Attentional Bias towards Angry Faces in the General Population

Dissertation
zur Erlangung des akademischen Grades eines
Doktors der Naturwissenschaften
der Fakultät HW
Bereich Empirische Humanwissenschaften
der Universität des Saarlandes

vorgelegt von

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aus München

Saarbrücken, 2018

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Tag der Disputation: 19.02.2018

Author note

This thesis is based on several manuscripts that are currently in different stages of the publication process. Chapter 5 is largely identical to a manuscript that has been submitted for publication and is currently under review (Wirth & Wentura, 2017c). Capter 6 is largely identical to a manuscript that has been accepted for publication in *The Quarterly Journal of Experimental Psychology* and is currently available as an advance online publication (Wirth & Wentura, 2017a). Chapter 7 is largely identical to a manuscript that is still in preparation (Wirth & Wentura, 2017b). Therefore, minor redundancies might occur in these chapters. I am the first author of all three manuscripts contained in the present thesis. Nevertheless, the term “we” is employed throughout the thesis to refer to myself and the co-author of these manuscripts (Dirk Wentura).

Acknowledgements

First, I would like to thank my supervisor Dirk Wentura for his constant support throughout the PhD project. He always supported me in pursuing own ideas, but gave me helpful guidance and advise when needed. Whenever a problem occurred, I knew he had an open door.

Furthermore, I would like to thank my colleagues from the Cognition and Action Unit and from the IRTG “Adaptive Minds” for fruitful discussions. Some of the suggestions that came up during these discussions found their way in the work that is presented here.

Moreover, I am thanking my undergraduate assistants, Nancy Fischer and Jonas Hinze. They independently and conscientiously conducted countless testing sessions, which was a great contribution to my studies.

Also, I would like to thank the various proof-readers from Australia, the UK, and the USA who corrected different chapters and thus improved the linguistic quality of the thesis.

Special thanks go to my family, who always helped me in pursuing my goals. Without their constant support throughout my whole life, I would not have been in the position to write this thesis.

Finally, I want to thank Roxanne Sopp for always having my back, for encouraging me to carry on when something did not work out as planned, and for providing me with food when I was at the risk of starvation during long work sessions.

Abstract

The present thesis aimed to resolve a controversy between cognitive psychology and clinical psychology. While cognitive models of emotional attention claim that all individuals show an attentional bias to threat, clinical models of anxiety claim that this bias only occurs in anxious individuals. Therefore, three studies (comprising six experiments in total) were conducted to investigate whether the general population shows a reliable bias towards angry faces. These studies employed several variants of the dot-probe task to identify the determinants for the occurrence of such a bias.

Study 1 investigated whether attentional bias towards angry faces in unselected samples is contingent on a natural confound (exposed teeth) that makes these faces perceptually more salient. We found an anxiety-related bias towards angry faces with concealed teeth, but no bias towards faces with exposed teeth occurred. This result suggests that attentional bias towards angry faces is not contingent on perceptual confounds of these faces.

Study 2 (consisting of three experiments) investigated the impact of top-down processes on attentional bias towards angry faces. Experiment 1 tested the hypothesis that a bias towards angry faces only occurs in unselected samples if an attentional control setting tuned to threat is activated due to current task demands. We found an anxiety-independent bias that was, however, not moderated by attentional control settings. Experiment 2 was a control experiment that ruled out the possibility that due to technical shortcomings of Experiment 1 no moderation by attentional control settings occurred. Experiment 3 tested the alternative hypothesis that attentional bias towards angry faces in unselected samples is contingent on the number of stimuli presented during the target display. Participants performed a dot-probe task involving presentation of a stand-alone target or a target competing with a distractor. A bias towards angry faces only occurred when the target had to compete for attention with a distractor. These results suggest that attentional bias towards angry faces in unselected samples is not contingent on attentional control settings, but on target competition.

Study 3 (consisting of two experiments) tested the hypothesis that attentional bias towards angry faces is contingent on the activation of a social processing mode in unselected samples. Participants performed a dot-probe task where they had to classify socially meaningful targets (schematic faces) or socially meaningless targets (scrambled schematic faces in Experiment 1 and schematic houses in Experiment 2). Consistent with the hypothesis, participants in both experiments showed larger biases towards

angry faces when they were classifying socially meaningful targets than when they were classifying socially meaningless targets.

In sum, the reported studies suggest that the general population can show an attentional bias towards angry faces. However, this bias does not seem to be unconditional. More specifically, the bias seems to be contingent on a search mode for targets that compete for attention with distractors and on the activation of a social processing mode.

Zusammenfassung

Das Ziel der vorliegenden Dissertation ist es, eine Kontroverse zwischen kognitiver Psychologie und klinischer Psychologie aufzuklären. Während kognitive Modelle emotionaler Aufmerksamkeit davon ausgehen, dass alle Personen einen Aufmerksamkeitsbias auf bedrohliche Stimuli zeigen, postulieren klinische Modelle der Ängstlichkeit, dass dies nur bei ängstlichen Personen zutrifft. Zur Klärung dieser Inkonsistenz wurden drei Studien (bestehend aus insgesamt sechs Experimenten) durchgeführt, um zu erforschen, ob die Allgemeinbevölkerung einen Bias auf wütende Gesichter zeigt. Diese Studien wendeten verschiedene Varianten der Dotprobe-Aufgabe an, um die Determinanten des Auftretens eines derartigen Bias zu identifizieren.

Studie 1 erforschte, ob ein Aufmerksamkeitsbias auf wütende Gesichter in unselektierten Stichproben von einer natürlichen Konfundierung (entblößte Zähne) abhängt, die diese Gesichter perzeptuell salienter macht. Es wurde ein ängstlichkeitsbedingter Aufmerksamkeitsbias auf wütende Gesichter mit verdeckten Zähnen, aber nicht auf Gesichter mit entblößten Zähnen gefunden. Dies legt nahe, dass ein Aufmerksamkeitsbias auf wütende Gesichter in unselektierten Stichproben nicht von entblößten Zähnen abhängt.

Studie 2 (bestehend aus drei Experimenten) erforschte den Einfluss von Top-Down Prozessen auf den Aufmerksamkeitsbias auf wütende Gesichter. Experiment 1 testete die Hypothese, dass ein Bias auf wütende Gesichter nur dann in unselektierten Stichproben auftritt, wenn ein Aufmerksamkeitskontrollsetting, das auf Bedrohlichkeit ausgerichtet ist, aufgrund gegenwärtiger Aufgabenanforderungen aktiv ist. Es zeigte sich ein ängstlichkeitsunabhängiger Aufmerksamkeitsbias, der jedoch nicht durch Kontrollsettings moderiert wurde. Die Möglichkeit, dass der fehlende Effekt der Kontrollsettings in Experiment 1 eine Folge unpassender Experimentalparameter war, wurde über ein Kontrollexperiment (Experiment 2) ausgeräumt. Experiment 3 testete die Alternativhypothese, dass ein Aufmerksamkeitsbias auf wütende Gesichter in unselektierten Stichproben von der Anzahl der im Zielreizbildschirm präsentierten Stimuli abhängt. Die Probanden absolvierten eine Dotprobe-Aufgabe, bei der der Zielreiz entweder einzeln oder gemeinsam mit einem Distraktor präsentiert wurde. Ein Bias auf wütende Gesichter trat nur dann auf, wenn der Zielreiz gleichzeitig mit einem Distraktor präsentiert wurde. Diese Ergebnisse legen nahe, dass der Aufmerksamkeitsbias auf wütende Gesichter in unselektierten Stichproben nicht von

Kontrollsettings abhängt, sondern davon, ob der Zielreiz mit einem Distraktor um Aufmerksamkeit konkurrieren muss.

Studie 3 (bestehend aus zwei Experimenten) testete die Hypothese, dass der Aufmerksamkeitsbias auf wütende Gesichter bei unselektierten Stichproben von der Aktivierung eines sozialen Verarbeitungsmodus abhängt. Die Probanden absolvierten eine Dotprobe-Aufgabe, bei der sie entweder sozial bedeutsame Zielreize (schematische Gesichter) oder sozial bedeutungslose Zielreize (durcheinandergebrachte schematische Gesichter in Experiment 1 und schematische Häuser in Experiment 2) klassifizieren sollten. Entsprechend der Hypothese zeigten die Probanden einen stärkeren Bias auf wütende Gesichter während der Klassifikation von sozial bedeutsamen Zielreizen als während der Klassifikation von sozial bedeutungslosen Zielreizen.

Zusammengefasst zeigen die beschriebenen Studien, dass die Allgemeinbevölkerung durchaus einen Bias auf wütende Gesichter zeigen kann. Das Auftreten dieses Bias scheint jedoch an gewisse Voraussetzungen gebunden zu sein. Insbesondere scheint der Bias davon abzuhängen, dass nach Zielreizen gesucht wird, die mit Distraktoren um Aufmerksamkeit konkurrieren müssen, sowie von der Aktivierung eines sozialen Verarbeitungsmodus.

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ADM	Affective Decision Mechanism
GES	Goal Engagement System
RAM	Resource Allocation Mechanism
RT	Response Time
SOA	Stimulus Onset Asynchrony
T1	Target 1 (within the attentional-blink paradigm)
T2	Target 2 (within the attentional-blink paradigm)
TES	Threat Evaluation System
VES	Valence Evaluation System

1 Introduction and overview: A dangerous encounter at night

Imagine you are absentmindedly walking through a dark forest at night. Suddenly, from the corner of your eye, you notice two glaring dots staring at you from the underwood. Immediately, your ongoing thoughts are interrupted, your body becomes tense as your muscles start to contract, and you intensely focus on the dark creature while it quickly approaches you. A few seconds later, as the beast leaps out of the shadows, you realise that it is only a cat in desperate need of affection. While the cat clings to your legs, you start to wonder why the two glaring dots in the dark caused you to elicit such a strong reaction on a cognitive, physiological, and behavioural level. As you think about the encounter, you find it surprising that you even noticed the cat's eyes at all. Why did you notice them even so you were absorbed in thought and not paying much attention to your environment at the time of the "attack"? And why did these two tiny dots among all the other things that surround you in the forest capture your attention?

There is not only anecdotal evidence that potential threats might be potent stimuli to capture visual attention in humans. Indeed, a large amount of psychological research has investigated the influence of stimuli that are associated with threat on visual attention (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Yiend, 2010 for reviews). While there is broad consensus that threatening stimuli affect visual attention in some way, the specific mechanisms that underlie this process are still debated. For example, if we return to the anecdotal example given above, how exactly did the eyes of the cat capture your attention? Would they, for example, also capture your attention if they did not glow in the dark and were thus not such a salient stimulus in the nocturnal forest. Would they also capture your attention in a different environment than a nocturnal forest, for example, in a crowded underground station? Would they still capture your attention while you are looking for the red signs that mark the way to the specific line you want to take at this underground station? Or did the cat's eyes, maybe, just capture your attention because you are a rather anxious person whereas a calmer person might not have noticed the cat at all?

These questions provide a rough impression of the motivation for the present studies. More specifically, the thesis aims to investigate whether the general population shows an attentional bias towards threatening stimuli and if so, under which conditions this bias occurs. The thesis comprises three studies consisting of six experiments in total. In these six experiments, we assessed attentional bias towards angry (i.e., threatening) faces under varying conditions using different variants of the dot-probe task. This experimental paradigm was originally proposed by MacLeod, Mathews, and Tata (1986) and is widely used in clinical psychology and experimental psychopathology to assess attentional biases towards threatening stimuli (see Frewen, Dozois, Joanisse, & Neufeld, 2008 for a meta-analytic review on the paradigm).

Chapter 2 describes a controversy between two psychological subdisciplines regarding the question whether humans generally show an attentional bias towards threatening stimuli. Whereas theories from cognitive psychology often claim that all human individuals show an attentional bias to threat, many theories from clinical psychology claim that attentional bias to threat only occurs in anxious individuals, but not in the general population. The chapter gives a brief description of these theories and discusses the extent to which the individual theories are supported by empirical evidence. Chapter 3 describes experimental paradigms that are used to investigate attentional bias to threat and demonstrates—in light of basic visual attention research—why different paradigms might yield different results when investigating the phenomenon of attentional bias to threat. Chapter 4 gives a brief overview of the conducted studies, their specific research questions, and their experimental parameters.

Chapter 5 investigates the question whether attentional bias towards angry faces is moderated by the perceptual saliency of these faces. Participants performed a dot-probe task with two types of angry faces. One type of angry faces was salient due to a natural perceptual confound (exposed teeth) whereas the other type of angry faces did not have this confound (concealed teeth) and was therefore less salient. Consistent with previous dot-probe studies, we found an attentional bias towards angry faces for anxious, but not for non-anxious participants. More importantly however, this bias occurred for perceptually unconfounded angry faces and can therefore not be attributed to mere perceptual saliency.

Chapter 6 describes three experiments investigating top-down influences on attentional bias towards angry faces. Contingent-capture theory claims that so-called attentional control settings are tuned to specific feature values according to current tasks and goals. Thus, an irrelevant stimulus will only capture attention if it matches an attentional control setting (Folk, Remington, & Johnston, 1992). Therefore, we tested the hypothesis that attentional bias towards angry faces is contingent on the activation of an attentional control setting tuned to threat in unselected samples. Participants performed a dot-probe task with two types of target stimuli to activate corresponding attentional control settings. More specifically, participants had to classify schematic target faces that were either defined by an angry expression (threat set) or by an open mouth (control set). We found an anxiety-independent bias towards angry faces, which is remarkable by itself because dot-probe studies usually find an attentional bias to threat only in anxious participants (Bar-Haim et al., 2007). Surprisingly however, this bias was not moderated by attentional control settings. Therefore, we conducted two further experiments to clarify the reasons for the occurrence of this bias. First, we conducted a control experiment where we replicated typical contingent-capture effects for cues and targets of matching and non-matching colours. This replication rules out the possibility that technical shortcomings of the previous experiment were responsible for the absence of any contingent-capture effects. We presented two stimuli (i.e., one target and one distractor) on the target display in the first experiment, (a necessity for the activation of control settings), but most dot-probe studies only employ a single target. Therefore, we conducted an experiment to test the hypothesis that attentional bias in the general population is contingent on the number of stimuli presented during the target display. Participants performed a dot-probe task involving presentation of a stand-alone target or a target competing with a distractor. Participants only showed an attentional bias towards angry faces when they were classifying targets that competed for attention with a distractor. This result suggests that attentional bias towards angry faces is not contingent on an attentional control setting tuned to threat, but on target competition.

However, there was another potential explanation for the obtained result pattern. In those experimental conditions where participants showed an attentional bias towards angry faces, they were performing a task that required social processing of the target stimuli. Therefore, the study reported in Chapter 7 was conducted to test the hypothesis that an attentional bias towards angry faces is contingent on the activation of a social processing mode in unselected samples. We conducted two dot-probe experiments where participants had to classify target stimuli that were either socially meaningful or meaningless. In both experiments, participants showed larger attentional biases towards angry faces when socially meaningful targets had to be classified. This suggests that attentional bias towards angry faces is contingent on the activation of a social processing mode in unselected samples. In Chapter 8, a summary and comprehensive analysis of the results is given. Moreover, limitations and open questions of the present studies are discussed.

2 A peculiar inconsistency between cognitive and clinical psychology

An interesting observation marked the origin of the present dissertation project. A large amount of psychological research discusses the effects of threatening stimuli on human visual attention (see Bar-Haim et al., 2007; Yiend, 2010 for reviews). However, within this research, two large groups of studies make claims about this subject that are clearly inconsistent to one another. On the one hand, studies on emotional attention from the field of cognitive psychology claim that all human individuals show an attentional bias towards threatening stimuli in their environment. On the other hand, studies on anxiety from the field of clinical psychology often state that only anxious individuals (both clinical and sub-clinical) show an attentional bias to threat whereas the general population does not. This inconsistency between the two psychological subdisciplines is particularly unusual for three reasons. First, both fields generated numerous elaborate and plausible theories to explain their respective claims. Second, both fields have reported a large amount of empirical evidence that seems to support their respective claims and theories. Third, within those two fields, this inconsistency seems to be hardly noticed at all. Neither of the two subdisciplines seems to address research from the other discipline, either in an attempt to refute the other side or in an attempt to integrate and reconcile both views. The present work aims to resolve this clear inconsistency between cognitive and clinical psychology. Based on concepts and methods from both subdisciplines, we investigated whether the general population shows an attentional bias towards threatening stimuli; and if so, under which conditions this bias occurs in the general population. Moreover, by identifying the conditions necessary for the occurrence of this bias, we aimed to explain the inconsistent results found by the two psychological subdisciplines. The following sections contain a brief overview on theories from both subdisciplines and their respective empirical support.

2.1 Cognitive models of emotional attention

The most prominent models of emotional attention from the field of cognitive psychology are the fear-module theory, circumplex-based models, and appraisal-based models (see also Pool, Brosch, Delplanque, & Sander, 2016 for a meta-analytic review of these models). As already discussed, all of these models claim that attention is biased towards threatening stimuli in all human individuals. However, they assume that different mechanisms underlie this bias.

The fear-module theory is derived from the categorical view on emotions, which claims that a small set of universal basic emotions exist that each are characterised by discrete psychological mechanisms and neural signatures (Ekman, 1992). Based on this assumption, fear-module theory claims that evolutionary pressure has formed a distinct module in the human cognitive system that preferentially reacts to stimuli that posed a threat to survival during human phylogeny (e.g., predators). This module is automatically activated by threatening stimuli and cannot be controlled by voluntary cognitive effort (Öhman & Mineka, 2001). According to this theory, threatening stimuli capture attention in all humans because it was an evolutionary advantage to quickly detect potential threats in one's environment and be able to execute appropriate behaviour to secure one's survival. Empirical evidence for this theory comes mainly from experiments based on the visual search paradigm (see Bacon & Egeth, 1994; Theeuwes, 2004; Wolfe, 1994 for descriptions of the basic paradigm). For example, Öhman, Fykt, and Esteves (2001) showed that participants were quicker to detect potentially dangerous animals (snakes and spiders) among non-threatening plants (flowers and mushrooms) than vice versa. Moreover, dangerous animals seemed to be processed pre-attentively because search time for snakes and spiders were not affected by the number of simultaneously presented plant distractors. Moreover, numerous studies using the face-in-the-crowd paradigm also support the fear-module theory. In this paradigm, participants are asked to search for a target face showing a specific or a discrepant expression among a set of distractor faces showing a different emotion. These studies often found that search for angry faces was more efficient than search for faces with other emotional expressions, a result often referred to as the "anger-superiority effect" (Fox et al., 2000; Hahn & Gronlund, 2007; Horstmann & Bauland, 2006; Moriya, Koster, & De Raedt, 2014; Pinkham, Griffin, Baron, Sasson, & Gur, 2010).[1] This finding is usually interpreted in terms of an attentional bias towards angry (i.e., threatening) faces that facilitates detection of these faces.

Another model of emotional attention is derived from the circumplex theory of emotion. In contrast to the categorical view on emotions, this model assumes that all emotions can be described by two underlying dimensions, valence and arousal (Russell & Fehr, 1987). For example, anger would be characterised by negative valence and high

[1] This is only a rough summary of the diverse and complex results obtained with the face-in-the-crowd paradigm. A more detailed description of these results is given in section 3.2.1

arousal whereas happiness would be characterised by positive valence and high arousal. The attentional model derived from this theory claims that arousal is the critical dimension that drives attentional bias towards emotional stimuli. Thus, positive stimuli should also attract attention if they are associated with high arousal. Support for this assumption comes from the attentional-blink paradigm. In this paradigm, stimuli are serially presented in rapid succession (usually approximately 100 ms per stimulus). Two of those stimuli are targets to which participants have to respond, while the rest of the stimuli are irrelevant distractors. The lower the number of distractors presented between target 1 (T1) and target 2 (T2) is (i.e., the shorter the temporal lag between T1 and T2), the more errors participants make responding to T2.[2] A common explanation for this effect is that the processing of T1 requires attentional resources, which are not available for the processing of T2 when both targets are presented in temporal proximity (e.g., Folk, Leber, & Egeth, 2002; Wyble, Folk, & Potter, 2013; but see also Olivers & Meeter, 2008). Thus, this impairment of response accuracy for T2 is referred to as *attentional blink*. Anderson (2005) found that the attentional blink was reduced for negative T2 stimuli compared to neutral T2 stimuli. However, the smallest attentional-blink effect occurred for negative T2 stimuli that were also associated with a high arousal. Moreover, positive T2 stimuli that were characterised by a high arousal were also less affected by attentional blink than neutral T2 stimuli. Therefore, the author argues that the allocation of processing resources is mainly driven by arousal, not by valence. Consistently, patients with a left-lateralised lesion of the amygdala—a subcortical structure selectively sensitive to stimulus arousal, but not valence (Kensinger & Corkin, 2004)—did not show a modulation of the attentional blink for threatening stimuli (Anderson & Phelps, 2001).

The third model of emotional attention is derived from appraisal theories of emotion. This group of theories postulate that emotional episodes are caused or elicited by *appraisal*. Appraisal is considered to be a permanent process that assesses the impact of the environment on one’s own well-being. More precisely, this process estimates whether specific environmental stimuli satisfy or obstruct so-called *concerns* of the individual. These concerns include the individual’s needs, values, motives, and current goals (see Moors, Ellsworth, Scherer, & Frijda, 2013 for a review). Importantly, concerns are considered to be a much broader concept than simple temporary goals that

[2] However, when T2 immediately follows T1, response accuracy to T2 is hardly impaired. This effect is referred to as *lag 1 sparing*.

can be experimentally induced by current task demands. According to the model of emotional attention derived from this group of theories, all stimuli that are of significance for the individual's concerns should capture attention. Notably, these stimuli can be both negative and positive. In line with this assumption, Brosch, Sander, Pourtois, and Scherer (2008) found an attentional bias both towards angry faces and towards baby faces in a dot-probe task. Additionally, a recent meta-analysis indicates that humans show a moderate, but reliable attentional bias towards positive emotional stimuli as compared to neutral stimuli. Moreover, the meta-analysis showed that personal relevance is a significant predictor for the magnitude of attentional bias towards positive stimuli (Pool et al., 2016).

