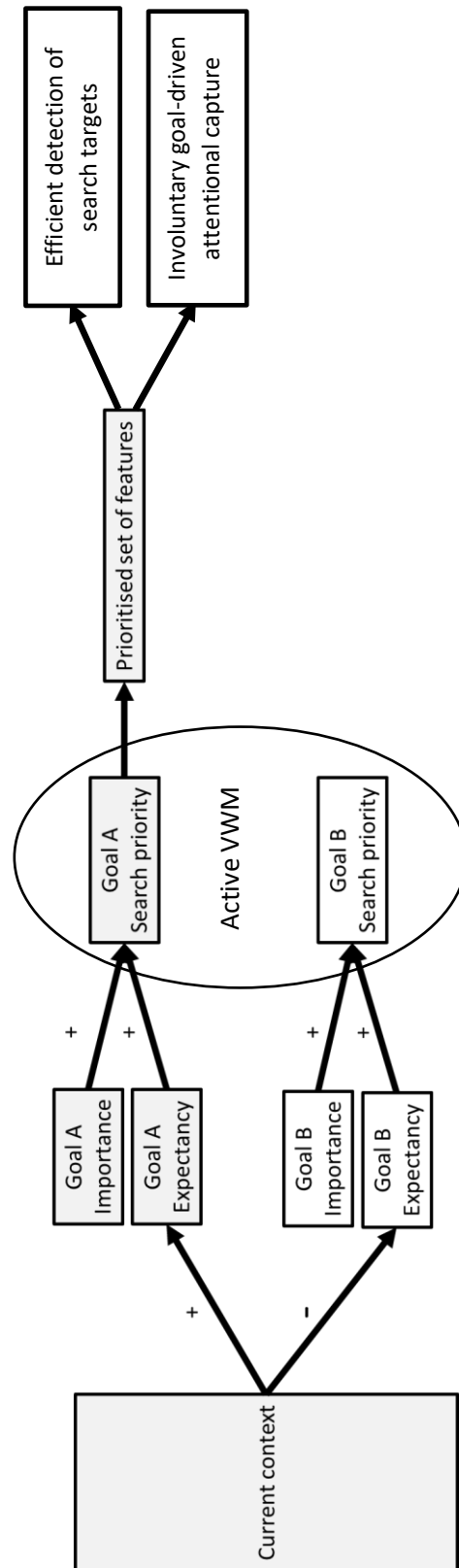
Figure 35. A schematic diagram of the Importance-Expectancy model of goal-driven attention. The model, from left to right, begins with the context in which the individual is in priming the expectancy of a particular goal's outcome. Contextual cues can include any sensory input which is indirectly related to a goal, within Chapter 6 I used the visual scene context to cue a search goal, however, other sensory inputs such as smells or sounds could also prime a search goal. The link between context and expectancy could occur through either instructed or associative learning; the individual learns that the context is predictive of the appearance of goal A over goal B. Subsequently, the contextual cueing effect has a positive influence on the expectancy of Goal A's outcome occurring, and a negative influence on expecting Goal B's outcome occurring, which is not associated with that context. The importance of the goals' outcome is determined separately from the current context, but is also determined through prior experience with the goal's outcome. If achieving the goal's outcome is rewarding or beneficial to the individual then it's importance will be larger. Both the importance and expectancy independently, and positively, predict the priority of a given search goal. Both search goals can be active in visual working memory (VWM) at one time, however, only the features of the highest priority search goal are then searched for across the visual field, and are capable of driving involuntary attentional allocation to these features.

The evidence which has previous suggested a goal-independent third mechanism (e.g. selection history) is based on results from several tasks which often have similar features (see Chapter 1 and 2 for detailed discussion). In particular, these tasks have often presented the distractors in task-relevant locations, where participants would be unable to completely disengage goal-driven attention (cf. Forster 2013). In the current investigation, we found that when the motivationally salient distractors were presented in task-irrelevant locations that did not require goal-driven priority, there was evidence against attentional capture independent of the current search goal, across all experiments, as revealed by Bayes factors favouring the null hypothesis within each experiment.

To highlight the absence of goal-independent attentional capture we meta-analytically computed an effect size across conditions where the motivationally salient distractor was incongruent with the current goal. In this analysis, to increase the chance that the motivationally salient distractors could compete for attention against the target, we isolated conditions where participants were searching for a neutral category of stimuli. According to stimulus-driven theories, the motivationally salient stimuli should effectively compete for attention against these stimuli, which are only prioritised based on their task relevance and visual qualities (see Figure 36). The categories of stimuli in this case were shoes, pots/pans, and cars in Chapter 4, and images of people reading in Chapter 5. The meta-analysis was conducted using a method identical to the other meta-analyses in this chapter, and revealed a near zero and non-significant effect size when comparing the motivationally salient distractor to a neutral distractor, Hedges' $g = .01$, $Z = .11$, $p = .916$, 95% CI [-.15, .17].

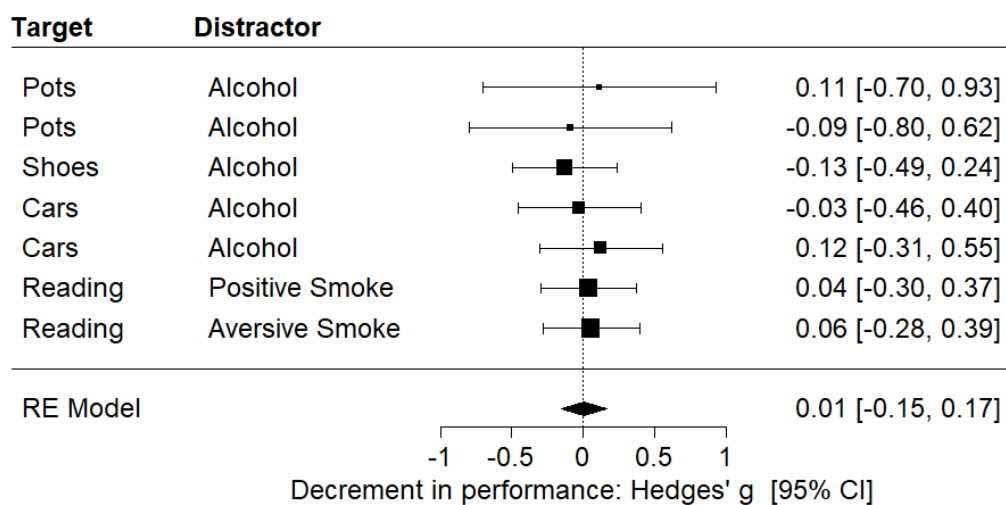Figure 36. A forest plot depicting hedges' *g* effect size and 95% confidence intervals from a DerSimonian-Laird random effects model. Effects are weighted by sample size. The decrement in performance, versus a neutral distractor, when a motivationally salient distractor is presented prior to a neutral target. The neutral target type and distractor type within each condition are presented in columns.

The current results, therefore, do not find any support for any involuntary influence of motivational salience upon attention independent of goal-driven attention. We highlight that the current aim of the investigation was to test a goal-driven account of involuntary capture by motivationally salient stimuli, rather than to discount a stimulus-driven mechanism which may well influence attention under some conditions. Furthermore, we note that the sensitivity of the present investigation to detect stimulus-driven effects may have been restricted by certain features of my experimental paradigm. Specifically, the task was more perceptually demanding than previous investigations; in the current task participants had to search for a visually complex category amongst rapidly presented images. It has been found that the perceptual load of a task can reduce processing of a distractor because there aren't enough perceptual resources remaining to attend to the distractor (cf. Lavie, 1995; 2005). Indeed, it has been found that fearful faces are only more distracting than neutral faces in a perceptually simple task, compared to a perceptually complex task (Bishop, Jenkins & Lawrence, 2006). It may be that stimulus-driven effects do result in attentional capture by task-irrelevant motivationally salient stimuli, but that this only occurs when the task is perceptually undemanding. Indeed, there are some instances when peripherally presented reward associated distractors do appear to interfere with target detection, and this is in a task that could be considered perceptually undemanding (e.g. flanker task; Anderson, Laurent & Yantis, 2011, though for conflicting findings see also Reeck et al., 2012; Notebaert et al., 2013). Future work should investigate directly whether the current results are replicated in both high and low perceptual load conditions.