All of the three models presented above assume different mechanisms that underlie attentional biases towards environmental stimuli. Therefore, these models make partially inconsistent predictions regarding the debate as to which specific stimuli capture visual attention. Importantly, however, all three models assume that the general population shows an attentional bias towards threatening stimuli, because threatening stimuli trigger an evolutionary-formed fear module (fear module theory), because they are associated with a high arousal (circumplex theory of emotion), or because they are of general relevance for the individual's concerns—in this case for the need for safety (appraisal theories of emotion).

2.2 Clinical models of anxiety

As already discussed, the second group of studies that investigated attentional bias to threat consists of clinical research on anxiety. In contrast to cognitive models on emotional attention, this research usually claims that only anxious individuals show an attentional bias towards threatening stimuli, but the general population does not. There are numerous clinical models on the impact of trait anxiety on attentional bias to threat. For the sake of brevity and readability, only the three most influential of those models are discussed in the present chapter.[3] These are the two-stage theory (Williams, Watts, MacLeod, & Mathews, 1988), the cognitive-motivational analysis of anxiety (Mogg et al., 2000; Mogg & Bradley, 1998), and the model by Mathews and Mackintosh (1998).

[3] Interested readers are referred to extensive review articles on that topic for a more exhaustive and detailed description of clinical models on the relationship between anxiety and attentional bias to threat (Cisler & Koster, 2010; Weierich, Treat, & Hollingworth, 2008; Yiend, 2010).

According to the two-stage theory (Williams et al., 1988), two mechanisms underlie the relationship between anxiety and attentional bias to threat. First, the threat value of incoming environmental stimuli is assessed by an *Affective Decision Mechanism* (ADM). The output of the ADM feeds into a *Resource Allocation Mechanism* (RAM), which deploys processing resources across incoming stimuli. The theory assumes that state anxiety affects primarily the ADM. That is, identical environmental stimuli will be assigned higher threat values when the individual is in an anxious mood versus when the individual is in a calm mood. In contrast, trait anxiety affects mainly the RAM. The theory assumes that in anxious individuals, the RAM allocates attention towards threatening stimuli whereas in non-anxious individuals, the RAM allocates attention away from threatening stimuli. Moreover, the theory claims that differences between anxious and non-anxious individuals become more apparent with increasing output from the ADM. Thus, anxious individuals should show a larger attentional bias for stimuli with high perceived threat intensity than for stimuli with low perceived threat intensity. In contrast, non-anxious individuals should become more avoidant of threatening stimuli with increasing threat intensity. The latter prediction, however, seems rather counterintuitive because a system that directs attention away even from severe threats (e.g., an armed assailant) is dysfunctional.

The cognitive-motivational analysis of anxiety (Mogg et al., 2000; Mogg & Bradley, 1998) addresses this issue. Similar to the two-stage theory, the cognitive-motivational analysis assumes that two mechanisms drive attentional bias to threat. First, a *Valence Evaluation System* (VES) assesses the threat value of an incoming stimulus (similar to the ADM in the two-stage theory). However, the cognitive-motivational analysis emphasises that this threat-value assessment is not only driven by perceptual characteristics of the stimulus itself, but also by numerous other variables (e.g., the context of the stimulus, or past learning experiences of the individual). Output from the VES feeds into a *Goal Engagement System* (GES). If a stimulus is assessed to have a high threat value, the GES interrupts ongoing activity of the individual and allocates attention towards the potential threat. If, however, an incoming stimulus is assigned a low threat value by the VES, the GES allocates processing resources away from that incoming stimulus to maintain attention on current goals and tasks. Thus, the GES works analogously to the ADM of the two-stage theory. In contrast to the two-stage theory, however, the cognitive-motivational analysis assumes that trait anxiety affects the VES (i.e., the system that assesses the threat value of incoming stimuli and not the system that subsequently deploys processing resources across stimuli). Specifically, the cognitive-motivational analysis assumes that anxious individuals have an extremely sensitive VES. Thus, anxious individuals also tag moderately negative stimuli that non-anxious individuals would consider to be unimportant with a relatively high threat value. Consequently, the theory assumes that differences in attentional bias between anxious and non-anxious individuals should decrease with increasing threat intensity. Whereas only anxious individuals should show an attentional bias towards moderately threatening stimuli, both anxious and non-anxious individuals should show a bias towards highly intense threat stimuli.

The model proposed by Mathews and Macintosh (1998) emphasises the role of competition for attention between multiple stimuli. Thus, it claims that differences between anxious and non-anxious individuals in response to threatening stimuli should only occur when at least two stimuli compete for a thorough representation and elaborate processing in the cognitive system (see also Desimone & Duncan, 1995). According to this model, danger-related attributes of events or stimuli are stored in a *Threat Evaluation System* (TES), either due to biological preparedness or due to previous learning experiences. During early and non-conscious processing stages, incoming stimuli are matched with danger-related attributes stored in the TES. When a stimulus matches a danger-related attribute, it receives attentional priority. Furthermore, the model assumes that trait anxiety lowers the threshold at which the TES produces output. Thus, similar to the cognitive-motivational analysis, the model predicts that non-anxious individuals can show an attentional bias towards severely threatening stimuli because the TES will always produce output if the threat intensity is high enough. In contrast to the cognitive-motivational analysis, however, the model by Mathews and Macintosh proposes a second system that can oppose the TES. Via a *task-demand unit*, top-down control processes that require voluntary effort can prioritise processing of task-relevant stimuli (targets) and thus counteract the tendency to attend to a threatening but irrelevant stimulus.

These clinical models on anxiety assume different underlying mechanisms for the relationship between trait anxiety and attentional bias to threat. Moreover, they make partially different predictions. While the two-stage theory predicts that non-anxious individuals should avoid stimuli with extremely high threat intensities, the remaining two models predict an attentional bias towards such stimuli in non-anxious individuals. However, for practical, technical, and ethical reasons, psychological experiments on attention usually employ pictorial stimuli presented on a computer screen. Thus, these stimuli naturally have only moderate threat intensities (when compared to real-life threats).[4] For these kinds of moderately threatening stimuli, all three of the discussed clinical models predict the same pattern of results. Anxious participants should show an attentional bias towards threatening stimuli, but non-anxious participants should fail to show this bias (or even show attentional avoidance of threat). Numerous clinical studies that employed different paradigms like the emotional Stroop task, the dot-probe task, and emotional spatial cueing found exactly this result pattern (see Bar-Haim et al., 2007; Frewen et al., 2008 for meta-analyses). Thus, the results of these clinical studies are inconsistent with the results of the aforementioned studies from cognitive psychology, which found an attentional bias towards threatening stimuli in unselected samples (which are assumed to represent the general population and thus to consist mainly of non-anxious individuals).

[4] Studies that systematically attempt to vary the threat intensity of the presented stimuli are very rare (e.g., Mogg et al., 2000).

3 Experimental paradigms for the assessment of attentional bias to threat

As discussed in the previous chapter, numerous studies from clinical psychology found an attentional bias towards threatening stimuli only in anxious participants, whereas many studies from cognitive psychology found a threat bias also in the general population. However, the two disciplines usually use different paradigms to assess attentional bias to threat. While cognitive psychology mostly applies visual-search paradigms (like the face-in-the crowd task) and the attentional-blink paradigm, clinical psychology mostly applies the emotional Stroop task, the dot-probe task, and emotional spatial cueing. The use of different experimental paradigms might explain why the two disciplines yield different results and thus reach different conclusions regarding the occurrence of attentional bias to threat in the general population. The present chapter gives an overview of the experimental paradigms most commonly used to assess attentional bias to threat. Moreover, it describes the underlying processes that might be responsible for the inconsistent results between these paradigms. In general, paradigms for the assessment of attentional bias to threat can be divided into two groups, spatial paradigms and non-spatial paradigms. In non-spatial paradigms, all stimuli are presented in the same screen location. Thus, these paradigms cannot make any inferences about the spatial allocation of visual attention, but only on the effects of threatening stimuli on non-spatial aspects of attention. In contrast, in spatial paradigms, all stimuli (both target stimuli and task-irrelevant stimuli) can be presented in at least two different locations. Therefore, these paradigms require participants to shift their spatial attention to different locations to solve the task. Consequently, these paradigms can draw inferences about the effects of threatening stimuli on the spatial deployment of attention. Since the aim of the present thesis is to investigate whether threatening stimuli attract spatial attention, this chapter focuses on spatial paradigms while non-spatial paradigms are discussed only briefly.

3.1 Non-spatial paradigms

The most common non-spatial paradigms for the assessment of attentional bias to threat are the emotional Stroop task and the attentional-blink paradigm. In the emotional Stroop task, threatening and non-threatening words are presented centrally on a screen. Participants are asked to name the font colour of these words as fast as possible (e.g., Everaert, Spruyt, & De Houwer, 2013; Frings, Englert, Wentura, & Bermeitinger, 2010). Usually, anxious participants are faster to name the colour of non-threatening words than of threatening words (Bar-Haim et al., 2007; Yiend, 2010). The common interpretation of this effect is that anxious participants automatically attend to the emotional content of threatening words instead of the task-relevant word colour. In contrast, anxious participants do not automatically attend to the non-emotional content of neutral words and can therefore respond faster to the word colour. However, since both word colour and word content are presented in the same screen location, the paradigm does not require participants to perform spatial shifts in attention. Therefore, the emotional Stroop task assesses attentional filtering at best because participants have to filter out the task irrelevant word content (Yiend, 2010). At worst, the emotional Stroop task does not assess attentional processes at all, but entirely response-related processes. For example, it is possible that slowed responses to threatening words represent a kind of freezing mechanism that inhibits ongoing motor activity in the presence of threat (Mogg, Holmes, Garner, & Bradley, 2008; Mulckhuyse & Crombez, 2014).

The second common non-spatial paradigm is the attentional-blink paradigm, which was already briefly described in the previous chapter. In the attentional-blink paradigm, multiple stimuli are presented in a rapid serial succession (usually approximately 100 ms per stimulus) on each trial. Participants are asked to respond to two target stimuli; the rest of the presented stimuli are irrelevant distractors. Generally, response accuracy to the second target (T2) decreases with increasing temporal proximity to the first target (T1). That is, the fewer distractor stimuli are presented between T1 and T2, the lower the response accuracy to T2 becomes. However, when T2 immediately follows T1, response accuracy to T2 is not impaired, an effect referred to as *lag 1 sparing*. Common explanatory approaches (e.g., Folk et al., 2002; Wyble et al., 2013) assume that the processing of T1 depletes attentional resources that are not available for the processing of T2 if both targets are presented in temporal proximity (i.e., an attentional "blink" occurs after processing of T1). It is assumed that lag 1 sparing is the result of a process of attentional enhancement that is triggered by T1 and precedes the attentional blink. This process peaks at approximately 150 ms after the onset of T1. Thus, if T2 is presented immediately after T1, it falls within the timeframe of the attentional enhancement process. If T2 is presented a bit later, it falls within the timeframe of the attentional blink. In contrast, the boost-and-bounce theory (Olivers & Meeter, 2008) assumes that the attentional blink is not caused by depleted processing resources. Instead, it assumes that attention enhances ("boosts") visual input in an excitatory manner when a relevant stimulus (i.e., a target) is encountered. In contrast, attention blocks ("bounces") visual input in an inhibitory manner when an irrelevant stimulus (i.e., a distractor) is encountered. When T1 is presented, excitatory activation is triggered to allow T1 to enter working memory. Crucially, it takes approximately 100 ms for the excitatory activation to accumulate. Thus, the peak of activation occurs when the stimulus succeeding T1 is presented. If the stimulus succeeding T1 is T2, it benefits from the excitatory activation triggered by T1 and receives enhanced access to working memory (which explains lag 1 sparing). However, if the stimulus succeeding T1 is a distractor, irrelevant information enters working memory. In response to that, attention inhibits the access of the visual input to working memory. Since it takes some time for inhibition to accumulate, the peak of inhibition occurs during the presentation of the next stimulus, which is blocked from entering working memory. Consequently, if that stimulus is T2, response accuracy for T2 is dramatically reduced (attentional blink). Over time, as the strong transient inhibition triggered by the distractor succeeding T1 gradually decreases, performance gradually improves.

Importantly, the attentional blink is affected by the valence of the target stimuli. If T1 is a threatening stimulus, no lag 1 sparing occurs, that is the attentional blink occurs faster (Sigurjónsdóttir, Sigurðardóttir, Björnsson, & Kristjánsson, 2015). If T2 is a threatening stimulus, response accuracy to T2 is generally less affected by the temporal proximity to T1, that is, participants recover faster from the attentional blink (Anderson, 2005; Sigurjónsdóttir et al., 2015). These findings suggest that processing resources are preferentially allocated to threatening stimuli and that the processing of neutral stimuli presented in temporal proximity to these threatening stimuli is suppressed. However, since in the attentional-blink paradigm, all stimuli are presented in the same location, participants do not have to perform spatial shifts of attention to perform the task. Thus, this paradigm can draw inferences about the effects of threatening stimuli on the temporal dynamics of attention, but not on the spatial deployment of attention.

3.2 Spatial paradigms

As just discussed, it is not entirely clear whether different non-spatial paradigms assess the same aspects of attention (if they assess attentional processes at all). Thus, it does not seem surprising that non-spatial paradigms yield inconsistent results regarding the question as to whether the general population shows an attentional bias to threat. In contrast, all spatial paradigms claim to assess the effects of threatening stimuli on the spatial allocation of attention. Therefore, it is rather unexpected that paradigms based on visual search (e.g., the face-in-the-crowd paradigm) usually find an attentional bias towards threatening stimuli in the general population whereas the dot-probe task and emotional spatial cueing usually find this bias only in anxious participants. Furthermore, there exists a disagreement between dot-probe studies and emotional spatial-cueing studies regarding which specific aspect of spatial attention is biased to threat in anxious individuals. The following sections give a detailed description of these paradigms and show how methodological differences inherent to these paradigms might be responsible for the inconsistent results.

3.2.1 The face-in-the crowd paradigm and related variants of visual search

Visual search is one of the most influential paradigms in basic attention research. In this paradigm, participants are asked to search for a target stimulus among several distractor stimuli. For example, participants are presented several green and red bars in horizontal and vertical orientations and are asked to indicate whether a vertical green bar (target) is present or absent. Critically, the number of distractor stimuli (in this case all horizontal green bars, vertical red bars, and horizontal red bars) is varied between trials. Inferences about attentional processes are drawn by analysing the reaction times required for target detection as a function of the number of simultaneously presented distractors (e.g., Bacon & Egeth, 1994; Theeuwes, 2004; Treisman & Gelade, 1980; Wolfe, 1994). For example, a green target among only red distractors is so salient that it is immediately found, no matter how many red distractors are presented; thus, the green target is said to “pop out” from its environment (Hancock & Phillips, 2004; Theeuwes, 2004; Theeuwes, Atchley, & Kramer, 2000; Wolfe, 1994). In contrast, it is far more difficult to find the vertical green bar in the example given above and attention is deployed in a rather serial fashion on each stimulus until the target is found (Treisman & Gelade, 1980; Wolfe, 1994). Thus, the more distractors present, the longer it takes to find the target. The number of items presented on one trial (i.e., target + distractors) is referred to as *set size* or *display size*. By varying the set size between trials, researchers can estimate how much search time increases on average when one additional (distractor) item is added to the display. These estimated increases in search times are referred to as *search slopes*. If search slopes for a specific target are smaller than 10 ms per item, search is considered to be *efficient*. If search slopes for a specific target are larger than 20 ms per item, search is considered to be *inefficient* (Wolfe, 1998). Attentional capture by a specific stimulus is inferred if search for that stimulus is efficient (i.e., if search times for that stimulus in a given context are hardly affected by the number of presented items).

In the emotional variant of visual search, participants are asked to search for either a threatening target among neutral (or positive) distractors or for a neutral (or positive) target among threatening distractors. However, the criterion for the presence of an attentional bias is more liberal than in the original paradigm. Thus, it is not necessary that search for a threatening stimulus is efficient in the strict sense in order to infer that this threatening stimulus is processed in a prioritised manner. Instead, an attentional bias towards threatening stimuli is inferred, given that either two of the following criteria is met: (1) if participants are faster to detect a threatening target among neutral (or positive) distractors than to detect a neutral (or positive) target among threatening distractors; (2) if search slopes for finding a threatening target among neutral (or positive) distractors are smaller than search slopes for finding a neutral (or positive) target among threatening distractors (i.e., if search for a threatening target is more efficient than for a neutral or positive target). Thus, the emotional variant of visual search aims to detect *search asymmetries* between threatening and non-threatening targets.

The emotional variant of visual search has been conducted with different kinds of stimuli, such as with dangerous animals (Öhman, Flykt et al., 2001) and with threatening words (Rinck & Becker, 2005). However, the most common variant is the face-in-the-crowd paradigm that employs emotional faces as stimuli (see Frischen, Eastwood, & Smilek, 2008 for a review). Participants are asked to search for a face displaying a specific or a discrepant emotion among a crowd of distractor faces. For example, participants would be presented a crowd of happy faces and would be asked whether there is an angry face / a non-happy face among them. Numerous studies employing both photographic faces (Horstmann & Bauland, 2006; Moriya et al., 2014; Pinkham et al., 2010) and schematic faces (Fox et al., 2000; Hahn & Gronlund, 2007; Öhman, Lundqvist, & Esteves, 2001) as stimuli have found a search advantage for angry faces compared to faces with different expressions—a finding often referred to as the *anger-superiority effect*. The anger-superiority effect is usually interpreted in terms of an attentional bias towards threatening faces that facilitates search for angry faces among happy (or neutral) faces and impairs search for happy (or neutral) faces among angry faces. Thus, the reliable occurrence of the anger-superiority effect in unselected samples supports the claim that the general population shows an attentional bias towards threatening stimuli.

For two reasons, however, fast search times for angry faces in the face-in-the-crowd paradigm might not actually reflect an unconditional attentional bias towards those faces. First, angry faces could be more salient than faces with other emotions due to bottom-up perceptual confounds. Second, since participants are asked to search for angry faces, these faces gain task relevance. Thus, voluntary top-down processes might be activated that help guide attention to potential target candidates.

3.2.1.1 Perceptual confounds of emotional expressions

The anger-superiority effect was first reported by Hansen and Hansen (1988). In three experiments, they showed faster search for angry faces among neutral and happy faces than vice versa. Moreover, they even found efficient search for angry faces in the strict sense; that is, search times for angry faces were not at all affected by the number of presented distractor faces. However, a later re-examination showed that these results were merely caused by perceptual confounds of the employed face stimuli (Purcell, Stewart, & Skov, 1996). Hansen and Hansen (1988) used sketch-like black-and-white pictures[5] of only two identities in the critical experiments (Experiments 2 and 3) and both angry faces were characterised by conspicuous black patches in the chin area. Purcell et al. (1996) could not replicate the initial results with unconfounded greyscale pictures of the same faces. Thus, it seems that the efficient search for angry faces in Hansen and Hansen’s (1988) study was entirely caused by the perceptual salience of these faces.

More recent studies have found anger-superiority effects using facial stimuli that did not have artificially created perceptual confounds (Horstmann & Bauland, 2006; Moriya et al., 2014; Pinkham et al., 2010). However, several other studies have found the opposite result of the anger-superiority effect, that is, a search advantage for happy faces over angry faces (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Juth, Lundqvist, Karlsson, & Öhman, 2005). Even a recent meta-analysis claims that for photographic faces (as opposed to schematic faces), search for happy expressions is

[5] These sketch-like black-and-white pictures were similar to the iconic Mooney Faces (Mooney, 1957).

generally more efficient than search for angry expressions (Nummenmaa & Calvo, 2015). A potential explanation for these inconsistent results is that facial expressions can have natural perceptual confounds that are easily detected in a crowd, such as the high luminance of exposed teeth in an angry snarl or in a toothy grin (Horstmann, Lipp, & Becker, 2012), or the high luminance of the exposed sclera in a fearful stare (Hedger, Adams, & Garner, 2015). Consistently, Horstmann and Bauland (2006) found a search advantage for angry faces and this search advantage also occurred when all facial features except the mouth were removed from the stimuli. Conversely, Calvo and Nummenmaa (2008) found a search advantage for happy faces and this search advantage also occurred when only isolated mouths were presented. Since isolated mouths hardly convey any emotional expression, these findings can only be explained by the perceptual properties of the mouth regions of the respective stimuli employed by the two studies. The finding that differences in search efficiency between specific emotional expressions are hardly affected by face inversion also suggests that these differences are caused by isolated facial features and not by a holistic emotional impression conveyed by these faces (Savage & Lipp, 2015). Moreover, Savage, Lipp, Craig, Becker, and Horstmann (2013) found a search advantage for angry faces when using faces from a stimulus database where angry faces are particularly salient, but a search advantage for happy faces when using faces from a database where happy faces are particularly salient. Additionally, Horstmann et al. (2012) showed that search advantages for specific emotions are largely caused by the perceptual saliency of exposed teeth. When happy faces had exposed teeth while angry faces did not, search was more efficient for happy faces. Conversely, when angry faces had exposed teeth while happy faces did not, search was more efficient for angry faces.

These findings suggest that the anger-superiority effect found by face-in-the-crowd studies using photographic face stimuli (e.g., Horstmann & Bauland, 2006;

Moriya et al., 2014; Pinkham et al., 2010) should be interpreted cautiously.[6] The search advantage in these studies was probably caused by natural perceptual confounds of the angry faces employed in these studies and not by the threatening nature of the angry faces. However, an anger-superiority effect has been consistently found in studies employing schematic faces (see Nummenmaa & Calvo, 2015 for a meta-analysis), which are highly standardised (hence unconfounded) stimuli. However, when face-in-the-crowd studies employ schematic faces, all distractors are identical; so, the whole stimulus array becomes extremely homogenous. Thus, participants can also apply an "odd-one-out strategy" by searching for the only stimulus that is different than the remaining stimuli. Thus, Öhman, Lundqvist et al. (2001) found that both happy and angry schematic faces popped out from a crowd of neutral schematic faces because the curved lines of the target faces were easily detectable among the straight lines of the distractor faces. Moreover, Horstmann and Becker (2008) argued that anger-superiority effects in studies with schematic faces might occur because happy schematic faces are perceptually less complex than angry schematic faces (e.g., because the line of the mouth runs parallel to the outline of the face). Thus, happy distractor faces can be rejected faster than angry distractor faces and participants become slower to search through a crowd of happy distractors than through a crowd of angry distractors.