If stimulus-driven effects do influence attention but only under low perceptual load, then this implies that a goal-driven mechanism is resistant to perceptual load when a stimulus-driven mechanism is not. This, therefore, provides further evidence for the strength of the goal-driven mechanism and would position it as the primary driver of involuntary attention to motivationally salient stimuli (i.e. across all situations, rather than only those involving a perceptually undemanding task).

As well as demonstrating that motivationally salient stimuli can be integrated into existing models of mainstream attention, my findings reveal for the first time, how these search goals may actually be set. Research which has tested how top-down search goals guide attention has only explored the influence of instructions, rather than self-selected goals. In the current investigation, we found that a simple two factor model predicted self-reported goal prioritisation, across contexts. Thus, the current thesis not only builds on existing mechanisms of mainstream models of goal-driven attention, but also introduces a novel extension to these models to explain how top-down goals are set.

Emotion and attention literature

The current findings also have implications for the attention to emotion literature, not just mainstream models of attention. In recent years, researchers within this field have suggested

that attention to threat and emotion may not be entirely unconditional as predicted by a stimulus-driven mechanism. Instead, evidence from this field suggests that the current task-relevance of the affective content modulates the attentional capture by these stimuli (e.g. Everaert et al., 2013).

Based on the finding that motivational salience isn't unconditional but is pervasive, it has been suggested that the attentional capture by motivationally salient stimuli occurs because individuals are more likely to consider threatening stimuli relevant to their current aims, and have a habitual goal to stay safe (e.g. Vogt et al., 2013). The current research is aligned with this recent work within the field of emotional attention, however, the current findings refine and advance this conclusion. Specifically, my finding that involuntary capture by motivationally salient stimuli can be induced by top-down goals demonstrates a plausible mechanism for task-relevance effects, suggesting that these may be driven by relevance cueing specific top-down goals for the affective stimuli. Given the findings of Chapter 6, it appears plausible that task-relevance might act through the proposed Importance-Expectancy model. For instance, by increasing the task-relevance of non-motivationally salient features, this may increase the importance of these features and enable them to compete as a search goal against the motivationally salient stimuli, which would usually be prioritised as a search goal. Alternatively, by presenting the distractors in a task-irrelevant location it could reduce the perceived expectancy of them appearing across the task, and reduce the prioritisation of these stimuli through that route; in most experimental tasks because the images are presented consistently across the task then expectancy is usually high, and would result in them competing for priority as a search goal.

Further, it had not yet been explored whether the attentional capture was due to an explicit or implicit prioritisation of the affective stimuli. My current findings suggest that although multiple features can be active as a search goal, involuntary attentional capture can only be induced through voluntary prioritisation of a specific set of features. Within Chapter 3 we found that capture was only induced by the deliberate prioritisation of a single conceptual category of threat. Further, evidence from Chapter 4 revealed that even when individuals held alcohol stimuli active in VWM, these features did not guide attention to task-irrelevant alcohol distractors, despite evidence that when alcohol was a single search goal these same distractors captured attention.

It, therefore, appears that explicit search mediates the effect of the motivational content on attention. Complementary to this conclusion, we found that in Chapter 6 participants reported that they believed that they should intentionally lookout for motivationally salient stimuli in their environment when they expected them to appear. Chapter 7 also revealed that participants were able to explicitly state what motivational goal they had been pursuing, and that this strongly predicted actual goal target detection. Thus, we have direct evidence that

individuals would be likely to intentionally prioritise detection of these stimuli when they were aware that they would appear.

More generally, the present work creates useful new linkages between mainstream models of goal-directed attention and the specific field of attention to emotion, and other motivationally salient stimuli. For example, the extensive existing work on contingent capture may now be applied to illuminate how general mechanisms of attention can account for attentional capture by motivationally salient stimuli, as well as the potential exceptions to this general top-down mechanism.

Applications of Current Findings

As well as providing important novel findings for theoretical models of attention, the current results can also be used to inform real-world applications. One particularly promising finding is the absence of attentional capture in individuals who should be predisposed to distraction by these stimuli. For instance, previous evidence has found that cigarette cues interfere with attention tasks in nicotine dependent smokers, however, this effect was absent in the current investigation (Mogg, Bradley, Field & De Houwer, 2003; Field, Mogg & Bradley, 2008). It has been proposed that the attentional bias to drug cues can induce a state of craving which could result in maladaptive consumption of the drug (Field et al., 2016).

The current results suggest that when an individual adopts a search goal which is unrelated to a motivationally salient stimulus category, then they do not attend to the stimulus. This could potentially have therapeutic applications, especially for informing attentional bias retraining. It has been proposed that subtly manipulating attention away from the image of either an addictive substance or threat associated stimulus, then the pathological attentional biases observed in clinical samples can be reduced, and that this could result in a reduction in drug consumption or anxiety over time (Schoenmakers et al., 2010; Hakamata et al., 2010). This retraining technique has, however, had mixed results, and has produced several null findings (Christiansen, Schoenmakers & Field, 2015; Mogoase & Koster, 2014). One potential reason for this is that the training tasks focus on training participants to attend away from the craving or anxiety inducing stimuli. My results suggest that attentional capture to motivationally salient stimuli are suppressed or prevented when participants search for a competing goal, not through training avoidance of the motivationally salient stimulus, as has been done in previous interventions. Based on the current empirical findings, I would design an attentional training task which uses contextual cues to train the activation of a search goal towards an adaptive competing category of stimuli when in the presence of the maladaptive category of stimuli. For instance, with alcoholic individuals, the task would present a relevant contextual cue (e.g. image of a bar) as a signal for the appearance of a target from a healthy positive category of stimuli (e.g. smiling faces). Thus, when encountering this context in real life, the individual may learn

to search for the competing healthy category of stimuli, blocking the usual competing search goal for alcohol.

Additionally, the current research findings would also suggest that giving individuals healthier and more adaptive goals to pursue would enable these goals to compete for attention against the more maladaptive goals. Previous evidence supports this, for instance alcohol abusers with more adaptive non-alcohol related goals (e.g. more chance of success or greater joy on completion of the goal) responded better to standard treatment; further, treatments which focused on encouraging individuals to pursue more adaptive life goals also reduced alcohol consumption (Cox & Klinger, 2002). Therefore, my current findings also lend support for these types of interventions, and suggests that interventions targeting goal selection may be successful.

The finding that motivationally salient stimuli do not capture attention involuntarily, even in individuals who these images are personally relevant for, suggests that graphic health warnings on certain product such as cigarette packaging may not be effective unless individuals are searching for them. Indeed, it has previously been found that smokers preferentially attend to branding information on cigarette packages, rather than any other features (Maynard, Brooks, Munafo & Leonards, 2017). Further, removing this branding information appears to increase the salience of the graphic warning (Munafo, Roberts, Bauld & Leonards, 2011). My results suggest that branding information and other salient features on the packaging may allow smokers to search for these features, and prevent them from attending to the graphic health warnings. One recommendation would be to increase the size of the graphic warning and remove any other competing visual features, thus making the graphic warning the only identifying feature on the packet. In this case, the only way to search for the cigarette packet would be to tune attention towards the graphic health warning.

Another important role that my findings have beyond theoretical models is the highlighting of contextual factors in top-down search goals. Top-down goals are often considered to be centred on the individual, and therefore places the focus of behaviour change on personal choices. The finding that contextual cueing plays a strong role in goal-selection bridges the gap between the individual and the environment. An application for the current research, therefore, would be to provide evidence in support of interventions which target the context the individual is embedded in. This can include 'nudge' research which aims to make small changes to the environment to prime healthier behaviour (Hollands et al., 2013). For instance, priming individuals to pursue healthier food choices through healthy eating posters in food shops (Papies & Hamstra, 2010; Papies, 2016). Interestingly, priming individuals with a health goal cue has been found to result in an increase in attention to healthier foods, as index by eye-tracking measures, which would suggest that the contextual cueing of health behaviour could be mediated through attentional processes (van de Laan, Papies, Hooge & Smeets, 2017).

Future Directions

In regard to future directions, the Importance-Expectancy model provides a starting point for future research. The model is not intended to be a finished product, but rather to generate future research questions within a clear theoretical framework. One important aim for future research should be to replicate the finding that importance and expectancy influence the selection of motivational search goals, found in the survey task, but within an experimental task. For instance, in the goal-competition task in Chapter 7, it should be possible to decrease the selection of one goal (e.g. reward seeking) over another (e.g. threat avoidance) by decreasing the magnitude of the outcome of one of the goals (e.g. switching from 5 pence to 1 pence reward); similarly, reducing the expectancy of an outcome should also produce a similar reduction in goal-selection (e.g. switching from 100% probability of winning money to 50% probability). Through this novel paradigm, it should be possible to determine whether there are instances when search goal selection is more influenced by importance or expectancy, and what factors may influence this. For instance, awareness of the motivational associations, motivational personality traits, or current state may influence goal selection through either importance, expectancy or both.