3.2.1.2 Top-down influences on attentional bias towards angry faces

While the problem of perceptual confounds could be controlled with a rigorous selection process of stimulus faces (although some emotional expressions might seem

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[6] It should be added that Horstmann and Bauland (2006) do not consider natural perceptual confounds of specific expressions to be problematic for the paradigm. The authors argue that two evolutionary processes could potentially have formed attentional biases towards angry faces in humans. The threat-detection hypothesis claims that the visual system has evolved special capabilities to efficiently detect facial threat. In contrast, the sensory-bias hypothesis claims that facial expressions of emotion evolved in ways that exploit the perceptual capabilities of the extant perceptual system. Consequently, the authors argue that the finding that attentional bias towards angry faces is largely driven by perceptual confounds supports the sensory-bias hypothesis. However, while this hypothesis might be plausible, there is no way to test it against the more parsimonious alternative hypothesis that natural perceptual confounds of specific emotional expressions are purely coincidental.

somewhat artificial without perceptual confounds), there exists another problem with the face-in-the-crowd paradigm. Since participants are asked to search for an angry face among a crowd of distractor faces during the critical trials, the angry face necessarily gains task relevance. Due to this task relevance, it is possible that top-down processes are activated which in turn facilitate search for the angry target face. In a recent review article on the role of top-down control in visual search, Eimer (2014) states that representations of the search goal, so-called *attentional templates*, are held in working memory. These templates then provide guidance signals in a global fashion to bias the allocation of spatial attention to target-candidate stimuli. Importantly, this attentional guidance is not necessarily limited to simple visual features like colour and orientation, but can also operate during search for more complex real-world objects. Contingent-capture theory, a theory that was originally developed within the spatial cueing paradigm (and that is therefore discussed in more detail in the following chapters), makes similar assumptions. According to this theory, *attentional control settings* (which are conceptually very similar to attentional templates) are tuned to task-relevant target features to facilitate target detection (Folk et al., 1992; Folk & Remington, 1998, 2006). Thus, more efficient search for angry faces among happy or neutral distractor faces than for positive or neutral faces among angry faces might not necessarily reflect attentional capture by angry faces that occurs involuntarily. These search asymmetries rather occur potentially because attentional control settings (or attentional templates) can more readily be tuned to angry faces than to happy or neutral faces. This interpretation is supported by two recent studies employing a variant of spatial cueing. These studies found that participants only showed an attentional bias towards spiders when spiders were a task-relevant stimulus class, but not when spiders were an irrelevant stimulus class (Vromen, Lipp, & Remington, 2015; Vromen, Lipp, Remington, & Becker, 2016).

3.2.2 The dot-probe task

Within clinical psychology, the most commonly used paradigm to investigate attentional biases to threat is the dot-probe task. Similar to the face-in-the-crowd paradigm, which is derived from visual search, the dot-probe task is also a variant of a paradigm from basic attention research, namely the spatial cueing paradigm. The spatial cueing paradigm was first employed by Posner, Snyder, and Davidson (1980) to investigate shifts in *covert attention*. Covert attention refers to the spatial allocation of processing resources that is independent of saccadic eye-movements. In contrast, *overt attention* refers to the allocation of processing resources to a specific location via saccades and fixations (Chica, Martín-Arévalo, Botta, & Lupiáñez, 2014; Petrova, Wentura, & Bermeitinger, 2013; Stevens, Rist, & Gerlach, 2011).[7] In the spatial cueing paradigm, participants are asked to detect or classify a target that can appear in one of several (in the simplest case: two) positions. Before the onset of the target, a cue stimulus is presented. The spatial cueing literature distinguishes two types of cues: In the case of *endogenous* spatial cueing, a symbolic cue (e.g., a number, or a colour) is centrally presented representing one of the potential target positions (e.g., participants are instructed that red represents the left position and blue represents the right position). In the case of *exogeneous* spatial cueing, a peripheral onset cue abruptly appears in one of the potential target positions. Crucially, the cue is *valid* on some trials and *invalid* on the remaining trials. If the cue is valid, the target appears in the cued location. If the cue is invalid, the target appears in one of the uncued locations. It is assumed that if the cue affects the allocation of attention, participants should be faster to respond to the target when it was preceded by a valid cue than when it was preceded by an invalid cue. Therefore, the cueing effect is defined as the reaction time difference between trials with invalid cues and trials with valid cues ($RT_{invalid} - RT_{valid}$). It has been shown that central cues only affect reaction times to the target when they are informative, that is, when they predict the position of the target above chance level (Jonides, 1981; Posner et al., 1980). Thus, it is assumed that central cues affect the allocation of attention via a voluntary and controlled mechanism.[8] In contrast, peripheral cues that abruptly appear in one of the target positions also affect reaction times to the target when they are uninformative, that is, when the position of the cue is uncorrelated with the position of the target (Jonides, 1981). Therefore, it has been determined that abrupt onset cues capture attention via a reflexive and automatic mechanism that cannot be disrupted by

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[7] Usually, the allocation of covert attention precedes the allocation of overt attention. For example, if we return to the anecdotal episode presented at the beginning of the thesis, the person walking through the dark forest first noticed the cat's eyes from the corner of their eyes (covert attention) and subsequently focused the cat moving in the underwood (overt attention).

[8] For the sake of completeness, it should be mentioned that it has been shown that specific central cue types like arrows or direction words also produce reliable cueing effects if they are uninformative. Thus, it is assumed that overlearned symbols with conventional spatial meanings affect attention allocation via a reflexive mechanism (Chica et al., 2014; Hommel, Pratt, Colzato, & Godijn, 2001).

voluntary effort. Consequently, it has been shown that uninformative peripheral cues even capture attention when attention is guided to a different location by a preceding, informative central cue (Müller & Rabbitt, 1989; Experiment 2).

The dot-probe task is a variant of exogeneous spatial cueing that was developed by MacLeod and colleagues (1986). In its most typical form, participants have to also respond to a target that can appear in either of two positions. In contrast to basic exogenous cueing, however, two cue stimuli are presented, one in each potential target location. One of the stimuli is always emotional (usually threatening; e.g., an angry face) and the other one neutral (e.g., a neutral face). Importantly, the position of the emotional stimulus is not informative regarding the position of the target. If the emotional stimulus captures attention, participants should be faster to respond to the target when it appears in the same location as the emotional cue (valid emotional cue) than when it appears in the opposite location (invalid emotional cue). Thus, both exogeneous spatial cueing and the dot-probe task have the same reasoning. If a cue automatically captures visual attention (either because of its abrupt onset or because of its emotional content), participants should be faster to respond to a succeeding target that appears in the same location than to a target that appears in a different location, even if the cue stimuli are uninformative.

Dot-probe studies usually find an attentional bias to threat in anxious, but not in non-anxious participants. This result pattern is well-replicated and even corroborated by meta-analyses (Bar-Haim et al., 2007; Frewen et al., 2008). Consistently, Puls and Rothermund (2017) did not find any attentional biases towards threatening faces for unselected samples in a large study comprising seven dot-probe experiments with a combined sample size of $N = 308$. However, these findings are inconsistent with the results from numerous studies applying the face-in-the-crowd paradigm (or other variants of visual search), which found an attentional bias in unselected samples (i.e., in the general population). This inconsistency could be explained by methodological shortcomings of the face-in-the-crowd paradigm. As already discussed, the face-in-the-crowd paradigm has two problems. First, emotional expressions can have perceptual confounds that make them very salient. Second, participants are asked to search for threatening faces in this paradigm, Thus, the attentional bias towards threatening faces might be caused by top-down control processes on attention.

Therefore, it is possible that non-anxious individuals only show an attentional bias towards threatening stimuli if these stimuli are (a) perceptually salient or

(b) relevant to the current task or (c) both salient and task-relevant. This could explain why non-anxious participants usually do not show an attentional bias towards threatening stimuli in the dot-probe task. First, the cues (both the threatening and the neutral cue) are always task-irrelevant in the dot-probe task because participants only have to respond to the succeeding target. Second, previous dot-probe studies have used a wide range of cue stimuli (words, scenes, and faces). Thus, it seems unlikely that threatening cues were consistently more salient than neutral cues in the majority of previous dot-probe studies. Consequently, it is possible that only anxious participants show an attentional bias towards threatening stimuli when these stimuli are not perceptually salient and / or relevant to the current task.

Conversely, it is also possible that non-anxious individuals do show an attentional bias towards threatening stimuli; however, this bias cannot be detected due to a methodological shortcoming of the dot-probe task. In particular, it is unclear whether the dot-probe task assesses biases in the initial allocation of attention to threatening stimuli or whether it assesses biases in the attentional disengagement from threatening stimuli (Cisler, Bacon, & Williams, 2009; Clarke, MacLeod, & Guastella, 2013; Rudaizky, Basanovic, & MacLeod, 2014). It is possible that all individuals show an attentional engagement bias towards threatening stimuli, while only anxious individuals show a bias in disengagement from threatening stimuli. If the dot-probe task was only sensitive to disengagement biases, the engagement bias in non-anxious participants would go unnoticed. This issue is discussed in more detail in the following section.

3.2.2.1 The engagement-disengagement problem

From a technical point of view, dot-probe studies show that anxious participants are faster to respond to a target if the cue stimulus preceding the target was emotional than when it was neutral. In contrast, this reaction time difference is usually not found in non-anxious participants. Although this pattern is frequently interpreted in terms of an attentional bias to threat in anxious individuals, there are actually two distinct attentional processes that could produce this pattern.

First, there could be a difference in attentional engagement to threat between anxious and non-anxious individuals (e.g., Williams et al., 1988). At the beginning of each trial, participants attend to the fixation cross. As soon as the two cue stimuli are presented laterally, anxious individuals' attention is shifted to the position of the threatening stimulus. Therefore, anxious participants' attention is already in the optimal location to classify the target if it appears in the same location, but in the wrong location if the target appears in the opposite location. In contrast, non-anxious participants' attention is not allocated to the threatening cue stimulus and stays in the position of the fixation cross. Therefore, non-anxious participants' reaction times are not affected by the relation between the position of the threatening cue and the position of the target.

Second, there could be a difference in attentional disengagement from threat between anxious and non-anxious individuals. The explanation assumes that both anxious and non-anxious participants' attention is initially allocated to the threatening stimulus. However, non-anxious participants are able to quickly disengage from the location of the threat stimulus once the target appears, whereas anxious participants' attention is maintained at the position of the threat cue (e.g., Fox, Russo, Bowles, & Dutton, 2001).

Unfortunately, the dot-probe task does not have any means to directly distinguish these two processes. However, observing the temporal parameters of the dot-probe task might be an indirect way to distinguish these two processes. Most dot-probe studies employ a stimulus onset asynchrony (SOA) of 500 ms between the onset of the cue stimuli and the onset of the target stimuli. If such a long SOA is employed, the dot-probe task seems to be rather sensitive to disengagement biases than to engagement biases for two reasons. First, spatial cueing studies have shown that stimulus driven shifts in covert attention peak at 100-150 ms (Müller & Rabbitt, 1989). Thus, SOAs that are longer than 200 ms possibly tap into shifts of overt attention (Petrova et al., 2013; Stevens et al., 2011; Weierich et al., 2008). Second, when long cue-target SOAs are employed in the spatial cueing paradigm, negative cueing effects often occur (i.e., response times are faster on invalid trials than on valid trials). This phenomenon is referred to as *inhibition of return* and interpreted in terms of a subsequent avoidance of the initially attended location to prevent redundant scanning of the same area. Inhibition of return usually occurs after approximately 200 ms in target-detection tasks (Samuel & Kat, 2003) and somewhat later, after 500-700 ms, in target-classification tasks (Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997).

Thus, it is plausible that the results of typical dot-probe studies reflect the following processes. Non-anxious participants' attention is initially captured by the threatening cue. However, due to the long SOA, attention (both overt and covert) shifts multiple times and returns to the fixation cross before the onset of the target. Therefore, no attentional bias can be detected for non-anxious participants. Similarly, anxious participants' attention is initially captured by the threatening cue. However, due to problems disengaging from threat, their attention dwells in the position of the threatening cue for the whole SOA until the target is presented. Thus, anxious participants are faster to respond to the target when it appears in the same location as the threatening cue than when it appears in the opposite location. Consequently, several authors have argued that non-anxious participants also do show an attentional bias to threat when a short cue-target SOA is used in the dot-probe task (Cooper & Langton, 2006; Yiend, 2010). Thus, inconsistent results between the face-in-the-crowd paradigm are not necessarily caused by shortcomings of the face-in-the-crowd paradigm (see previous chapter), but can also be caused by the dot-probe task's inability to detect biases in attentional engagement.

Since the dot-probe task is not able to disentangle biases in attentional engagement from biases in attentional disengagement, another paradigm has been developed to specifically address this issue. This paradigm is called *emotional spatial cueing.* As the name already suggests, this paradigm also belongs to the family of spatial paradigms. The following sections give a brief overview of this paradigm, its underlying assumptions, and its methodological shortcomings.

3.2.3 Emotional spatial cueing

The emotional spatial cueing paradigm was specifically designed to disentangle anxiety-related biases in attentional disengagement from biases in attentional engagement. Similar to the dot-probe task, participants have to respond to a target that appears in one of two potential target locations. In contrast to the dot-probe task, only one cue stimulus is presented before the onset of the target, which can appear in the same location as the target (valid cue) or in the opposite location (invalid cue). Furthermore, this cue stimulus is emotional (usually threatening) on some trials and neutral on the remaining trials. The paradigm was first applied in an unselected sample by Stormark, Nordby, and Hugdahl (1995). The authors found that participants were faster to respond to validly cued targets when the cue was a negative word than when it was a neutral word. Moreover, participants were slower to respond to invalidly cued targets when the cue was a negative word than when it was a neutral word. The authors claimed that the first finding reflects faster allocation of attention to negative words than to neutral words (i.e., an engagement bias) and that the second finding reflects an impairment to shift attention away from negative words (i.e., a disengagement bias). Fox et al. (2001) were the first to assess differences between anxious and non-anxious participants regarding attentional engagement and disengagement with this paradigm. Thus, their rationale was slightly different. The authors argued that if anxious participants showed faster reaction times than non-anxious participants on trials with valid emotional cues, this would indicate an anxiety-related engagement bias. Conversely, if anxious participants showed slower reaction times than non-anxious participants on trials with invalid emotional cues, this would indicate an anxiety-related disengagement bias. The authors only found a difference between anxious and non-anxious participants in trials with invalid emotional cues and argue therefore that anxious individuals have a bias in attentional disengagement.

Although the emotional spatial cueing paradigm is an influential and widely used approach to disentangle biases in attentional engagement and disengagement, it has methodological shortcomings. More specifically, the measurement of attentional engagement biases is in fact not possible with this paradigm while the measurement of disengagement biases is potentially confounded by non-attentional processes

3.2.3.1 The paradigm's inability to measure biases in attentional engagement

As already discussed, early emotional spatial cueing studies (Fox et al., 2001; Stormark et al., 1995) claimed that the paradigm can measure both biases in attentional engagement and biases in attentional disengagement. Meanwhile, however, it is evident that the paradigm is not able to measure biases in attentional engagement. Thus, one year after their original article (Fox et al., 2001), Fox, Russo, and Dutton (2002) acknowledged that "this task cannot measure enhanced attentional orienting towards a threat stimulus." (p. 357). Contrary to the initial assumption, reaction times on trials with valid cues cannot be used to measure engagement biases because any cues (emotional or neutral) readily capture attention in this paradigm for two reasons. First, the paradigm purposely employs predictive cues, that is, the percentage of valid cues is higher than the percentage of invalid cues (e.g., Fox et al., 2001; Fox et al., 2002; Stormark et al., 1995). Thus, participants are encouraged to strategically shift their attention towards the cue (no matter if it is threatening or neutral) because it predicts the position of the target above chance level. Second, even if the cues are not predictive, neutral cues are likely to capture attention because they are the only stimulus presented during the cue display (unlike in the dot-probe task) and are therefore characterised by an abrupt onset. Onset stimuli are assumed to capture visual attention via reflexive bottom-up mechanisms (Theeuwes, 1991; Yantis & Jonides, 1990). Moreover, since the target is also characterised by an abrupt onset, participants probably adopt an onset-singleton search mode (Bacon & Egeth, 1994; Folk et al., 1992), which additionally increases attentional capture by the onset cue via top-down mechanisms. In three experiments, Mulckhuyse and Crombez (2014) found attentional capture by non-predictive neutral cues even when those cues were not characterised by an abrupt onset (because they were isoluminant with the background).

Thus, any reaction time differences on valid trials in this paradigm cannot be explained by the assumption that threatening cues capture attention, but neutral cues do not. Neither can it be assumed that threatening cues only capture attention in anxious, but not in non-anxious participants. Since the speed of stimulus-driven shifts in covert attention is rather stable (Müller & Rabbitt, 1989), it is also highly unlikely that reaction time differences on valid trials reflect an acceleration of the initial shift of attention to the cue (see also Koster, Crombez, Verschuere, van Damme, & Wiersema, 2006 for this argument).

Nevertheless, some emotional spatial cueing studies found reaction time differences on valid trials between emotional and neutral cues (e.g., Koster et al., 2006; see also Cisler et al., 2009 for a review}). However, what does the reaction time difference between trials with valid emotional and valid neutral cues reflect if it cannot reflect an attentional engagement bias? It is possible that reaction time differences on valid trials are caused by an additional methodological flaw that is not inherent to the emotional spatial cueing paradigm per se. Specifically, many emotional spatial cueing studies unnecessarily employ a target-localisation task, that is, participants are asked to indicate whether the target appears in the left or in the right screen position (e.g., Fox et al., 2001; Koster et al., 2006; Sigurjónsdóttir et al., 2015; but see Stormark et al., 1995 for a study employing a target-detection task). When a target-localisation task is used, the potential cue positions (left and right) are confounded with the potential responses (left and right). Consequently, it is possible that threatening cues simply modulate a motor process, which primes the correct response (i.e., participants might be faster to push “left” when a threatening stimulus appeared on the left). This interpretation is also proposed in a recent study by Mulckhuyse and Crombez (2014) comprising five emotional spatial cueing experiments with fear-conditioned colours as cues. In their experiments, the cueing effect was only moderated by the acquired valence of the cue colours when participants performed a target-localisation task (Experiment 4), but not when they performed a target-detection (Experiments 1-3) or a target-classification task (Experiment 5).

3.2.3.2 Problems in the measurement of attentional disengagement

As already discussed, the emotional spatial cueing paradigm infers a bias in attentional disengagement when participants are slower to respond to a target that was preceded by an invalid threatening cue than to respond to a target that was preceded by an invalid neutral cue. The reasoning behind this approach is that the cue captures attention, regardless of its valence (as previously discussed). Thus, on invalid trials, participants have to perform an additional attentional shift to the target position. When participants are slower on trials with invalid threatening cues than on trials with invalid neutral cues, it is assumed that the threatening cue stimulus holds visual attention and the additional shift to the target location is delayed. However, it has been shown that this measure is potentially confounded with non-attentional processes.

Mogg et al. (2008) showed that longer reaction times in anxious participants after invalid threatening cues versus after invalid neutral cues might not be caused by a disengagement bias, but by a more general response-slowing mechanism. In their study, participants had to respond to a target that was always centrally presented. Before the onset of the target, a face cue was presented in the same location that was either neutral, happy, or angry. Anxious participants were significantly slower to respond to targets that were preceded by angry face cues than targets that were preceded by neutral face cues, although the task did not require any shifts in spatial attention. The authors conclude that the mere presence of a threatening stimulus leads to a general response slowing effect that is interpreted in terms of an evolutionary freezing response.

For the sake of completeness, it should be mentioned that further modifications of the dot-probe task and the emotional spatial cueing paradigm are currently developed to allow for a more accurate differentiation of engagement biases and disengagement biases (e.g., Grafton & MacLeod, 2014; Rudaizky et al., 2014). A widely used modification of the dot-probe task is the inclusion of trials with two neutral cue stimuli, so called neutral-neutral trials. An engagement bias is inferred if participants are faster to respond to the target on trials with valid threatening cues than on neutral-neutral trials. A disengagement bias is inferred if participants are slower to respond to the target on trials with invalid threatening cues than on neutral-neutral trials (e.g., Jovev et al., 2012; Klumpp & Amir, 2009; Koster, Crombez, Verschuere, & De Houwer, 2004; Salemink, van den Hout, & Kindt, 2007). However, this approach has the same shortcoming as the emotional spatial cueing paradigm. The mere presence (valid and invalid trials) vs. absence (neutral-neutral trials) of threatening stimuli can cause general response-slowing processes that are confounded with attentional processes.

3.3 Summary

In summary, paradigms for the assessment of attentional bias to threat can be divided into spatial paradigms and non-spatial paradigms. It is unclear whether non-spatial paradigms like the emotional Stroop or the attentional- blink paradigm assess the same attentional processes (some of them might even measure non-attentional processes). In contrast, all spatial paradigms (i.e., the face-in-the-crowd paradigm, the dot-probe task, and emotional spatial cueing) claim to assess biases in the spatial allocation of visual attention to threatening stimuli. Therefore, it is rather surprising that these paradigms yield different results regarding the question whether the general population shows an attentional bias towards threatening stimuli. However, the previous sections have shown that all of the spatial paradigms have limitations. Importantly, these methodological shortcomings could explain why some paradigms find an attentional bias in the general population while others find this bias only in anxious participants.

4 Overview of the conducted studies

In light of the considerations of the previous chapters, the present thesis reports three studies that aim to investigate the question as to whether the general population shows an attentional bias towards threatening stimuli. In these studies, we employed different variants of the dot-probe task. As previously discussed, only anxious participants usually show an attentional bias towards threatening stimuli in this paradigm. By varying specific parameters within the dot-probe task, we aimed to identify the necessary preconditions for the occurrence of an attentional bias to threat in unselected samples (that represent the general population).

The dot-probe task has been conducted with a large variety of visual stimuli, for example with emotional words (MacLeod et al., 1986; Salemink et al., 2007), emotional scenes (Everaert et al., 2013; Mogg et al., 2000; Putman, 2011; Vogt & De Houwer, 2014), emotional faces (Cooper & Langton, 2006; Holmes, Green, & Vuilleumier, 2005; Mogg & Bradley, 1999a; Petrova et al., 2013), and fear-conditioned colour stimuli (Müller, Rothermund, & Wentura, 2016; Vogt, De Houwer, Crombez, & van Damme, 2013, Experiment 3). In the present studies, we decided to employ angry faces as threatening stimuli for two reasons. First, emotional faces are the stimulus class most commonly used in paradigms based on visual search. Since we aimed to investigate the inconsistent results between dot-probe studies and visual search studies, we decided to keep the stimulus material of our studies comparable to the stimulus material of most visual search studies. Second, in contrast to emotional faces, words or scenes do not often convey a distinct emotional impression in observers. For example, the word "spider" or a picture of a spider can elicit both disgust and fear reactions. In contrast, facial expressions of emotion convey a universally understandable and distinct emotional impression (Ekman, 1992).

Previous dot-probe studies have used different emotional expressions as threatening stimuli, such as fear (Holmes et al., 2005; Murphy, Downham, Cowen, & Harmer, 2008; Reinecke, Cooper, Favaron, Massey-Chase, & Harmer, 2011), anger (Cooper & Langton, 2006; Mogg & Bradley, 1999a; Petrova et al., 2013), and disgust (Mills, Grant, Judah, & White, 2014; Sigurjónsdóttir et al., 2015). In our studies, we chose angry faces as threatening stimuli because other expressions of negative emotions do not necessarily convey the impression of imminent threat. For example, disgust might be a clearly negative impression, but it is characterised by rather moderate arousal (Russell & Fehr, 1987). In contrast, fear is characterised by high arousal

(Russell & Fehr, 1987), but its social meaning is rather ambiguous. For example, a person observing an expression of fear in another person's face could interpret this expression either as a signal of imminent threat in the environment or as a signal of submission from the expresser (Paulus & Wentura, 2014). In contrast, the perception of an angry expression always signals imminent threat to the observer because he or she might be attacked by the expresser. Consistent with this idea, a masked affective priming study has shown that subliminally presented anger expressions can be distinguished from fearful and sad expressions, but fearful and sad expressions cannot be distinguished from each other—most likely because angry expressions are primarily relevant for the observer, whereas fearful and sad expressions are primarily relevant for the expresser (Rohr, Degner, & Wentura, 2012). Moreover, facial expressions of fear are not ideally suited to investigate attentional biases because the increased exposure of the bright sclera and the dark iris in a fearful stare cause a salient perceptual confound that is an inherent part of this emotional expression (Hedger et al., 2015).

As previously discussed, the main limitation of the dot-probe task is that it cannot precisely disentangle biases in attentional engagement towards threat and in disengagement from threat. We indirectly addressed this issue by employing a short cue-target SOA of 100 ms in all of our experiments. Since stimulus-driven shifts in covert attention take approximately 100-150 ms (Müller & Rabbitt, 1989) and since inhibition of return does not occur until 200 ms after cue onset (Samuel & Kat, 2003), a SOA of 100 ms would be ideal to assess biases in the initial allocation of covert attention (Cooper & Langton, 2006; Petrova et al., 2013; Stevens et al., 2011).[9] One could assume that all individuals show a bias in attentional engagement towards threatening stimuli, but only anxious participants show an additional bias in attentional disengagement from threatening stimuli (which is detected in typical dot-probe tasks

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[9] It should be noted that the employment of a short cue-target SOA does not entirely rule out the possibility that disengagement processes can affect reaction times. For example, it is possible that a participant's attention dwells at the position of a threatening cue for a few hundred milliseconds although the cue has already disappeared and the target has already appeared in the opposite location. However, a SOA of 100 ms maximises the likelihood that the onset of the target display occurs during (or immediately after) the first shift of covert attention elicited by the cue display. In contrast, SOAs of 500 ms and longer allow participants to perform multiple shifts in covert (and overt) attention before the onset of the target display.

with long SOAs). If that was the case one would expect to find an attentional bias towards threatening faces for all participants in the dot-probe task if a short cue-target SOA is used because a short SOA should be sensitive to engagement biases (Cooper & Langton, 2006). However, although we consistently employed a short SOA of 100 ms in all experiments, the occurrence of an anxiety-independent bias was always contingent on additional factors in these experiments. That is, a short cue-target SOA does not seem to be a sufficient (but maybe a necessary) condition for the occurrence of attentional bias towards angry faces in unselected samples. As a consequence, inconsistencies between dot-probe studies and face-in-the-crowd studies cannot be explained by the hypothesis that all individuals show an engagement bias (which is measured in the face-in-the-crowd paradigm) and that only anxious participants show a disengagement bias (which is measured in typical dot-probe tasks with long SOAs).

Study 1 tested whether the general population shows only an attentional bias towards angry faces when these faces are perceptually salient. As previously discussed, many face-in-the-crowd studies found search advantages for threatening faces in unselected samples. However, many of these results could be explained by the relative saliency of specific facial expressions. Thus, we conducted a dot-probe experiment with two types of angry faces as threatening cue stimuli. In one half of the trials, angry face cues had exposed (snarling) teeth and were thus more salient than the neutral face cues. In the other half of the trials, angry face cues had concealed teeth and compressed lips and were thus equally salient as the competing neutral face cues. If attentional bias to threat was contingent on the perceptual saliency of threatening stimuli, it would be expected to find an anxiety-independent attentional bias towards angry faces with exposed teeth, but not towards angry faces with concealed teeth. Inconsistent with this hypothesis, no attentional bias towards perceptually salient angry faces was found. In contrast, an attentional bias towards non-salient angry faces was found in anxious participants, but not in non-anxious participants. This result suggests that attentional bias towards threatening stimuli in the general population is not merely driven by the perceptual saliency of these stimuli. Moreover, the result corroborates previous dot-probe studies that found attentional biases to threat only in anxious participants.

Study 2 aimed to investigate whether attentional bias towards angry faces is contingent on top-down mechanisms. As already discussed, angry faces are task-relevant in the critical conditions of face-in-the-crowd studies. Thus, participants might activate specific top-down mechanisms that help guide attention to potential target faces. These top-down processes might cause the attentional bias towards threatening stimuli. This assumption is consistent with contingent-capture theory of spatial cueing (Folk et al., 1992; Folk & Remington, 2006). This theory states that attentional control settings are tuned to relevant target features to facilitate target detection. Thus, an irrelevant cue only captures attention if it matches a relevant feature of the target. In Experiment 1 of Study 2, we conducted a dot-probe task with two types of targets to manipulate attentional control settings. In the angry-target condition, participants had to classify schematic target faces that were defined by their angry expression. In the non-angry target condition, participants had to classify schematic target faces that were defined by a non-emotional feature (open mouth). If attentional bias towards angry faces was contingent on attentional control settings in the general population, participants should show an attentional bias towards angry face cues in the angry-target condition, but not in the non-angry target condition. Surprisingly, we found an anxiety-independent attentional bias towards angry face cues in both conditions. To rule out the possibility that this result was simply a failure to detect contingent-capture effects due to technical shortcomings, we replicated typical contingent-capture effects for cues and targets of matching and non-matching colours in Experiment 2 with identical parameters. Experiment 3 tested an alternative hypothesis for the occurrence of attentional bias towards angry faces in both conditions of Experiment 1. In order to induce attentional control settings in participants, two stimuli had to be presented during the target display (one target and one distractor). However, typical dot-probe studies only employ a single target. Thus, we tested whether attentional bias towards angry faces only occurs in the general population when targets have to compete for attention with simultaneously presented distractors. In Experiment 3, participants conducted a dot-probe task with two target conditions. In the onset-target condition, only the target was presented during the target display. In the no-onset target condition, both a target and a distractor were presented during the target display. An attentional bias towards angry face cues only occurred in the no-onset target condition, but not in the onset target condition. This result suggests that attentional bias towards angry faces is contingent on target competition, but not on a control setting tuned to threat in the general population.

Study 3 investigated an alternative explanation for the occurrence of attentional bias towards angry faces in Study 2. Since socially meaningful target stimuli (schematic faces) were employed throughout Study 2, it is possible that attentional bias towards angry faces is contingent on the activation of a social processing mode in the general population. This hypothesis could explain the occurrence of attentional bias towards angry faces in the face-in-the-crowd paradigm because participants have to perform a social judgment in this paradigm ("is a face with a discrepant expression present?"). We conducted two dot-probe experiments where participants had to classify either social targets (schematic faces) or non-social targets (scrambled schematic faces in Experiment 1 and schematic houses in Experiment 2). In both experiments, larger biases towards angry face cues occurred when participants were classifying social targets than when they were classifying non-social targets. This result suggests that attentional bias towards angry faces in the general population is not contingent on an attentional control setting tuned to threat, but on a broader social processing mode.

5 Study 1: The influence of perceptual confounds on attentional bias towards angry faces[10]

Facial expressions are undoubtedly an important social signal in everyday life. Therefore, a considerable amount of research has discussed the question of whether emotional faces are processed in a prioritised manner. As previously discussed, two paradigms in particular have been applied to investigate this issue. The first paradigm, the face-in-the-crowd task, is a variant of visual search. Participants are asked to search for a face displaying a specific or discrepant emotion among a set of distractor faces (e.g., Hansen & Hansen, 1988; Horstmann & Bauland, 2006; Pinkham et al., 2010; Purcell et al., 1996). An attentional bias to a specific emotion is inferred if search for faces displaying this emotion is more efficient than search for faces displaying other facial expressions. The second paradigm comprises variants of spatial cueing, most importantly the dot-probe task (e.g., Cooper & Langton, 2006; Mogg & Bradley, 1999a; Petrova et al., 2013; for a meta-analysis, see Bar-Haim et al., 2007).

In this paradigm, participants are asked to respond to a target stimulus that is preceded by two face cues. An attentional bias towards emotional faces is inferred if the processing of targets appearing at the same position as faces displaying a specific emotion is faster than of targets appearing at the position of the other (usually neutral) faces. As already discussed, this pattern could be caused by two mechanisms. First, if emotional faces attract attention, the participant's attentional focus is already in the right position if the target appears at the location of the emotional face, thereby decreasing response times (e.g., Williams et al., 1988). Second, if attention dwells on an emotional face, problems with disengagement can increase response times when the target appears at the location of the neutral face (e.g., Fox et al., 2001).

Unfortunately, studies applying the face-in-the-crowd paradigm have produced largely inconsistent results so far. Whereas some studies found search advantages for angry faces (e.g., Hansen & Hansen, 1988; Pinkham et al., 2010), others found advantages for happy faces (e.g., Becker et al., 2011; Juth et al., 2005). This led to studies investigating the influence of low-level perceptual stimulus features on search times for emotional faces (see, e.g., Purcell et al., 1996). Recent studies investigated the influence of a natural low-level confound of emotional faces: teeth-exposure. Whereas

[10] This chapter is largely identical to a manuscript that has been submitted for publication and is currently under review (Wirth & Wentura, 2017c).

teeth-exposure is an integral component of some emotional expressions (e.g., the smile in happy expressions), it is not usually part of others (e.g., sadness) and some expressions can occur both with and without exposed teeth (e.g., compressed lips vs. bared teeth in anger expressions). Taken together, these studies suggest that teeth-exposure is a strong perceptual confound that can guide visual attention and thus explain inconsistent results of previous studies (Calvo & Nummenmaa, 2008; Horstmann et al., 2012; Horstmann & Bauland, 2006; Savage et al., 2013).

To our knowledge, such rigorous tests for low-level confounds have not been done in dot-probe research. This might be due to the fact that this research is more focused on individual differences in anxiety and that an attentional bias towards threatening (i.e., angry or fearful) faces is quite consistently found in anxious, but not in non-anxious participants (Bar-Haim et al., 2007). Of course, although this differential effect is well replicated, it cannot be ruled out that the perceptual characteristics of exposed teeth play a role in its occurrence.

It seems plausible that angry faces with exposed teeth have been used in numerous dot-probe studies since teeth-exposure is not controlled for in some emotional face databases. For example, 32.9 % of the angry faces contained in the KDEF database (Goeleven, De Raedt, Leyman, & Verschuere, 2008) show exposed teeth. Moreover, it seems plausible that angry faces with exposed teeth are preferentially selected as stimuli in dot-probe studies because their emotional intensity is usually perceived to be higher than that of angry faces with concealed teeth. For example, the validation data of the KDEF database (Goeleven et al., 2008) show that angry faces with exposed teeth obtained an average intensity rating of $M = 5.94$ on a 9-point likert scale, whereas angry faces without exposed teeth obtained an average rating of $M = 5.42$, $t(68) = 2.27$, $p = .026$, $d_S = 0.58$. Therefore, in the present study, we investigated the effect of teeth-exposure on the attentional bias towards angry faces in a dot-probe task.

Since we aimed to assess participants' biases in the initial engagement of covert attention, we used a short cue-target SOA of 100 ms. As already discussed in previous chapters, we believe that such a short SOA is ideal for the assessment of biases in attentional engagement for two reasons. First, within longer time ranges, saccadic eye-movements (i.e. shifts in overt attention) can occur, disguising any effects on covert attention (Petrova et al., 2013; Stevens et al., 2011). Second, during long intervals between the onset of cues and targets, participants can potentially perform multiple shifts in attention. This assumption is supported by the occurrence of inhibition of return in spatial cueing tasks employing long cue-target SOAs. For detection tasks, inhibition of return usually occurs after approximately 200 ms (Samuel & Kat, 2003), for classification tasks, somewhat later at 500-700 ms (Lupiáñez et al., 1997).

5.1 Methods

5.1.1 Participants

Seventy-eight non-psychology university students were paid 6 € for their participation. Four participants were excluded from data analysis since their accuracy was more than 2.0 interquartile ranges below the first interquartile of the distribution. Of the remaining $N = 74$ participants, 50 were female. Their ages ranged from 19 to 35 ($M = 24.0$ years, $SD = 3.5$). All participants reported normal or corrected-to-normal vision and gave their informed consents prior to testing. Participants' raw scores on the trait scale of the State-Trait Anxiety Inventory (STAI; Laux, Glanzmann, Schaffner, & Spielberger, 1981) ranged from 25 to 67 ($M = 39.5$, $SD = 10.7$).

5.1.2 Design

We employed a 2 (*cue validity:* valid cue vs. invalid cue) × 2 (*teeth-exposure:* exposed teeth vs. concealed teeth) × STAI design with cue validity and teeth-exposure as within-subjects factors and STAI as a continuous (centred) covariate.

With regard to power considerations, we made the assumption of $r = .30$ (i.e., a "medium" effect as defined by Cohen, 1988) for the STAI-cueing correlation.[11] To detect an effect of this magnitude with a probability of $1 - \beta = .80$ and an α-value of .05 (one-tailed), a minimum sample size of 64 participants was required; calculations were done using G.Power 3.1.3 (Faul, Erdfelder, Lang, & Buchner, 2007).

5.1.3 Materials

Stimulus faces were taken from the NimStim database (Tottenham et al., 2009) as it contains photographs with both open and closed mouths for each facial expression. We selected photographs of eight female and eight male individuals displaying angry expressions with both exposed and concealed teeth. All images were cropped using a

[11] In their meta-analysis, Bar-Haim et al. (2007) reported an average effect size of $d = 0.56$ (i.e., $r = .27$) for dot-probe studies with short presentation durations. Since most of these studies suffer from the *cost of dichotomization* (Cohen, 1983) by using median splits of the anxiety measure, $r = .30$ is an adequate estimate.

standard oval shape concealing hair and external features and converted to greyscale (see Figure 1).

5.1.4 Procedure

The study was conducted on five PCs equipped with 17" CRT monitors using a resolution of 1024 × 768 Pixels, a refresh rate of 100 Hz, and a colour depth of 32 bit. The experimental routine was programmed using the Psychtoolbox-3 (Kleiner, Brainard, & Pelli, 2007) for Matlab 2014a (Mathworks, Natick, MA).

Participants were seated in an individual testing booth approximately 65 cm from the monitor. After giving their informed consents, participants were presented with an instruction screen explaining the experimental procedure. Figure 1 depicts a schematic illustration of a typical trial and the design of the study. Throughout the study, a grey fixation cross was centrally presented on a black background to maintain participants' focus at the central location. To indicate the beginning of a trial, the fixation cross blinked for 100 ms. The fixation cross then remained on the screen for an interval randomly chosen from the set 1,000, 1,100, 1,200, 1,300, or 1,400 ms to avoid any anticipatory effects. Two face cues were then presented laterally for 100 ms. The faces had a size of 4.5 × 6.2 cm (4.0 × 5.5°) and their centre-to-centre distance was 11.1 cm (9.8°). One of the face cues always wore an angry expression, the other one a neutral expression. On 50 % of the trials, the angry face had exposed teeth, on the remaining trials the mouth was closed. The face cues always had the same gender, but never the same identity. Immediately after the offset of the face cues, a target stimulus appeared at the location of one of the faces for 50 ms. Thus, the stimulus onset asynchrony, between the onset of the cues and the onset of the target was 100 ms. We chose this SOA because we aimed to assess anxiety-related biases in shifts of covert attention. As already mentioned, it is recommended to use short SOAs to investigate stimulus driven shifts in covert attention because they peak at 100-150 ms after stimulus onset (Müller & Rabbitt, 1989). Thus, SOAs longer than 200 ms possibly tap into shifts of overt attention (Petrova et al., 2013; Stevens et al., 2011; Weierich et al., 2008). The target stimulus was either a “×” or a “=” symbol and participants' task was to classify the stimulus as fast as possible by pressing the “t” or “v” button of a standard German QUERTZ keyboard. We chose a red-coloured target stimulus so any effects of teeth-exposure could not be attributed to the target having a similar colour to teeth (see Folk et al., 1992). On 50 % of the trials, the target appeared at the location of the angry face (valid cue) and on the remaining trials it appeared at the location of the neutral face (invalid cue). Each response was followed by a 500 ms inter-trial interval. If participants submitted an incorrect response or took longer than 1,500 ms, they received a 1,000 Hz warning tone lasting 500 ms via headphones. The whole procedure comprised 448 trials and lasted approximately 35 minutes. Trials were presented in a randomised order in four blocks of 112 trials, separated by self-paced breaks. At the beginning of the procedure, participants were presented with 24 training trials that were not included in data analysis.

The emotional intensity of angry faces baring their teeth is usually perceived to be higher than that of angry faces with compressed lips. Since this confound occurs naturally, it cannot be avoided, but it can be controlled for statistically. Therefore, after completing the dot-probe task, participants rated the stimuli with regard to intensity of the displayed emotional expression on a seven-point Likert scale. At the end of the procedure, participants completed the trait scale of the German version of the STAI (see Participants).

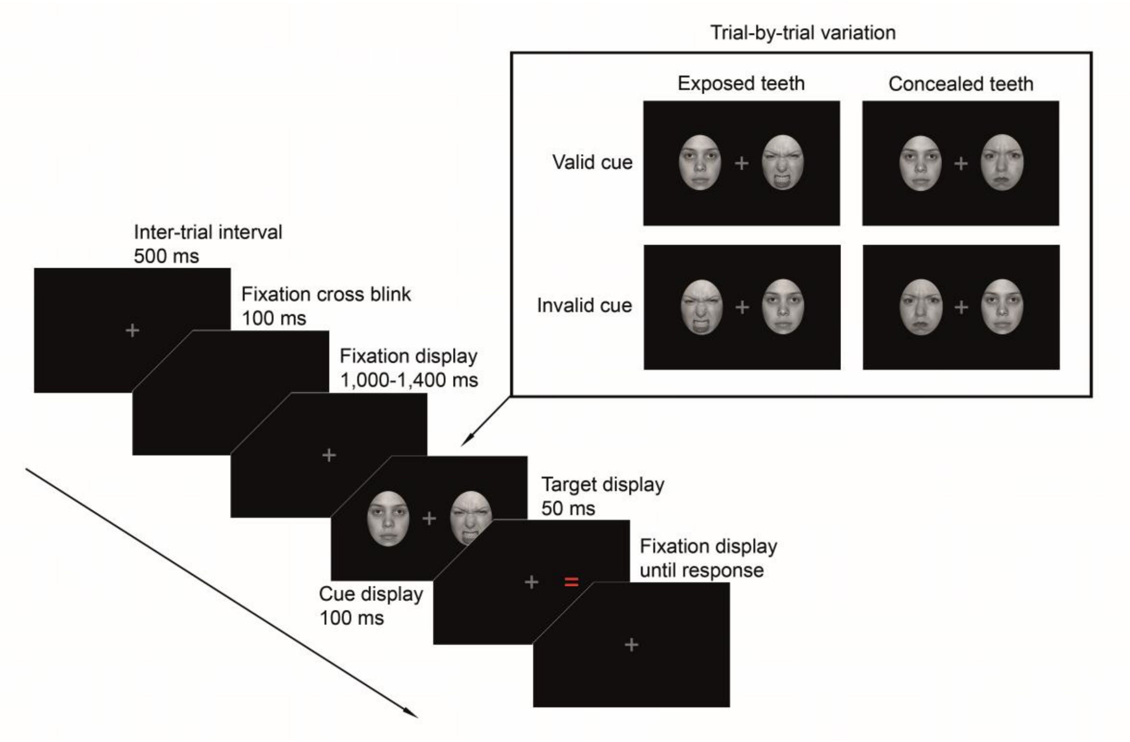

Figure 1. Schematic illustration of a typical trial and the design of Study 1. For the sake of visibility, proportions are not true to scale.