One factor which appeared to influence the goal-competition but was not included in the importance expectancy model was the current emotional state of the individual. It is not clear whether elevated state anxiety had a direct influence upon goal-selection, or whether it was mediated by elevated importance of the outcome or increased expectancy that the outcome would occur. An individual differences design where variation across individuals is correlated with a task measure could be used to test this, however, another possibility would be to induce an anxious state in participants and determine whether this directly resulted in increased threat avoidance versus reward seeking. Additionally, expectancy ratings and importance ratings could be measured at intervals throughout the task. It could be possible that state anxiety would increase the importance rating of detecting the threat related target, and this was what indirectly increase threat avoidance; or, it could be that more anxious participants expected the threatening outcome on a greater percentage of trials and therefore chose threat avoidance as a preferred goal.

It is interesting that we only found evidence of a relationship between individual differences and task performance where participants were allowed free choice between two competing goals. In this task, participants had the choice of searching for reward or threat related stimuli, state anxious individual appeared to search for threat more, versus reward. Interestingly, this increased threat avoidance resulted in a reduction in distraction by task-irrelevant reward associated distractors. This preliminary investigation, therefore, suggests that individual differences in goal-driven attentional capture may emerge when participants are given free choice between competing goals; whilst when participants were given a single goal,

as in Chapters 2 -5, this obscures individual differences. Alternatively, the absence of individual differences across many of the empirical chapters, with the exception of some preliminary evidence in Chapter 7, could suggest that individual differences do not influence attention through a goal-driven route, and instead effect attention through a more implicit mechanism (Stacy & Weirs, 2010). If this were the case, this would not undermine a goal-driven explanation of attentional capture by motivationally salient stimuli. It would, however, suggest that individual variation across some participants was independent of this goal-driven mechanism. Future evidence is required to determine how individual differences in affective traits and states can be accommodated within the Importance-Expectancy model of goal-driven capture. Further, the Importance-Expectancy model must accommodate conditions which seem to cause more general context independent attentional biases, such as the bias towards all threat in Generalised Anxiety Disorder (GAD; Mogg & Bradley, 2016). The general attentional bias towards threat in this case could either reflect expectancy independent mechanism, or these individual simply expecting threat across all contexts and perceiving none of them to be safe (Browning, Behrens, Jocham, O'Reilly & Bishop, 2015).

It has been posited that the mental representations which guide goal-driven attention are stored in VWM as prioritised features (Downing, 2000; Soto, Heinke, Humprehys & Blanco, 2005; Woodman, Carlisle & Reinhart, 2013). In Chapter 4, Experiment 2, when participants held an alcohol image active in VWM whilst searching for a separate category, however, we found that alcohol distractors did not capture attention versus neutral distractors; but when participants were searching for alcohol as a primary search goal, this did induce an involuntary capture effect by the same distractors. It, therefore, appears that multiple valued goals can be active at any one time in VWM, but only currently prioritised features guide attention (Olivers, Peters, Houtkamp & Roelfsema, 2011; Olivers & Eimer, 2011). Further, in Chapter 3, even when participants were actively searching for multiple categories of motivationally salient stimuli, distractors which were congruent with exemplars from one of these categories did not capture attention. If multiple goals are searched for at one time, and there is no clear prioritisation, then involuntary attentional capture does not seem to occur, even if a distractors' features overlap with the content of one of the search goals. This could be considered maladaptive in some contexts where individuals may want to detect multiple features; however, if it is considered that only a small subset of features can be prioritised in the attention system at one time (Olivers et al., 2011), then such a mechanism could prevent participants over committing to a single goal and missing an equally likely or important goal outcome.