5.2 Results

Average classification accuracy was 96.2 % (*SD* = 3.1). Reaction time outliers of less than 150 ms or more than 1,000 ms were excluded from data analysis (1.1 % of all correct responses). After outlier removal, average individual reaction times ranged from 383 to 621 ms (*M* = 487 ms, *SD* = 49).

We calculated a 2 × 2 within-subject ANCOVA with the factors *cue validity* (valid cue vs. invalid cue) and *teeth-exposure* (exposed teeth vs. concealed teeth), the participants' z-standardised (i.e., centred) STAI scores as a covariate, and (correct) reaction times as the dependent variable. The ANCOVA revealed no significant main effects, both *F*s < 0.45, but a significant *cue validity* × STAI interaction, $F(1, 72) = 5.17$, $p = .026$, $\eta_p^2 = .067$, which was further moderated by a significant *cue validity* × *teeth-exposure* × STAI interaction, $F(1, 72) = 6.89$, $p = .011$, $\eta_p^2 = .087$ (all *F*s < 1.84 for the remaining interactions). In order to clarify the meaning of these interactions, we calculated cueing scores by subtracting participants' reaction times to validly cued trials from reaction times to invalidly cued trials. For overall cueing scores (i.e., scores collapsed over the teeth-exposure conditions), we found a positive correlation with STAI scores, $r(72) = .259$, $p = .026$. However, there was a clear moderation by teeth exposure. For trials with exposed teeth, we found no correlation between cueing and STAI, $r(72) = .001$, $p = .991$). For trials with concealed teeth, however, the correlation was marked, $r(72) = .384$, $p < .001$ ($r(71) = .443$, $p < .001$, without a bivariate outlier; standardised residuum $r_s = 3.6$). Figure 2 contains scatterplots illustrating these correlations.

As expected, anger expressions with exposed teeth were rated as more intense ($M = 6.48$, $SD = 0.31$) than anger expressions without exposed teeth ($M = 5.46$, $SD = 0.72$) and this difference was significant, $t(30) = 5.27$, $p < .001$, $d_S = 1.86$. We conducted hierarchical linear modelling analyses to investigate whether the moderating effect of teeth-exposure was caused by confounding differences in intensity of the emotional expressions. We used the *lme4* and *lmerTest* packages of R 3.1.3 (Bates, Maechler, Bolker, & Walker, 2015) with the significance of predictors assessed using Satterthwaite's approximation for degrees of freedom (Kuznetsova, Brockhoff, & Christensen, 2016). A random effects model with cue validity (coded -1/+1), teeth exposure (coded -1/+1), *z*-standardised STAI and all possible interaction terms as predictors and response times as dependent variable yielded again the significant two-way interaction of cue validity with STAI, $t = -2.21$, $p = .027$, which was further moderated by teeth exposure, $t = 2.17$, $p = .030$. Thus, the results found by the ANCOVA (see above) could also be seen in the linear mixed model. Adding to the model the mean rating of stimuli (centred), its interaction with cue validity and STAI, as well as the corresponding three-way interaction, yielded no significant three-way interaction *cue validity* × *rating* × STAI, $t = 0.55$, $p = .585$. Thus, the intensity of stimuli is not the driving force behind the *cue validity* × *teeth-exposure* × STAI interaction.

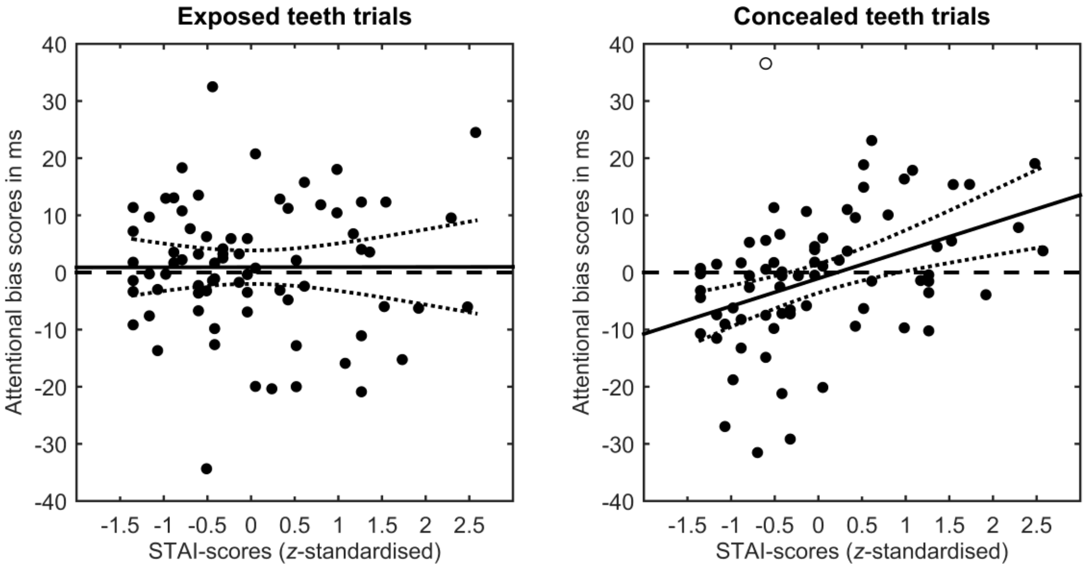

Figure 2. Scatterplots illustrating the relationship between participants' STAI-scores and their individual attentional bias scores (in ms) on exposed teeth trials (left panel) and concealed teeth trials (right panel) in Study 1. The empty circle marks an excluded bivariate outlier (see text). The solid line depicts the slope of the regression, the dotted lines the 95%-confidence interval of the slope. Note that on trials with concealed teeth, high trait anxious participants show a significant bias towards angry faces whereas low trait anxious participants show a significant bias away from angry faces.

5.3 Discussion

In the present dot-probe study, we replicated the well-established result that attentional bias towards angry faces is positively correlated with participants' trait anxiety (Bar-Haim et al., 2007). More interestingly, we found that this effect is moderated by the degree of teeth-exposure in the angry face cues. Specifically, in the present study, anxious participants only showed a larger attentional bias towards angry faces than non-anxious participants if the angry faces did not have exposed teeth. In general, this result validates previous dot-probe studies since it shows that their results were not merely driven by a perceptual stimulus confound (exposed teeth), but have to be accounted for by the emotional content of the stimuli.

However, three aspects of our results have to be discussed in further detail. First, it might be seen as surprising that teeth exposure boosts effects in visual search (Calvo & Nummenmaa, 2008; Horstmann et al., 2012; Horstmann & Bauland, 2006; Savage

& Lipp, 2015) whereas it eliminated cueing effects for angry faces in the present study. Second, it is striking that we did not find any effect of participants' trait anxiety on attentional bias towards angry faces with exposed teeth. The emotional intensity of angry faces baring their teeth is perceived to be higher than that of angry faces with compressed lips. Therefore, one might expect that any differences between anxious and non-anxious individuals that occur for angry faces without teeth-exposure should also occur for angry faces exposing teeth—and possibly be even larger. Third, a closer look at Figure 2 reveals that non-anxious individuals actually show a bias away from angry faces without teeth-exposure.

With regard to the first point (i.e., teeth-exposure boosting effects in visual search studies, but eliminating effects in the present dot-probe study), there is one critical difference between the face-in-the-crowd-paradigm and the dot-probe task. In the former, the stimulus faces' emotions are task-relevant. Thus, when participants are searching for emotional faces, they are likely to intentionally use confounds in order to detect the emotional face as fast as possible (Purcell et al., 1996). In contrast, the emotions of the face cues are task-irrelevant in the dot-probe task. Therefore, one might argue that participants do not benefit from strategies of using low-level confounds of specific emotions.

With regard to the second point (i.e., no individual differences with regard to teeth-exposed stimuli), this detail in our results is consistent with a well-established cognitive model of anxiety. Mogg and Bradley's (1998) cognitive-motivational analysis of anxiety claims that trait anxiety affects the sensitivity of the valence evaluation system, to the effect that anxious individuals tag even mildly threatening stimuli with a high subjective threat value, and subsequently allocate processing resources towards it. In contrast, non-anxious individuals do not tag such stimuli with a high subjective threat value and therefore subsequently avoid the stimulus to maintain attention on current goals and to retain a positive mood state. However, with increasing threat intensity of the stimulus, non-anxious individuals should also tag the stimulus with high relevance and allocate resources to it. Thus, differences between anxious and non-anxious individuals should decrease or even vanish with increasing threat intensity of the stimulus. In an empirical test of their model, Mogg et al. (2000) actually obtained comparable results to ours with mild and high threat scenes as stimuli. However, the results of the hierarchical linear model analyses suggest that the pattern of our results was not caused by confounding differences in emotional intensity. Thus, it seems more likely that the perceptual properties of teeth-exposure, a homogenously bright area on a darker background, are striking enough to add noise to the data and therefore blur any effects of the emotional characteristics of the stimuli, but not striking enough to reliably attract attention.

With regard to the third point, (i.e., the finding of a bias away from angry faces for non-anxious individuals), we are again in line with Mogg and Bradley (1998) since these authors assume that individuals with low trait anxiety tend to avoid low threat stimuli (see above). This explanation, however, seems not very plausible in light of our short SOA (given that avoidance can only follow initial processing of the stimulus). An alternative explanation for the negative bias scores of low anxiety participants focuses on the meaning of neutral faces in a social context. Neutral faces are ambiguous in social meaning and ask for clarification. Thus, a bias towards neutral faces could reflect the motivation to assess the mood and intentions of the expresser. If so, the bias score might reflect the individual balance between two different tendencies, that is, to attend to clearly threat-related information versus to attend to ambiguous information. Given our results, this balance seems to be moderated by trait anxiety. Note again that dot-probe effects might reflect attentional capture or attentional dwelling (i.e., a difficulty to disengage attention from a stimulus). Thus, even if one does not accept the hypothesis of attentional capture by something ambiguous, attentional dwelling on an ambiguous stimulus is highly plausible. Of course, in case of a dwelling hypothesis, one has to assume that attention is initially directed to one of the stimuli of a dot-probe pair on a random basis.

In apparent contrast to our results, Cooper and Langton (2006) found a non-significant attentional bias towards angry faces for a SOA of 100 ms in an unselected sample. However, since they did not control for participants' anxiety, the non-significant trend towards an early bias towards angry faces might have occurred due to anxious participants attending to the angry faces and non-anxious participants attending to the neutral faces.

In general, the results corroborate the validity of the dot-probe paradigm. In contrast to studies applying the face-in-the-crowd paradigm, attentional biases towards angry faces reported by dot-probe studies cannot be explained by the perceptual properties of exposed teeth. Nevertheless, the present study shows that teeth-exposure can affect attentional biases towards emotional faces. Therefore, future studies using emotional faces to investigate attentional biases should carefully control for the teeth-exposure of their stimuli.

6 Study 2: The influence of attentional control settings and target competition on attentional bias towards angry faces[12]

In the dot-probe task, participants are asked to classify a target stimulus that can appear in either of two positions. Before the onset of the target stimulus, two cue stimuli are presented in the two positions, one emotional (usually threatening; e.g., an angry or fearful face) and the other neutral (e.g., a neutral face). Importantly, the location of the emotional cue stimulus is not correlated with the position of the target. An attentional bias towards the emotional stimulus is inferred if participants are faster to respond to the target stimulus if it appears in the position of the emotional cue compared to the position of the neutral cue. Studies employing this task usually find an attentional bias to threat in trait anxious participants, but not in non-anxious participants (Bar-Haim et al., 2007).

The latter finding is the focus of the present chapter. Hence, we do not aim to investigate the nature of anxious individuals' attentional bias here, but rather the assumed absence of this bias in non-anxious individuals. It is surprising that non-anxious individuals do not usually exhibit such a bias, for three reasons. First, from an evolutionary perspective, it seems intuitively adaptive if potential threats in the environment are processed in a prioritised manner in all individuals. Second, a related paradigm—the face-in-the-crowd paradigm—yields contradictory results. In this paradigm, which is a variant of visual search, participants are asked to search for a face displaying a specific or discrepant emotion among a set of distractor faces. An attentional bias towards a specific emotion is inferred if either of the following two criteria (or both) is met: (1) if search times for faces showing this emotion are generally faster than for faces showing other emotions (2) if increasing the number of distractor faces (set size) leads to smaller increases in search time for that emotion compared to the increases in search time for other emotions. Studies applying this paradigm often find a search advantage for angry faces, which is not related to participants' anxiety (the so-called anger-superiority effect) both for schematic faces (Fox et al., 2000; Hahn & Gronlund, 2007) and real faces (Horstmann & Bauland, 2006; Moriya et al., 2014;

[12] This chapter is largely identical to a manuscript that has been accepted for publication in *The Quarterly Journal of Experimental Psychology* and is currently available as an advance online publication (Wirth & Wentura, 2017a). In the original manuscript, Experiment 2 has been relegated to the supplemental materials.

Pinkham et al., 2010). Third, even within the dot-probe paradigm, some studies report attentional biases towards threatening stimuli in unselected samples (Brosch et al., 2008; Holmes et al., 2005; Müller et al., 2016; Petrova et al., 2013). However, only a minority of dot-probe studies has yielded this result.

In the present study, we aimed to investigate if a bias towards threatening stimuli can be reliably found in unselected samples and if so, under what conditions. For this purpose, we drew on the structural equivalence of the dot-probe task with the exogenous spatial cueing task (Jonides, 1981). In this paradigm, participants are asked to classify or detect a target stimulus that can appear in one of several (typically two) positions. Before the onset of the target stimulus, an abrupt-onset cue stimulus is presented in one of the positions. Attentional capture by the cue is inferred if participants are faster to respond to targets if they appear in the cued location than an uncued location (Posner et al., 1980). It has been shown that peripheral cues capture attention even when they are uninformative in regards to the position of the target, and even when participants have explicitly been instructed to ignore the cues (Jonides, 1981; Experiment 2). Moreover, uninformative peripheral cues even capture attention when attention is guided to a different location by a preceding informative cue presented centrally (Müller & Rabbitt, 1989; Experiment 2). Therefore, it is claimed that peripheral cues capture attention via a reflexive and automatic mechanism that cannot be disrupted by voluntary effort. Thus, the dot-probe task can be regarded as a variant of spatial cueing with peripheral cues: While in the spatial-cueing paradigm, the two potential cue locations differ only with regard to whether an abrupt-onset cue appears or does not appear, in the dot-probe task the two potential cue locations differ only with regard to whether a threat appears or does not appear.

So, what could be the reason for the (typical) null finding with non-anxious participants in the dot-probe task? Some authors claim that attentional bias to threat in the general population is limited to short cue-target SOAs (Cooper & Langton, 2006; Yiend, 2010). This seems plausible because stimulus-driven covert orienting effects peak at 100-150 ms (Müller & Rabbitt, 1989) and SOAs of 200 ms and more possibly tap into shifts of overt attention (Petrova et al., 2013; Stevens et al., 2011; Weierich et al., 2008). However, dot-probe studies employing SOAs of 200 ms or less showed rather inconsistent results in regards to attentional bias to threat in non-anxious participants:

Some studies found a significant bias towards threatening stimuli in unselected samples or healthy control participants (Bocanegra, Huijding, & Zeelenberg, 2012; Brosch, Pourtois, Sander, & Vuilleumier, 2011; Holmes et al., 2005; Müller et al., 2016), but others did not (Cooper & Langton, 2006; Murphy et al., 2008; Putman, 2011; Reinecke et al., 2011; Sigurjónsdóttir et al., 2015; Stevens, Rist, & Gerlach, 2009). Two studies even found tentative evidence for a significant bias away from threatening stimuli in healthy control participants (Jovev et al., 2012; Mills et al., 2014). Thus, it seems that a short SOA is a necessary, but not a sufficient condition to detect an attentional bias towards threatening stimuli in unselected samples[13]

Two hypotheses, on what the occurrence of attentional bias to threat might depend in unselected samples, are investigated in the present chapter. The first hypothesis revolves around top-down influences on spatial attention. As already discussed, the dot-probe task can be regarded as a variant of spatial cueing. Within the spatial-cueing literature, contingent-capture theory (Folk et al., 1992; Folk & Remington, 1998, 2006) can explain why identical cue stimuli capture attention under certain conditions but fail to do so otherwise. Contingent-capture theory claims that a cue will only capture visual attention if it matches a feature of the target on a target-relevant dimension. For example, Folk and colleagues (1992) asked participants to categorise a target stimulus that could appear in one of four possible target locations. The target stimulus was either defined by onset or by colour: if defined by onset, only a single white stimulus appeared on the target screen, which had to be classified; if defined by colour, four stimuli appeared on the target screen, namely three white stimuli and one red target stimulus that had to be classified. The authors showed that onset cues only produced reliable cueing effects when participants had to respond to an onset target, but not when they had to respond to a colour target. Conversely, colour cues only captured attention when participants had to classify colour targets, but not when they had to classify onset targets. In a follow-up study, Folk and Remington (1998) showed that contingent capture works analogously for cues and targets with different colours. When searching for a green target, participants' attention was only captured by green

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[13] The discussion about the appropriate duration of the cue-target SOA is closely related to the discussion as to whether anxious participants show a bias in attentional engagement towards or in attentional disengagement from threatening stimuli. However, this question is not the aim of the present chapter.

cues but not by red cues. Conversely, when participants were searching for a red target, reliable cueing effects only occurred for red cues but not for green cues.

From these results, the authors inferred that cue stimuli do not unconditionally capture attention due to their bottom-up perceptual characteristics (i.e., saliency), but that spatial attention can be affected by top-down processes—so-called attentional control settings—which can be tuned to certain feature values (e.g., red or green) according to current goals and tasks. We should hasten to add that this theory is not undisputed (e.g., Belopolsky, Schreij, & Theeuwes, 2010; Theeuwes, 2004) and that it is still a matter of debate whether certain stimulus features can capture attention unconditionally. However, the basic result of contingent capture has been replicated in numerous empirical studies (e.g., Folk & Remington, 2006).

In sum, we know from spatial-cueing studies that attentional control settings can affect which stimuli capture attention, and we know that in dot-probe studies—which can be regarded as variants of spatial cueing—we often find an attentional bias towards threat stimuli in anxious participants, but only rarely in non-anxious participants. Is it therefore possible that this attentional bias depends on an attentional control setting that is only occasionally tuned to threat in non-anxious individuals (but permanently in anxious individuals)? In their original article on contingent-capture theory, Folk and colleagues (1992) implicitly anticipated this possibility by stating that “Perhaps, in fact, all involuntary responses to stimuli have the potential to be modulated by programmable, internal control settings. These control settings, in turn, are a function of current behavioral goals, as well as past experience or enduring biases of the organism.” (p. 1043; see also Barratt & Bundesen, 2012). Moreover, a recent review argues that top-down processes based on prior knowledge, expectations, and goals play an important role in threat-related perception and attention (Sussman, Jin, & Mohanty, 2016). Thus, non-anxious participants might usually not show an attentional bias to threat in laboratory studies because they only tune their attentional control settings to threat in potentially dangerous situations, for example—to return to the example at the beginning of this thesis—during a nocturnal walk through a dark forest.

In order to test the assumption that attentional control settings can be tuned to emotional valence, especially to threat, and that such a control setting must be activated to detect an attentional bias to threat in non-anxious individuals, we conducted the first experiment employing a variant of the dot-probe task, where participants had to classify a target that was either defined by its emotional valence (anger) or by a non-emotional feature. We used photographic images of angry and neutral faces as cue stimuli. Based on the application of contingent-capture theory to the dot-probe task, we expected to find an anxiety-independent attentional bias towards angry faces when participants classified angry targets, but not when participants classified non-emotional targets.

To our knowledge, the hypothesis that attentional control settings can be tuned to threat has not yet been tested in terms of the contingent-capture paradigm. However, another theory that was developed within the context of affective priming research makes similar predictions, namely feature-specific attention allocation theory (FSAA; Spruyt, De Houwer, & Hermans, 2009). This theory predicts that the affective content of irrelevant stimuli will be processed in an automatic fashion only if attention is allocated to the affective features of the stimuli because of current goals and task demands. In a recent study by Everaert et al. (2013), the FSAA was applied to the dot-probe task. Participants performed a variant of the dot-probe task with picture pairs of neutral and aversive scenes on 50 % of the trials. The remaining 50 % of the trials were so called "induction trials", where participants had to decide if a single picture was neutral or negative (affective group) or whether it depicted a human or not (semantic group). Consistent with the idea of FSAA, the authors found an attentional bias towards threatening scenes in an unselected sample only when participants were assessing the affective valence of pictures during the induction trials. Conversely, when threat stimuli directly competed for attention with stimuli that were task-relevant in a secondary task, attention was captured entirely by the latter stimuli, even in anxious participants (Vogt et al., 2013). Thus, FSAA theory and the corresponding evidence support the idea of testing the affective variant of the contingent-capture paradigm.[14]

In accordance with the basic idea of contingent-capture theory, we defined the target stimuli of the dot-probe task in Experiment 1 by their emotional valence, in order to induce an anger-tuned attentional control setting in participants. If the attentional bias to threat in anxious individuals can be regarded as an attentional control setting, we expected to find attentional capture by angry faces in an unselected sample independently of trait anxiety when responding to angry target stimuli, but not when

[14] However, apart from the induction of affective (vs. non-affective) attention allocation, both studies investigating FSAA (i.e., Everaert et al., 2013; Vogt et al., 2013) differed in several other details (e.g., SOA, target-related task) from a straightforward adaptation of the contingent-capture paradigm. Therefore, detailed discussion of these studies is postponed to the General Discussion.

responding to neutral target stimuli. To anticipate the results of Experiment 1, we found an (anxiety-independent) attentional bias to threat. However, this bias was not contingent on attentional control settings. Therefore, we conducted two more experiments to clarify the results of Experiment 1. In Experiment 2, we ensured that Experiment 1 was not unsuitable to detect contingent-capture effects due to technical reasons. In Experiment 2, we tested the alternative hypothesis that characteristics of the target display of Experiment 1 (that were introduced to test the attentional control setting hypothesis) were responsible for the occurrence of an attentional bias.

6.1 Experiment 1

In Experiment 1, we employed a dot-probe task with two different types of targets to manipulate attentional control settings. If emotional valence can act as an attentional control setting, we expected to observe an attentional bias towards angry faces in an unselected sample when emotional valence was a task-relevant dimension, but not when emotional valence was task-irrelevant. In accordance with considerations given above, we employed a short cue-target SOA of 100 ms.

6.1.1 Methods

6.1.1.1 Participants

Seventy-four non-psychology university students were paid for their participation. The data of one participant were excluded from all further analyses because their overall accuracy was more than 3 interquartile ranges below the first quartile of the overall distribution (Tukey, 1977). Of the remaining $N = 73$ participants, 51 were female and their ages ranged from 19 to 36 ($M = 24.2$ years, $SD = 3.4$). Their raw scores on the trait scale of the State-Trait Anxiety Inventory (STAI; Laux et al., 1981) ranged from 24 to 62 ($M = 40.6$, $SD = 9.6$). All participants reported normal or corrected-to-normal vision and provided informed consent prior to testing.

6.1.1.2 Design

We employed a 2 (*cue validity:* valid cue vs. invalid cue) × 2 (*target type:* angry target vs. non-angry target) design with *cue validity* as a trial-by-trial within-subjects factor, *target type* as a blockwise within-subjects factor, and STAI score as a continuous (centred) covariate.

Our power considerations were threefold: First, we wanted to have sufficient power to detect an attentional bias in the angry target condition. Second, we wanted to have sufficient power to detect an interaction of cue validity and target type (i.e., to find an attentional bias in the angry target condition that is significantly larger than the bias in the non-angry target condition). Third, we wanted to rule out the possibility that any potentially found attentional biases are caused by a few highly anxious participants in our sample showing extremely large biases. Therefore, we wanted to have sufficient power to detect a possible correlation between participants' attentional bias and their trait anxiety.

With regard to the first two considerations, there are no studies that provide an adequate effect-size estimate, because studies testing for contingent-capture effects in basic attention research yield effect sizes that should be considered implausibly large for the present context. Our sample size of $N = 73$ allows to detect effects of $d_Z = 0.29$ with a probability of $1 - \beta = .80$, given an α-value of .05 (one-tailed). According to Cohen (1988), such an effect can be considered in-between "small" ($d_Z = 0.2$) and "medium" ($d_Z = 0.5$); a meta-analysis by Pool et al. (2016) that investigated attentional bias towards positive emotional stimuli indicates that these are reasonable estimates. With regard to the third consideration, our sample size allows to detect effects of $r = 0.28$ (i.e., an effect slightly below "medium" according to Cohen, 1988) with a probability of $1 - \beta = .80$, given $\alpha = .05$ (one-tailed). Calculations were done using G*Power 3.1.3 (Faul et al., 2007).

6.1.1.3 Materials

Face stimuli were taken from the NimStim database (Tottenham et al., 2009). We selected photographs of the same eight female and eight male individuals as in the previous study displaying angry and neutral expressions. As exposed teeth are a strong perceptual confound of angry expressions that can potentially distort dot-probe effects (see Chapter 5), we only used angry faces with concealed teeth in the present study. All images were cropped using a standard oval shape concealing hair and external features and were converted to greyscale (see Figure 3). Participants' trait anxiety was assessed with the trait scale of the German version of the State-Trait Anxiety Inventory (STAI; Laux et al., 1981). This self-assessment scale contains 20 items, each scored between 1 (low anxiety) and 4 (high anxiety).

6.1.1.4 Procedure

The study was conducted on five PCs equipped with 17" CRT monitors using a resolution of 1,024 × 768 Pixels, a refresh rate of 100 Hz, and a colour depth of 32 bit. The experimental routine was programmed using Psychtoolbox-3 (Kleiner et al., 2007) for Matlab 2014a (Mathworks, Natick, MA).

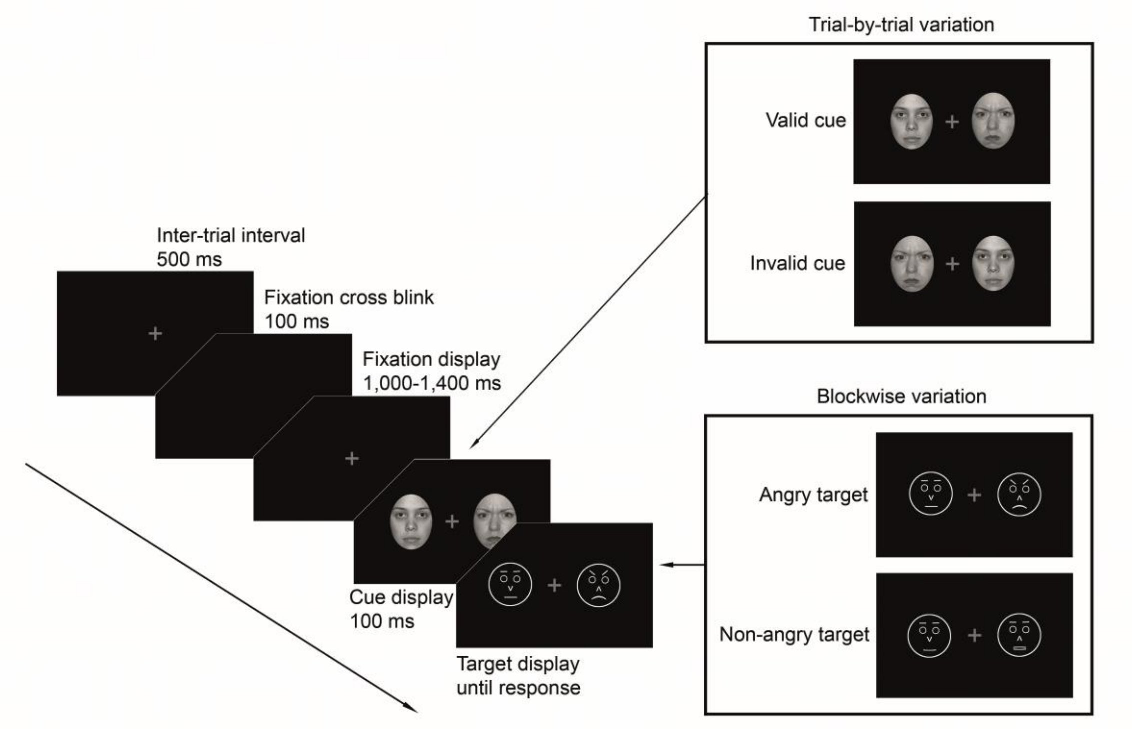

Figure 3. Schematic illustration of a typical trial and the design of Experiment 1 of Study 2. For the sake of visibility, proportions are not true to scale.

Participants were seated in an individual testing booth approximately 65 cm from the monitor and were presented with an instruction screen explaining the experimental procedure. Figure 3 depicts a schematic illustration of a typical trial and the design of Experiment 1. Throughout the experiment, a grey fixation cross was centrally presented on a black background to maintain participants’ focus at the central location. To indicate the beginning of a trial, the fixation cross blinked for 100 ms. The fixation cross then remained on screen for a variable interval (chosen randomly from the set 1,000; 1,100; 1,200; 1,300; or 1,400 ms) to avoid any anticipatory effects. Two face cues were then presented laterally for 100 ms. The faces had a size of 4.5 × 6.2 cm (4.0 × 5.5°) and their centre-to-centre distance was 11.1 cm (9.8°). One of the face cues always had an angry expression, the other one a neutral expression. Immediately after the offset of the cues, two white schematic faces—one target face and one distractor face—appeared at the cue positions and remained there until a response was given. The schematic faces had a size of 2.8 × 2.8 cm (2.5 × 2.5°) and the centre-to-centre distance between them was also 11.1 cm (9.8°).

The participants' task was to indicate in which direction the nose of the schematic target face was pointing (upwards or downwards) while the schematic distractor face had to be ignored. Nose directions of target and distractor faces were uncorrelated, i.e., the nose of the target face pointed in the same direction as the nose of the distractor face on 50 % of the trials and in the opposite direction on the remaining trials. In one block (non-angry target condition), the target was defined as the open-mouthed (as indicated by a double line) schematic face as opposed to the closed-mouthed distractor face. In the other block (angry target condition), the target was defined as the angry (as indicated by downwards-pointing mouth corners and slanted eyebrows) schematic face as opposed to the neutral distractor face. Participants were asked to respond as fast as possible by pressing the "t" key for up or the "v" key for down on a standard German QWERTZ keyboard. On 50 % of the trials, the target face appeared at the location of the angry face cue (valid cue) and on the remaining trials it appeared at the location of the neutral face cue (invalid cue). Each response was followed by a 500 ms inter-trial interval. If participants made an incorrect response or took longer than 1,500 ms to respond, they received a 1,000 Hz warning tone of 500 ms duration via headphones.

The experiment comprised 448 trials and lasted approximately 35 minutes. Trials were presented in two blocks—one with open-mouthed target faces, one with angry target faces, in a counterbalanced order—each consisting of 224 trials.[15] Within each block, a self-paced break was included after 112 trials. At the beginning of each block, participants were presented with 32 training trials that were not included in data analysis. At the end of the experiment, participants completed the trait-anxiety scale of the STAI (Laux et al., 1981).

6.1.2 Results

Average classification accuracy was *M* = 95.3 % (*SD* = 4.4). For the response time (RT) analysis, RTs below 150 ms were excluded, as were RTs more than 3 interquartile

[15] Since one participant was excluded from data analysis and one additional participant accidentally received the wrong block order, 35 participants completed the non-angry target block first, whereas 38 participants completed the angry target block first.

ranges above the third quartile of the individual participant's distribution (separately for both experimental blocks; Tukey, 1977). This led to the exclusion of 0.6 % of all trials with correct responses. After outlier removal, average individual RTs ranged from $M = 615$ to $M = 1{,}016$ ms (grand mean was $M = 812$ ms, $SD = 88$).

Table 1 reports average RTs as a function of the experimental manipulations. We calculated a 2 × 2 within-subject ANCOVA with the factors *cue validity* (valid cue vs. invalid cue) and *target type* (non-angry target vs. angry target), the participants' *z*-standardised (i.e., centred) STAI scores as a covariate, and (correct) RTs as the dependent variable. The analysis revealed significant main effects of *cue validity*, $F(1, 71) = 15.50$, $p < .001$, $\eta_p^2 = .179$, and *target type*, $F(1, 71) = 115.63$, $p < .001$, $\eta_p^2 = .620$, but no significant interactions, all *F*s < 1. The main effect of *target type* indicated faster RTs to non-angry targets ($M = 764$ ms, $SD = 88$) compared to angry targets ($M = 860$ ms, $SD = 103$). The main effect of *cue validity* reflected faster RTs to valid trials ($M = 807$ ms, $SD = 91$) than invalid trials ($M = 817$ ms, $SD = 87$; $M_\Delta = 10$ ms, $SD_\Delta = 22$, $d_Z = 0.46$).

Table 1. Mean RTs (in ms; Standard Deviations in Parentheses) in Experiment 1 of Study 2 as a Function of Target Type and Cue Validity.

Target type	**Cue validity**	
	Valid	Invalid
Angry target	855 (109)	865 (101)
Non-angry target	758 (89)	769 (88)

We calculated cueing scores by subtracting average individual RTs of valid trials from average individual RTs of invalid trials. As can be seen in Figure 4, cueing scores for angry target trials ($M = 9$ ms, $SD = 38$) and for non-angry target trials ($M = 11$ ms, $SD = 22$) were of almost equal size. Holm-Bonferroni corrected *t*-tests showed that cueing scores for both non-angry target trials, $t(72) = 4.20$, $p < .001$, $d_Z = 0.49$, and angry target trials, $t(72) = 2.10$, $p = .039$, $d_Z = 0.25$, significantly differed from zero.

It could be the case, however, that the attentional bias towards angry faces in the non-angry target condition was at least partially caused by carry-over effects between the experimental blocks. Those participants who completed the angry target block first might have kept their attentional control settings tuned to threat throughout the whole procedure, that is, also during the second, non-angry target block. Therefore, we calculated an additional 2 × 2 × 2 mixed-design ANCOVA with the within-subjects factors *cue validity* and *target type* and the additional between-subjects factor *block order* (non-angry target block first vs. angry target block first). The ANCOVA revealed no significant interactions involving the factors *cue validity* and *block order*, all Fs < 1.39, all ps > .243, all $\eta_p^2 < .020$. Moreover, those 35 participants who completed the non-angry target block first showed a significant cueing effect of $M = 9$ ms ($SD = 21$) in this condition, $t(34) = 2.56$, $p = .015$, $d_Z = 0.43$. Thus, carry-over effects cannot explain the attentional bias towards angry faces we found in the non-angry target condition.

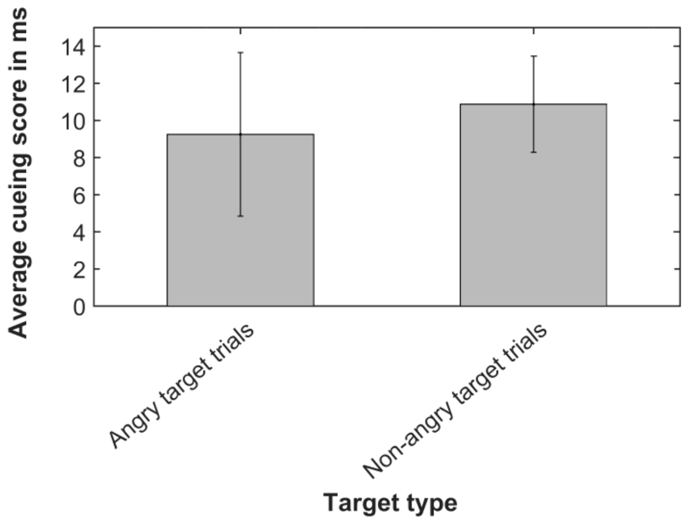

Figure 4. Average cueing scores for angry target and non-angry target trials in Experiment 1 of Study 2. Cueing scores represent the difference between the average reaction times to invalidly cued trials and validly cued trials (error bars depict ±1 standard error of the mean, SEM).

6.1.3 Discussion

In Experiment 1, participants were asked to classify schematic target faces that were preceded by two photographic face cues, one angry and one neutral. The targets were either defined by their emotional valence (angry expression) or by a non-emotional feature (open mouth). As expected, we found an attentional bias towards angry faces, which was not related to participants' anxiety, when participants had to respond to targets that were defined by their angry expression. However, we also found an attentional bias towards angry faces when participants had to classify targets that were defined by a non-emotional feature, that is, an open mouth. The attentional bias in the latter condition was numerically even larger than in the former condition (although not significantly so) and was not related to participants' trait anxiety, either. Therefore, attentional bias towards angry faces in an unselected sample was not contingent on attentional control settings induced by current task demands.

So why did we find an attentional bias towards threatening faces in an unselected sample if it was apparently not contingent on attentional control settings? The first potential explanation is rather technical. Maybe our experimental parameters were simply not suitable to detect contingent-capture effects. Therefore, we conducted Experiment 2 to make sure we were able to detect contingent-capture effects with the spatial and temporal parameters applied in Experiment 1.

The second potential explanation revolves around the target stimuli used in Experiment 1. In order to induce attentional control settings, we had to present two stimuli in each target display—one target face and one distractor face—that differed from each other regarding the dimension of the respective attentional control setting (i.e., angry expression vs. open mouth). However, in standard dot-probe studies only one stimulus (the target) is presented in the target display. If the target itself is the only stimulus presented in the target display, it is characterised by a strong abrupt onset, that is, the target is an onset singleton. It could be that an attentional bias to threat is only detectable in non-anxious individuals when targets are employed that are not characterised by an abrupt onset. We conducted Experiment 3 to test this hypothesis.

6.2 Experiment 2

We conducted Experiment 2 as a control experiment to make sure that the spatial and temporal parameters of Experiment 1 were suitable to detect potential contingent-capture effects. The aim of this experiment was to replicate typical contingent-capture effects for cues and targets of matching and non-matching colours while employing identical parameters to Experiment 1. Therefore, Experiment 2 was designed to be similar to Experiment 1 in most details (e.g., target materials) to maximise comparability and allow for a seamless transition from threat cues (Experiment 1) to colour cues (Experiment 2).

6.2.1 Methods

6.2.1.1 Participants

Forty non-psychology university students (28 female) were paid for their participation. Their ages ranged from 20 to 31 ($M = 23.5$ years, $SD = 3.0$). All participants reported normal or corrected-to-normal vision and provided informed consent prior to testing.

6.2.1.2 Design

We employed a 2 (*cue validity:* valid cue vs. invalid cue) × 2 (*cue colour:* green vs. red) × 2 (*target colour:* green vs. red) design with *cue validity* as a trial-by-trial within-subjects factor, *cue colour* as a between-subjects factor, and *target colour* as a blockwise within-subjects factor (counterbalanced for order).

We based our power considerations on Folk and Remington's (1998) results regarding attentional capture by matching and non-matching colour cues. For singleton targets, they reported a contingent-capture effect of size $d = 1.27$ (Folk & Remington, 1998, Experiment 1). Since we employed a between-subjects factor and made several additional changes to their original design, we made more conservative assumptions regarding our expected effects. With a sample size of $n = 20$ per group, we were able to detect effects of size $d = 0.85$ with a probability of $1 - \beta = .95$ and an α-value of .05 (two-tailed) within both groups. Calculations were done using G*Power 3.1.3 (Faul et al., 2007).

6.2.1.3 Procedure

Figure 5 depicts a schematic illustration of a typical trial and the design of Experiment 2. The experimental procedure was identical to the procedure of Experiment 1, apart from the following exceptions. During the cue display, instead of face cues, two colour cues were presented laterally for 100 ms. Each cue consisted of four dots aligned in a diamond shape, which had a size of 3.6 × 3.6 cm (3.2 × 3.2°). The centre-to-centre distance between the cues was 11.1 cm (9.8°). One of the cues was always white, whereas the other cue was green for one half of the participants and red for the other half of the participants. Immediately after the offset of the cues, two schematic faces—one coloured (green or red) target face and one white distractor face—appeared at the cue positions and remained there until a response was given. The schematic faces had a size of 2.8 × 2.8 cm (2.5 × 2.5°) and the centre-to-centre distance between them was again 11.1 cm (9.8°).

The participants’ task was to indicate the direction in which the nose of the target face was pointing (upwards or downwards), while the distractor face had to be ignored. In one block, the target was always green, in the other block it was always red. While of no immediate relevance to the present experiment, in order to keep Experiment 2 as similar as possible to Experiment 1, face colour was related to the emotional expression of the target faces: White distractor faces were always neutral and had a closed mouth, green target faces were always neutral and had an open (double-lined) mouth, and red target faces were always angry and had a closed mouth. On 50 % of the trials, the target face appeared at the location of the coloured cue (valid cue), and on the remaining trials it appeared at the location of the white cue (invalid cue).

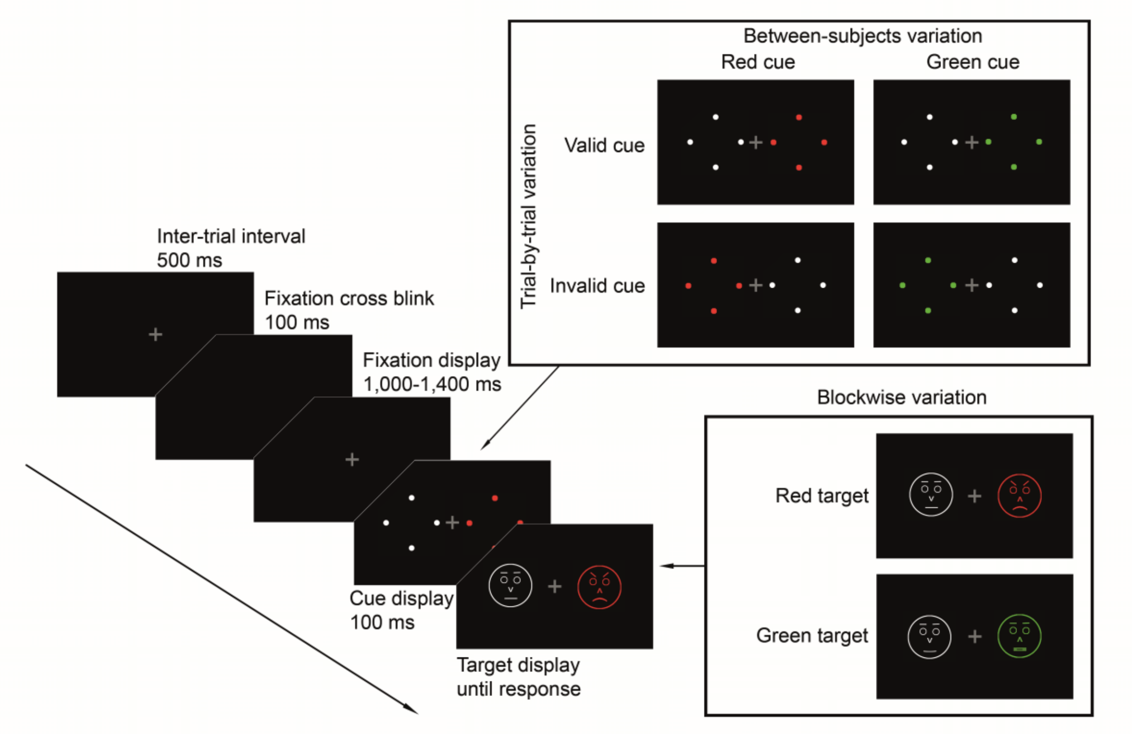

Figure 5. Schematic illustration of a typical trial and the design of Experiment 2 of Study 2. For the sake of visibility, proportions are not true to scale.

6.2.2 Results

Average classification accuracy was $M = 97.5$ % ($SD = 2.4$). Response time (RT) outliers were excluded following the same criteria as in Experiment 1. This led to the exclusion of 0.8 % of all trials with correct responses. After outlier removal, average individual RTs ranged from $M = 547$ to $M = 893$ ms (grand mean was $M = 669$ ms, $SD = 78$).