Within the current Importance-Expectancy model, it is likely that individuals would be constantly updating the prioritisation of each goal based on contextual cues. Thus, participants may hold several goals and their associated features active in VWM, but through the accumulation of contextual information, they may rapidly and dynamically update the priority

of each of the search goals until only a single goal is deprioritised. Within Chapter 7,weunexpectedly found evidence which suggests that this process may be very quick. In a task where participants had to search for two coloured targets representing different search goals, we found that a coloured distractor/cue, which was presented for 150ms prior to the target, appeared to prime attention towards either the associated location or feature of the goal which was congruent with this distractor/cue. This was demonstrated by participants inaccurately identifying the target which did not match the distractor/cue colour, likely due to them not prioritising the associated location or feature of this goal because the competing goal's target was prioritised. Within the Importance-Expectancy framework, this could be because the associated colour rapidly primed an increase in expectancy of the goal's outcome, or the appearance of the target, and lead participants to prioritise this search goal over the other goal, thus leading to an incongruent priming effect when the different target appeared. Future research could examine the temporal fluctuation of search goal priority over time, and how responsive the updating of an attentional goal is depending on manipulations of importance and expectancy.
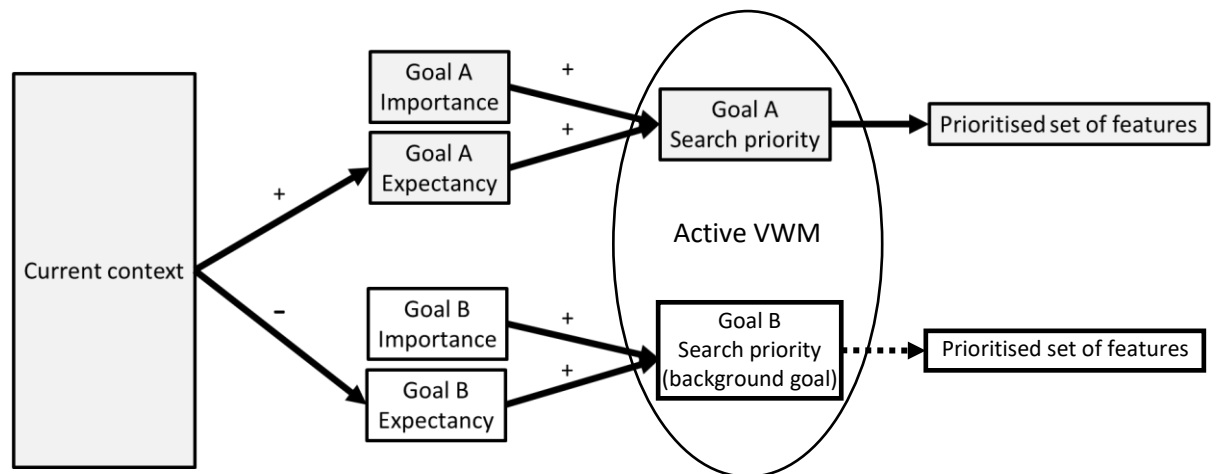

Figure 37. Potential revision to the model if background VWM goals can capture attention concurrent to searching for a primary search goal. In this model, the features associated with two goals can be active at any one time in VWM, and this can result in involuntary attentional capture by these multiple memory representations. This may emerge under specific conditions, such as during a low perceptual load task (Tan et al., 2015).

In the current investigation, we found that only a search goal for a single category of stimuli from images of motivationally salient real-world objects could drive involuntary attention to these images. we have therefore proposed a model in which only a single set of features can be prioritised to induce involuntary capture at any one time. There is, however, evidence which may suggest that this section of the model needs further investigation and refinement (Figure 37). There is some evidence that multiple visual memory representations can guide external attention simultaneously, and that this occurs when participants are forced into a situation where a task can only be completed by tuning attention to equally prioritised features,

although this requires more effort and is not the default search strategy (Grubert & Eimer, 2016; Irons, Folk & Remington, 2012). Additionally, there are some experimental conditions when an image stored in VWM can induce an involuntary capture to matching stimuli, despite these features not being prioritised as the primary target. The conditions when this occurs is in low perceptual load (Tan et al., 2015), when there is insufficient time to exercise cognitive control over the target selection (Han & Kim, 2009), or when the primary target is simple and repeated over multiple trials (Gunseli, Olivers & Meeter, 2016).