Table 2 reports average RTs as a function of the experimental manipulations. For the sake of simplicity, the two factors *cue colour* and *target colour* were combined into a new *cue-target congruence* factor with the levels colour match (green cue / green target; red cue / red target) and colour mismatch (green cue / red target; red cue / green target). We calculated a 2 × 2 within-subjects ANOVA with the factors *cue validity* (valid cue vs. invalid cue) and *cue-target congruence* (colour match vs. colour mismatch) and (correct) RTs as the dependent variable.

Table 2. Mean RTs (in ms; Standard Deviations in Parentheses) in Experiment 2 of Study 2 as a Function of Cue Colour, Target Colour, and Cue Validity.

Cue colour	**Target colour**	**Cue validity**	
		Valid	Invalid
Green cue	Green target	571 (75)	710 (66)
	Red target	640 (96)	680 (82)
Red cue	Green target	665 (56)	665 (64)
	Red target	647 (112)	777 (105)

The ANOVA revealed a significant main effect of *cue validity*, $F(1, 39) = 194.94$, $p < .001$, $\eta_p^2 = .833$, which was significantly moderated by the expected *cue validity* × *cue-target congruence* interaction, $F(1, 39) = 253.01$, $p < .001$, $\eta_p^2 = .866$. In order to check whether this interaction effect was similar in both participant groups (i.e., green-cue and red-cue groups), we repeated the ANOVA with the additional between-subjects factor *cue colour*. This ANOVA revealed a significant *cue validity* × *cue-target congruence* × *cue colour interaction*, $F(1, 38) = 5.05$, $p = .031$, $\eta_p^2 = .117$, suggesting that the *cue validity* × *cue-target congruence* interaction differed between both participant groups. Therefore, we calculated two separate 2 × 2 within-subjects ANOVAs for both participant groups. These ANOVAs showed that the *cue validity* × *cue-target congruence* interaction was significant both in the green-cue participant group, $F(1, 19) = 118.00$, $p < .001$, $\eta_p^2 = .861$, and the red-cue participant group, $F(1, 19) = 161.40$, $p < .001$, $\eta_p^2 = .895$. Thus, the overall three-way interaction only reached significance because the contingent-capture effect was slightly larger in the red-cue sample than in the green-cue sample.

Again, we calculated cueing scores by subtracting average individual RTs of valid trials from average individual RTs of invalid trials to facilitate interpretation of the *cue validity* × *cue-target congruence* interaction. As can be seen in Figure 6, cueing effects were much larger on colour-match trials (M = 134 ms, SD = 41) than on colour-mismatch trials (M = 20 ms, SD = 43). However, Holm-Bonferroni corrected t-tests showed that cueing scores for both colour-match trials, $t(39) = 20.85$, $p < .001$, $d_Z = 3.30$, and colour-mismatch trials, $t(39) = 2.99$, $p = .005$, $d_Z = 0.47$, significantly differed from zero.

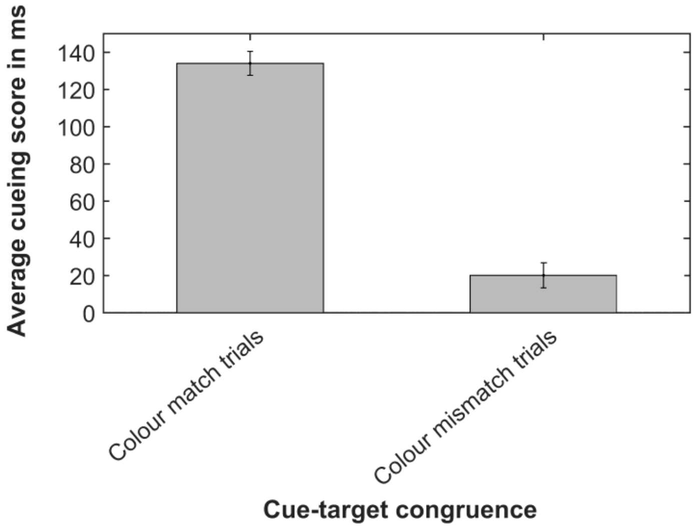

Figure 6. Average cueing scores for colour match and colour mismatch trials in Experiment 2 of Study 2. Cueing scores represent the difference between the average reaction times to invalidly cued trials and validly cued trials (error bars depict ±1 standard error of the mean, SEM)

Due to differences in target-selection difficulty, mean RTs were faster in Experiment 2 than in Experiment 1. Thus, one might argue that contingent capture is a phenomenon restricted to fast trials. To account for this argument, we calculated a 2 (*experiment:* Experiment 1 vs. Experiment 2) × 2 (*cue validity:* valid cue vs. invalid cue) × 2 (*cue-target congruence:* cue-target match vs. cue-target mismatch) ANCOVA with (correct) RTs as the dependent variable and (z-standardised) individual mean RTs as a covariate. As expected, we obtained a three-way *experiment* × *cue validity* × *cue-target congruence* interaction, $F(1, 110) = 90.91$, $p < .001$, $\eta_p^2 = .453$, which corresponds to the findings of non-contingent capture in Experiment 1 and contingent capture in Experiment 2. The "competing"[16] three-way interaction of *mean RT* × *cue validity* × *cue-target congruence*, however, was not significant, $F(1, 110) = 1.44$, $p = .233$, $\eta_p^2 = .013$.

6.2.3 Discussion

In Experiment 2, participants were asked to classify schematic target faces that were defined by specific colours (i.e., green or red). The target stimuli were preceded by matching or non-matching colour cues. Consistent with contingent-capture theory (Folk & Remington, 1998), we found larger cueing effects for matching colour cues compared to non-matching colour cues. Since we employed the same spatial and temporal parameters in Experiment 2 as in Experiment 1, technical shortcomings cannot account for the absence of contingent-capture effects in Experiment 1. Admittedly, the cueing effects found in Experiment 1 were only a fraction of the size of the cueing effects found in Experiment 2. This is not surprising as colour is a basic and salient feature that is easily detected in visual-search and change-detection tasks and seems to play a dominant role in the tuning of attentional control settings (Alvarez & Cavanagh, 2004; Nako, Smith, & Eimer, 2016; Theeuwes, 1992; Wolfe, 1994). By contrast, valence of facial expressions is a perceptually more complex higher-level feature. Nevertheless, if attentional bias towards threatening stimuli was contingent on attentional control settings, the difference in cueing effects between the angry and non-angry target conditions in Experiment 1 should have mimicked the difference between colour-match and colour-mismatch conditions in Experiment 2, even if the absolute cueing effects were on a much smaller scale.

6.3 Experiment 3

Experiment 1 and Experiment 2 showed that attentional bias towards angry faces is not contingent on attentional control settings in the general population. However, they cannot explain why we found attentional bias in an unselected sample in the first place, while so many other studies did not (Bar-Haim et al., 2007). Therefore, we conducted

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[16] Note that with regard to the three-way interactions, the ANCOVA is structurally equivalent to a multiple regression with the difference between the cueing effect (i.e., invalid-RT – valid-RT) for matching trials minus the cueing effect for non-matching trials as the dependent variable and experiment (-1 for Experiment 1; +1 for Experiment 2) and mean RT as predictors.

Experiment 3 to test the hypothesis that the target displays we employed in Experiment 1 produced this result. As already discussed, two stimuli were presented in target displays in Experiment 1 (a target and a distractor stimulus), whereas standard dot-probe studies use a single target stimulus. If this hypothesis is true, we expected to find a significant attentional bias towards angry faces that is not moderated by trait anxiety when two stimuli are presented in the target display, but not when only a single target is presented.

6.3.1 Methods

6.3.1.1 Participants

Seventy-nine non-psychology university students were paid for their participation. Three participants were excluded from all further analyses, two of them because their overall accuracy was more than 3 interquartile ranges below the first quartile of the overall distribution, and one because their average response time in one of the experimental blocks was more than 3 interquartile ranges above the third quartile of the overall distribution (Tukey, 1977). Of the remaining $N = 76$ participants, 55 were female and their ages ranged from 18 to 34 ($M = 24.3$ years, $SD = 3.6$). Their raw scores on the trait scale of the STAI (Laux et al., 1981) ranged from 23 to 68 ($M = 40.2$, $SD = 9.9$). All participants reported normal or corrected-to-normal vision and provided informed consent prior to testing.

6.3.1.2 Design

We employed a 2 (*cue validity:* valid cue vs. invalid cue) × 2 (*target type:* onset target vs. no-onset target) design with *cue validity* as a trial-by-trial within-subjects factor, *target type* as a blockwise within-subjects factor, and STAI score as a continuous (centred) covariate. Regarding power considerations, the same considerations as in Experiment 1 applied.

6.3.1.3 Materials and Procedure

The same materials as in Experiment 1 were used. Figure 7 depicts a schematic illustration of a typical trial and the design of Experiment 3. In the no-onset target block, the experimental procedure was identical to the non-angry target block of Experiment 1. The only difference in the onset target block was that only the open-mouthed schematic target face was presented, but no schematic distractor face was presented in the target display. Therefore, the schematic target face was characterised by an abrupt and strong onset in this block. In contrast to Experiment 1, the STAI was presented in a digital version instead of the paper-and-pencil version.

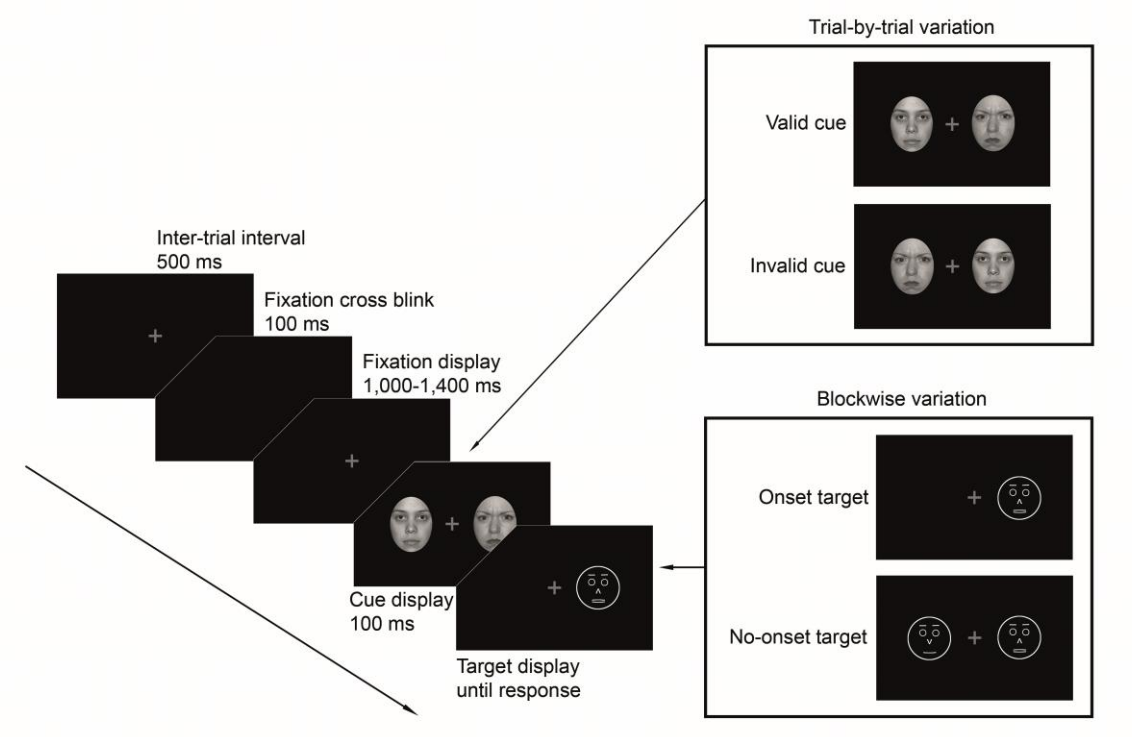

Figure 7. Schematic illustration of a typical trial and the design of Experiment 3 of Study 2. For the sake of visibility, proportions are not true to scale.

6.3.2 Results

Average classification accuracy was $M = 97.0$ % ($SD = 2.5$). Response time (RT) outliers were excluded following the same criteria as in Experiment 1 and Experiment 2 (0.5 % of all trials with correct responses were excluded). After outlier removal, average individual RTs ranged from $M = 551$ to $M = 819$ ms (grand mean was $M = 673$ ms, $SD = 63$).

Table 3 reports average RTs as a function of the experimental manipulations. We calculated a 2 × 2 within-subject ANCOVA with the factors *cue validity* (valid cue vs. invalid cue) and *target type* (onset target vs. no-onset target), the participants' z-standardised (i.e., centred) STAI scores as a covariate, and (correct) RTs as the dependent variable. The analysis revealed significant main effects of *cue validity*, $F(1, 74) = 4.89$, $p = .030$, $\eta_p^2 = .062$, and *target type*, $F(1, 74) = 434.12$, $p < .001$, $\eta_p^2 = .854$, as well as a significant *cue validity* × *target type* interaction, $F(1, 74) = 8.33$, $p = .005$, $\eta_p^2 = .101$. The main effect of *target type* indicated faster RTs to onset targets

(*M* = 610 ms, *SD* = 56) compared to no-onset targets (*M* = 737 ms, *SD* = 79). The main effect of *cue validity* reflected faster RTs to valid trials (*M* = 672 ms, *SD* = 63) than to invalid trials (*M* = 675 ms, *SD* = 63; M_{Δ} = 3 ms, SD_{Δ} = 13, d_Z = 0.25).

Table 3. Mean RTs (in ms; Standard Deviations in Parentheses) in Experiment 3 of Study 2 as a Function of Target Type and Cue Validity.

Target type	**Cue validity**	
	Valid	Invalid
Onset target	610 (56)	609 (56)
No-onset target	734 (80)	741 (80)

To clarify the meaning of the interaction, we again calculated cueing scores by subtracting average individual RTs of valid trials from average individual RTs of invalid trials. As can be seen in Figure 8, cueing scores for no-onset target trials (*M* = 8 ms, *SD* = 22) were clearly larger than cueing scores for onset target trials, which were actually below zero (*M* = -1 ms, *SD* = 13). Cueing scores for no-onset target trials significantly differed from zero, *t*(75) = 2.95, *p* = .004, d_Z = 0.34, whereas cueing scores for onset target trials did not, *t*(75) = 0.72, *p* = .472, d_Z = 0.08.

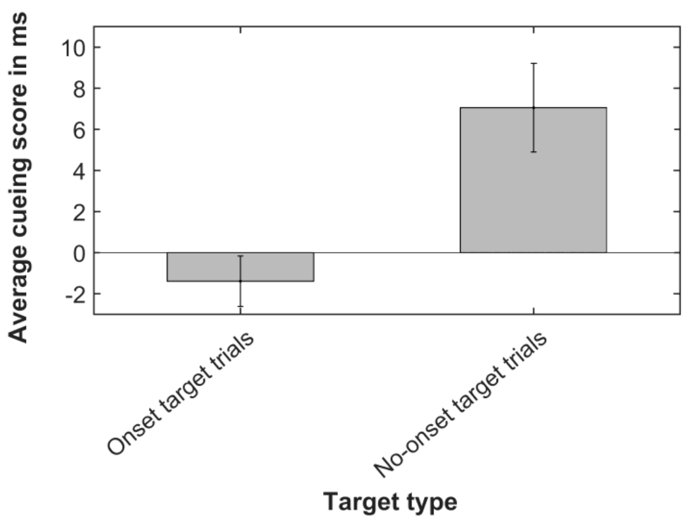

Figure 8. Average cueing scores for onset target trials and no-onset target trials in Experiment 3 of Study 2. Cueing scores represent the difference between the average reaction times to invalidly cued trials and validly cued trials (error bars depict ±1 standard error of the mean, SEM).

Due to differences in target selection difficulty, mean RTs were longer in the no-onset condition than in the onset condition. Therefore, one could argue that the result pattern is a consequence of the differences in reaction times. To account for this argument, we calculated a linear regression with participants' individual differences in average RTs between the two conditions (i.e., average no-onset RT – average onset RT) as the predictor and participants' individual differences in cueing effects between the two conditions (i.e., no-onset cueing effect – onset cueing effect) as the criterion. The regression did not reveal a significant impact of the predictor, $\beta = .002$, $t(74) = 0.02$, $p = .984$. Thus, this argument cannot explain the result pattern of Experiment 3.

6.3.3 Discussion

In Experiment 3, participants were asked to classify schematic target faces that were preceded by two photographic face cues, one angry and one neutral. In one experimental block, two stimuli were presented in the target display, an open-mouthed target face that had to be classified and a closed-mouthed distractor face that had to be ignored. Thus, this condition was identical to the non-angry target condition of Experiment 1. In the other experimental block, only the open-mouthed target face was presented. Thus, the target face was characterised by a strong abrupt onset. We found an attentional bias towards angry faces, which was not related to participants' anxiety, when two stimuli were presented in the target display. In contrast, we did not find any attentional bias when a single abrupt-onset target was presented in the target display. Therefore, it seems that our previous results can be explained by the number of stimuli in the target display.

6.4 General Discussion

In two experiments, we investigated whether an attentional bias towards threat stimuli can also occur in non-anxious individuals under specific conditions. First, we tested the hypothesis that an attentional control setting tuned to threat must be activated in non-anxious individuals. In Experiment 1, participants had to classify schematic target faces that were defined by emotional valence (angry expression) or by a non-emotional feature (open mouth). The schematic target faces were preceded by two photographic face cues, one angry and one neutral. Thus, angry face cues matched the target faces in the task-relevant dimension when participants had to respond to angry targets, but not when they had to respond to open-mouthed targets. As expected, we found a significant, anxiety-independent attentional bias towards angry faces, when participants had to classify targets that were defined by their angry expression. However, we also found an attentional bias towards angry faces when participants had to search for targets defined by a non-matching, non-emotional dimension. Importantly, this bias was not related to participants' trait anxiety, either. Moreover, the attentional bias towards angry faces did not differ in size between both conditions.

Based on this result, we reached two conclusions. First, a bias towards threatening stimuli (angry faces in this case) can be found in non-anxious participants under certain conditions. Second, this bias is not contingent on attentional control settings induced by current task demands. Regarding the second point, one could argue that Experiment 1 was simply not suitable for detecting the critical interaction between *cue validity* and *target type*. This seems implausible for two reasons. First, we had enough power to detect even modest effects (see *Methods* of Experiment 1). Second, the cueing effect in the non-angry target condition was significantly larger than zero and did not differ from the cueing effect in the angry-target condition.

Nevertheless, we conducted Experiment 2 as a control experiment to ensure that the experimental parameters of Experiment 1 were suitable to detect contingent-capture effects. In Experiment 2, we were able to replicate typical contingent-capture effects for cues and targets of matching and non-matching colours (Folk & Remington, 1998). Thus, technical shortcomings cannot account for the absence of any continent-capture effects in Experiment 1.

Taken together, these results suggest that attentional bias towards angry faces was not contingent on an attentional control setting tuned to threat. However, it is possible that participants activated a different attentional control setting and that this may have caused the effects in Experiment 1. In both conditions of Experiment 1, a neutral distractor face was presented in the target display, and thus participants' attentional control settings may have been tuned to non-neutrality in order to avoid the location of the distractor face. Thus, participants' attention could have been captured by the non-neutral, angry face cue. However, we are not aware of any studies investigating whether attentional control settings can be defined by the absence of a feature. Moreover, the hypothesis that angry faces captured attention unconditionally seems sparser than the hypothesis that an attentional control setting tuned to non-neutrality caused the attentional bias to angry faces, especially since the latter hypothesis implies that participants perceived the open-mouthed target face as non-neutral.

Our results seem inconsistent with the results of Everaert and colleagues (2013), who found that the attentional bias towards threat stimuli in a dot-probe task was affected by current task demands. However, there are some differences between the two studies that warrant consideration. First, Everaert et al.'s study used a rather long SOA (350 ms)—which makes comparison of the two studies difficult—although we do not believe that this feature is the main reason for obtaining seemingly different results.

Second, the induction of attentional control settings was different across the two studies in at least two ways. (a) In Everaert et al. (2013), whenever only a single image appeared in the centre of the cue display (instead of the picture pairs of standard dot-probe trials), participants had to categorise this image as "negative" versus "non-negative" (affective induction) or as "human" versus "non-human" (non-affective induction). Thus, the transfer of attentional control settings is an "across trials, same component" transfer: The categorised dimension of the single images on induction trials was assumed to transfer to the cue images on dot-probe trials. By contrast, in the contingent-capture paradigm, the transfer is a "within trials, different components" transfer: Targets have to be identified by a certain feature (e.g., colour, angry face) and it is assumed that this dimension transfers to the cue displays. (b) Both induction tasks (i.e., the affective and the non-affective task) can be applied to all cue stimuli used by Everaert and colleagues (e.g., a cockroach can be categorised as "negative" and as "non-human"). Thus, it might be that activating the feature that corresponds to the prevalent induction task is accompanied by inhibition of other stimulus features, including the feature corresponding to the non-prevalent induction task. Take, for example, the cue pair which consists of a neutral-looking male face (IAPS code 2190) and a picture of cockroaches (1274). If the affective induction task transfers to the cue display, a neutral stimulus (i.e., the face) is accompanied by a negative one (i.e., the cockroaches). In this case, processing the stimuli regarding valence might inhibit processing of the human/non-human dimension. If, however, the non-affective induction task transfers to the cue display, a human stimulus (i.e., the face) is accompanied by a non-human one (i.e., the cockroaches). In this case, processing the stimuli regarding the human/non-human dimension might inhibit processing of valence. In contrast, in the contingent-capture paradigm, the categorisation task of the control condition does not meaningfully apply to the cues because none of the cues belong to the target-defining category (i.e., there was no "open mouth" cue face).