Within Chapter 4, Experiment 2,wefound that a VWM representation of alcohol failed to induce attentional capture by alcohol distractors. The reason that this experiment did not produce evidence of background search goals may have been because it was perceptually demanding, and does not match the condition in which previous investigations have found that secondary VWM representations bias attention. To give a real-world example, we may be focusing our attention on our computer to do a task whilst thinking about how our phone may go off – if the computer task is perceptually complex and sufficiently engaging then only this attentional goal may drive attentional capture and the other VWM input may be suppressed; however, if the task is very simple and doesn't require much attentional engagement then the background goal of thinking about our phone may cause attention to be captured by these associated features, despite attending to the computer being the primary goal.

Interestingly, the conditions when this background VWM goal influences attention are also the conditions that motivational stimulus-driven or goal-independent effects are proposed to occur more strongly, with the tasks being relatively perceptually simple (e.g. Anderson et al., 2011). I, therefore, propose that previous instances of goal-independent or stimulus-driven capture by goal. Motivationally salient stimuli could conceivably be accounted for by the distractor's congruence with a background goal. This radical possibility would call into question whether any attentional capture by motivationally salient stimuli occurs independent of current top-down goals. Despite this position being extreme, there is some evidence to suggest that it is possible; for instance, Thomas, Fitzgibbon and Raymond (2016) found that a reward associated face was prioritised in VWM versus an unrewarded face, despite receiving the same attention during encoding. This result clearly suggests that by increasing the importance of a stimulus it also increases it's priority in VWM.

Additionally, holding an image of appetitive food active in VWM results in attentional orientation towards this image when it is a distractor in a perceptually simple visual search task; further, this distraction effect is larger when a food distractor is congruent with a food memory, compared to the distraction when a nonappetitive distractor was congruent with a nonappetitive memory (Higgs, Rutters, Thomas, Naish & Humphreys, 2012; Rutters, Kumar, Higgs & Humphreys, 2015). Therefore, more valued or important stimuli are more able to induce involuntary capture from VWM, versus less important neutral stimuli stored in VWM – at least

in a visually simple task. Therefore, these are the necessary conditions for top-down background goals to drive involuntary capture, 1) value associations causing the automatic prioritisation and maintenance of stimuli in VWM without instructions, 2) when a motivational stimulus is prioritised in VWM it results in a strong attentional capture by visually congruent stimuli. If future results confirmed that background goals to detect motivationally salient stimuli can drive involuntary capture, then this would result in a revision to the model depicted in Figure 35. It would require greater detail regarding the interaction between VWM storage states and the guidance of attention, as well as whether the importance and expectancy of the background goal can have a direct influence upon the prioritisation of these features enough that they can induce a concurrent involuntary attentional capture (see Figure 37).

Finally, the investigation of the neural substrates goal-driven attention to motivationally salient stimuli. It may be that there is a potential interaction between prefrontal regions, which are related to the maintenance of visual search template, and the amygdala which is indicative of detecting motivationally relevant stimuli, especially threat (Cunningham & Brosch, 2012; Bishop, 2009). Indeed, recent theories of emotional processing have posited that lower level brain regions (e.g. amygdala) are tuned towards specific goal-relevant stimuli from higher level brain regions (e.g. prefrontal cortex; Markovic, Todd & 2014; Cunningham, Van Bavel & Johnson, 2008), meaning that the role that the amygdala has in detecting threat is more flexible than assumed by some models (Le Doux, 1995; 1998; Öhman, 1992). A potential way of investigating this in future would be to use fMRI in combination with the RSVP task used in Chapters 2 and 3. This may reveal amygdala activity only when the threat related distractor is congruent with the current search goal.

Conclusions

In summary, the findings across my thesis reveal that individuals typically believe that motivationally salient stimuli are important to detect and deserving of attentional priority. Further, we also found that across a wide range of reward and threat associated stimuli that an involuntary attentional capture could be induced towards these stimuli if they were congruent with the current search goal. we also found preliminary evidence that this was also true for self-selected goals as well as instructed ones. Taken together, these findings demonstrate that a goal-driven mechanism can plausibly account for capture by motivationally salient stimuli. Building on these findings, we have also developed a new Importance-Expectancy model of attentional goal selection. In this manner, my thesis advances current understanding of goal-driven attention, revealing it to be a process more complex than simply the following of task instructions, which is closely linked to motivation and can have both voluntary and involuntary consequences.

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