Third, a further detail of the study by Everaert and colleagues (2013) should be mentioned in this context. The participants' task in the dot-probe trials was to categorise the location of the target stimulus. As stimuli were presented one above the other, participants had to indicate whether the target was presented in the top or in the bottom position. This turns the dot-probe task from a paradigm that purely tests for selective spatial attention into a combination of selective attention and response priming paradigms: A valid cue always contained the correct response-relevant feature, whereas an invalid cue contained the incorrect response-relevant feature. If, for example, a valid cue was presented in the top position, the target had to be categorised as “top”; conversely, if an invalid cue was presented in the top position, the target had to be categorised as “bottom”. Thus, due to the use of a localisation task, an attentional bias effect is confounded by potential response facilitation and/or interference processes. This could potentially explain the results of Everaert and colleagues: Arguably, the affective induction task enhanced the processing of the negative cue; this processing likely included all features of the cue (including its location). Thus, if the negative cue is valid, its location information is compatible with the correct response to the target. Conversely, if the negative cue is invalid, its location information is incompatible with the correct response to the target. Consequently, the negative cue also acts as a prime. This argument is strongly supported by a study by Mulckhuyse and Crombez (2014), employing the emotional spatial cueing paradigm. As discussed in Chapter 3, this paradigm is similar to the dot-probe task, but only one cue stimulus (either emotional or neutral) is presented during the cue display. Mulckhuyse and Crombez conducted five experiments using fear-conditioned colours as cues, and found a modulation of the cueing effect by the acquired valence of the cue colours when participants performed a localisation task (Experiment 4), but not when they performed a detection (Experiments 1-3) or a classification task (Experiment 5). The authors concluded that in the localisation task, threatening cues modulated a motor process that primed the response.

Yet, if attentional bias to threat in unselected samples is not contingent on attentional control settings, why did we find a reliable attentional bias towards angry faces in Experiment 1? A marked difference between our Experiment 1 and most other dot-probe studies that might have caused this result is the number of stimuli presented in the target display. Since we wanted to induce attentional control settings in Experiment 1, we had to present two stimuli in each target display, one target face and one distractor face, which differed in the dimension of the corresponding attentional control setting (i.e., anger vs. non-emotional feature). However, the standard in dot-probe studies is that only the target itself is presented in the target display. This target stimulus is therefore characterised by a strong abrupt onset, that is, it is an onset singleton. According to the concept of biased competition, both bottom-up and top-down processes can bias the activation of items competing for attention (Yiend, 2010). In the case of the dot-probe task, this means that a threatening stimulus will bias attention via bottom-up processes due to its emotional properties when competing with a neutral stimulus (Mathews & Mackintosh, 1998). Importantly, this implies that selective attentional effects can only be detected when stimulus presentation allows for competition between items. For example, in the emotional spatial cueing task, where only one stimulus (either emotional or neutral) is presented in the cue display, even a non-predictive neutral cue stimulus will necessarily capture attention since it does not compete with any other stimuli (e.g., Mulckhuyse & Crombez, 2014).[17] However, based on our results it seems that competition is not only necessary during the cue display, but also during the target display to detect attentional bias to threat in non-anxious participants.

How can we explain that the type of target display matters, although it is typically believed that the decisive process (i.e., the switch of attention to the threatening stimulus) has already occurred in the cue display? One key to understanding this lies in the fact that the target display can be considered a visual search display consisting of two stimuli—the target and the distractor—which are presented simultaneously. According to the Guided Search 2.0 model of visual search (GS2; Wolfe, 1994), stimuli across the entire visual field are filtered through broadly-tuned channels to produce feature maps for a limited set of visual features (e.g., colour, orientation). These feature maps contain activations at specific locations based on bottom-up processes (i.e., stimulus saliency) and top-down processes (i.e., task

[17] Since the emotional spatial cueing task was designed to specifically investigate disengagement from threat, it usually employs predictive cues (with a validity of 70 % and higher) to ensure initial capture by the cue (e.g., Fox et al., 2001; Fox et al., 2002). However, Mulckhuyse and Crombez (2014) conducted several emotional spatial cueing experiments with fear-conditioned colours as cues. In three experiments, they showed that non-predictive neutral cues also captured attention, even if they were not characterised by a salient onset as they were isoluminant with the background.

demands). A weighted sum of the bottom-up and top-down activations of different features forms an activation map with higher peaks representing higher overall activation; this activation map thus codes how much activation specific locations receive from the various features. Attention is then deployed in order of decreasing activation, that is, from highest to lowest peak.

During the presentation of the cue screen, a modestly larger activation peak will be created at the location of the angry face than at the location of the neutral face due to bottom-up processes reflecting the emotional content of the angry face. This small difference in activation will still persist when the temporally proximal target screen is presented. When a target display with two stimuli is presented, the target should create a peak at its location that is only slightly larger than the peak created by the distractor due to top-down activation of the target-relevant feature. Thus, in the valid cue condition, two activation differences—the bottom-up difference generated by the angry face cue and the top-down difference generated by the schematic target face—add up and determine that the target position is attended first. In the invalid cue condition, the two small activation differences are opposed to one another. If we assume that the difference generated by the angry face is a bit larger than the difference generated top-down, the invalid location will typically be attended first.

However, when only one stimulus is presented in the target display, the target itself creates a massive peak of activation due to its onset characteristic via two mechanisms. First, abrupt and temporally isolated onsets seem to produce substantial bottom-up activation (Hancock & Phillips, 2004; Yantis & Jonides, 1990). Second, since participants know that all targets will be characterised by onset, they could employ an onset-singleton search mode (Bacon & Egeth, 1994; Folk et al., 1992), additionally producing considerable top-down activation of the target location. Thus, when a single onset target is used, the massive activation peak at the target location will always exceed the activation of the opposite location by far, no matter whether the small activation difference transferred from the cue display is in favour of the target location or the opposite location. Due to this large difference in activation between the target location and the opposite location, the target "pops out" (Wolfe, 1994) and its location will be attended to first, no matter which location was cued by the angry face. Therefore, we conclude that target competition is necessary in the dot-probe task in order to detect attentional bias to threat in non-anxious participants.

Studies varying target competition in the spatial-cueing paradigm are rare. Variation in target competition is not, for example, mentioned in a recent comprehensive review of the spatial cueing paradigm (Chica et al., 2014). The existing studies offer only mixed results. Lupiáñez and Milliken (1999) as well as Lupiáñez, Milliken, Solano, Weaver, and Tipper (2001) compared exogenous cueing effects of onset cues for target displays with and without a distractor. Results are inconclusive with regard to the short SOA condition (i.e., 100 ms): Lupiáñez and colleagues (2001) found a positive cueing effect without a distractor and a null effect with a distractor in a between-participants design, a result that is inconsistent with ours. (Note, however, that it is consistent with the contingent-capture result found by Folk et al., 1992, for onset cues.) Lupiáñez and Milliken (1999) varied presence versus absence of a distractor on a trial-by-trial basis. While there was no difference in the size of the cueing effects with and without distractor if the distractor appeared in a minority of trials (i.e., 25 %), the cueing effect was significantly larger in trials with a distractor compared to trials without a distractor if the distractor appeared in the majority of trials (i.e., 75 %). Recently, Xu and Tanaka (2015) provided support for our claim in a cueing study using central, symbolic, but non-predictive cues (i.e., a head turn of a depicted person in Experiment 1 and arrows in Experiment 2). They compared conditions with a single target and a target-distractor combination and found the cueing effect to be larger in the distractor condition. They explicitly argued that the attentional capture effect caused by an abrupt onset target causes interference with the cueing effect triggered by the symbolic cue.

Note, however, that social and arrow cueing effects of the type observed by Xu and Tanaka (2015) are believed to be a specific class of cueing effects. For example, the effects typically have a later onset because the central cue needs interpretation. Thus, it is very likely that this effect is disturbed by a fast and reflexive abrupt onset effect. It is therefore remarkable that we have found a result comparable to Xu and Tanaka's results in an exogenous cueing study.

We have to acknowledge that our results could also be caused by a different mechanism. Using face-like target stimuli (i.e., schematic faces) might have caused participants to adopt an attentional control setting tuned to faces. Therefore, an attentional bias towards angry faces might not be found in unselected samples if non-facial target stimuli are used. However, this potential alternative explanation has two shortcomings: First, when participants' attentional control settings are not tuned to threat but to faces in general, why should the angry face cue attract attention but not the competing neutral face cue? Second, in the onset condition of Experiment 2, the targets were also schematic faces, but an attentional bias towards angry faces was not found. Thus, our initial interpretation of the present study's results arguably seems more plausible; however, future research will be needed to rule out this alternative interpretation.

To conclude, the present study examined if and under which conditions attentional bias to threat can be found in non-anxious participants. Our results suggest that an attentional bias towards threatening stimuli can be found in non-anxious participants. Contradicting our initial hypothesis, however, the occurrence of this bias is not contingent on attentional control settings induced by current task demands. It seems more likely that this bias is contingent on target competition. We argue that when target stimuli do not have to compete for attention, their strong activation due to abrupt onset overrides any attentional bias previously created by threatening cue stimuli.

7 Study 3: The activation of a social processing mode as a crucial determinant of attentional bias towards angry faces[18]

The human visual system is permanently confronted with an abundance of incoming information. Thus, stimuli entering the visual system are competing for attention, which determines what information is further processed (Desimone & Duncan, 1995). Various models of emotional attention from basic research disciplines like evolutionary psychology (Öhman & Mineka, 2001) or cognitive psychology (Brosch et al., 2008) claim that threatening stimuli efficiently attract visual attention in humans.[19] In contrast, several clinical models of anxiety and anxiety disorders claim that only anxious individuals show an attentional bias to threat, but that the general population does not (e.g., Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1988). As already discussed in previous chapters, this discrepancy might be a consequence of the experimental paradigms used by the respective fields to assess attentional bias to threat. Whereas basic research disciplines frequently use the face-in-the crowd paradigm, clinical studies widely use the dot-probe task to investigate attentional bias.

As already demonstrated in Chapter 3, the face-in-the-crowd paradigm is a variant of visual search (Bacon & Egeth, 1994; Theeuwes, 2004; Wolfe, 1994; Wolfe, 1998). In this paradigm, participants are asked to search for a target face displaying a specific or a discrepant emotion among a set of distractor faces displaying a different emotion (or a neutral expression). These studies usually find that angry (i.e., threatening) target faces are detected faster than target faces displaying other emotions (Fox et al., 2000, Experiments 1 and 2; Moriya et al., 2014; Pinkham et al., 2010) and that increasing the number of distractor faces (set size) leads to smaller increases in search times for angry target faces than for target faces with different emotional expressions (Fox et al., 2000, Experiment 5; Hahn & Gronlund, 2007; Horstmann & Bauland, 2006). This search advantage for angry faces (also referred to as the *anger-superiority effect*) is assumed to reflect an attentional bias to threat.

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[18] This chapter is largely identical to an existing manuscript that is currently in preparation (Wirth & Wentura, 2017b).

[19] It should be noted, however, that both theories disagree with regard to the question as to whether threatening stimuli exclusively attract attention. Whereas Öhman and Mineka (2001) argue that this is the case, Brosch et al. (2008) claim that all stimuli that are of general relevance to the individual attract attention (see Chapter 2).

The dot-probe task is a variant of the exogeneous spatial cueing paradigm (Chica et al., 2014; Jonides, 1981; Posner et al., 1980). In the dot-probe task, participants are asked to classify a target stimulus that can appear in either of two positions (usually left or right to the centre of the screen). Before the onset of the target, two cue stimuli are presented in these two positions, one emotional (usually threatening; e.g., an angry face) and one neutral (e.g., a neutral face). Importantly, the position of the emotional cue stimulus is not predictive regarding the position of the target. An attentional bias towards the emotional cue stimulus is inferred if participants are faster to classify the target when it appears in the location of the emotional stimulus (valid emotional cue) than when it appears in the location of the neutral stimulus (invalid emotional cue). The rationale of this approach is the following. If the emotional cue captures attention, attention will already be at the right location before target onset when the target appears in the same position (see, however, section 3.2.2.1 for a more detailed description of the potentially underlying mechanisms). Dot-probe studies usually find an attentional bias towards threatening stimuli in anxious, but not in non-anxious participants (see Bar-Haim et al., 2007; Frewen et al., 2008 for meta-analyses).

What could be the reason that the face-in-the-crowd paradigm usually finds an attentional bias towards threatening faces in unselected samples (i.e., in samples that consist mainly of non-anxious participants), whereas the dot-probe task does usually not find an attentional bias towards threatening stimuli in non-anxious participants? As already discussed (see Chapter 3), we think that the reason for the inconsistent results between the dot-probe task and the face-in-the-crowd paradigm might be related to the task requirements of these paradigms. The face-in-the-crowd paradigm uses a task that requires social processing and categorisation: The faces presented in the search display have to be processed and categorised according to a socially relevant dimension (i.e., emotional expression). In contrast, the cue stimuli in the dot-probe task are irrelevant for the target-categorisation task and participants are usually explicitly instructed to ignore the cue stimuli. Thus, even if faces are employed as cue stimuli, the dot-probe task does not require social processing. In the present study, we aim to test the hypothesis that a social processing mode must be activated in unselected samples to detect an attentional bias towards threatening faces in the dot-probe task.

A growing body of research has investigated top-down influences on attentional bias to threat (Sussman et al., 2016; for a review). To our knowledge, however, only a few studies in this field used the dot-probe task. Two studies aimed to test central assumptions of feature specific attention allocation (FSAA) theory. This theory, which has originally been developed within the context of affective priming (sometimes also referred to as *evaluative priming*) research, claims that the affective dimension of irrelevant stimuli will only be automatically processed if attention is allocated to the affective features of the stimuli because of current goals and task demands (Spruyt et al., 2009). Thus, in contrast to our hypothesis, FSAA claims that attentional bias to threat is not contingent on a social processing mode, but rather on an affective processing mode. To test this assumption, Everaert et al. (2013) conducted a dot-probe task with neutral and aversive scenes as cue stimuli on 50 % of the trials. The remaining 50 % of the trials, however, were so-called "induction trials". On those trials, only one picture of a scene was presented and participants had to indicate whether the picture was neutral or negative (affective induction group) or whether it showed a human or not (non-affective induction group). Consistent with the idea of an affective processing mode, only participants in the affective induction group showed an attentional bias towards aversive scenes in the dot-probe trials whereas the non-affective induction group did not. Conversely, Vogt et al. (2013) showed that when threat stimuli were competing with stimuli that were targets in a secondary task, attention was only captured by the latter stimuli, even in anxious participants.

In Study 2, we used a different approach to test the hypothesis that an affective processing mode must be activated in unselected samples to detect an attentional bias towards threatening faces (see Chapter 6). As already mentioned, the dot-probe task can be considered a variant of exogeneous spatial cueing. Within the exogeneous spatial cueing literature, contingent-capture theory can explain why some cues can capture attention under specific conditions, but fail to do so otherwise. According to this theory, so-called attentional control settings are tuned to specific feature values based on current task demands to guide visual attention. Therefore, a cue will only capture attention, if it matches a current target in a target-defining dimension (Folk et al., 1992; Folk & Remington, 2006). For example, Folk and Remington (1998) showed that green colour cues only captured participants' attention when they were searching for green targets, but not when they were searching for red targets. Conversely, red colour cues only captured attention, when participants were searching for red targets, but not when they were searching for green targets. In an attempt to apply contingent-capture theory to the dot-probe task, we conducted a dot-probe task with photographic face cues (angry and neutral) and two different kinds of targets (see section 6.1 and Figures 9a and 9b).

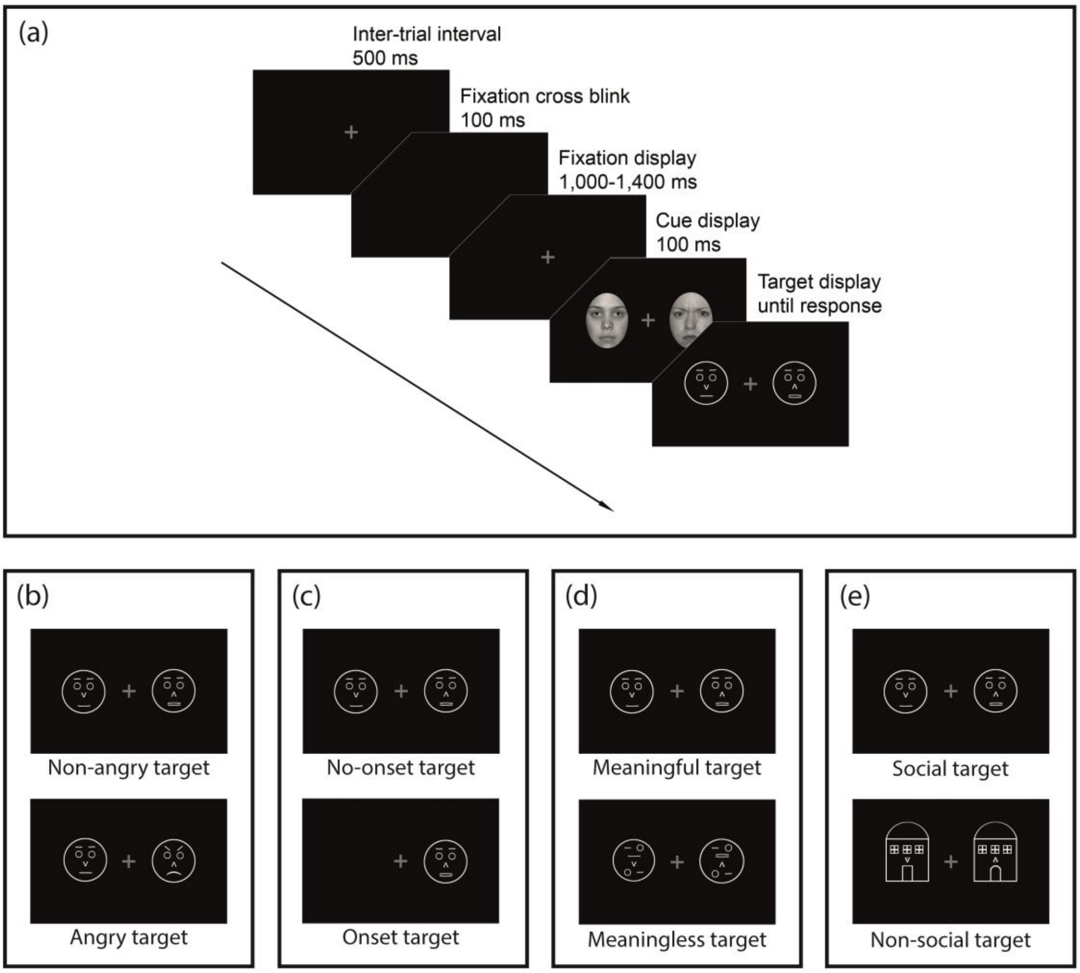

Figure 9. Schematic illustration of the experimental design in the previous study (Study 2, see Chapter 6) and the present study (Study 3). (a) Depiction of a typical trial and its temporal parameters. (b) Target types in Experiment 1 of Study 2. (c) Target types in Experiment 3 of Study 2. (d) Target types in Experiment 1 of Study 3. (e) Target types in Experiment 2 of Study 3. Note that the target conditions depicted in the top row of panels b-d are identical. For the sake of visibility, proportions are not true to scale.

In the angry-target condition, participants had to search for a schematic target face that was defined by its emotional expression (anger), whereas in the non-angry target condition, participants had to search for a schematic target face that was defined by a non-emotional feature (open mouth). If the occurrence of an attentional bias towards angry faces was contingent on an attentional control setting tuned to threat (or an affective processing mode in terms of FSAA), we would expect to find a bias towards the angry face cues only in the angry target condition, but not in the non-angry target condition. Surprisingly, participants showed an attentional bias towards angry face cues in both target conditions. This result showed that an attentional bias towards angry faces can be detected in unselected samples with the dot-probe task, but that this bias is not contingent on an attentional control setting tuned to threat.

Therefore, we assumed that the occurrence of an attentional bias was caused by another difference between our experiment and typical dot-probe studies, in particular the number of stimuli presented on the target display. In order to activate attentional control settings in participants, we had to present two stimuli in the target display, one target stimulus and one distractor stimulus that differed regarding the dimension of the corresponding attentional control setting (i.e., angry expression vs. neutral expression or open mouth vs. closed mouth; see Figure 9b). In contrast, typical dot-probe studies only present one stimulus in the target display (i.e., the target itself). Therefore, we conducted another experiment to test the hypothesis that the target must compete for attention with at least one distractor stimulus, so unselected samples show an attentional bias to threat in the dot-probe task (see section 6.3). Again, participants performed a dot-probe task with photographic face cues and two different target conditions (see Figure 9c). In the onset target condition, only one schematic target face appeared on the target display that had to be classified. In the no-onset target condition, two schematic faces were presented on the target display, one distractor and one target face. Participants had to select the target face based on a non-emotional feature (open mouth) and categorise it while ignoring the distractor face. We found a significant attentional bias towards the angry face cue only when targets had to compete for attention with a distractor (thereby replicating Experiment 1), but not when only a stand-alone target was presented. Therefore, we tentatively concluded that attentional bias to threat in unselected samples is contingent on target competition.

However, it could be that another detail of these experiments was crucial for the occurrence of an attentional bias towards angry faces in unselected samples: In all of the three conditions where an attentional bias occurred (both conditions depicted in Figure 9b and the no-onset condition depicted in Figure 9c), participants were presented two schematic faces and had to select the target face based on a feature (i.e., angriness, open mouth) which refers to the social character of the stimulus. Thus, participants had to perform a task that required social processing of the target stimuli. It is therefore possible that target competition by itself is not sufficient to detect an attentional bias towards threatening faces in unselected samples, but that this bias is contingent on the activation of a social processing mode. In the present study, we report two experiments that were conducted to test this hypothesis. In both experiments, participants performed a dot-probe task where two types of target stimuli were employed to manipulate the extent of social processing that was necessary to perform the target-categorisation task (see Figures 9d and 9e). If our hypothesis was true, we would expect to find an attentional bias towards angry face cues only when the target-categorisation task requires social processing.

As in our previous studies, we used a rather short stimulus onset asynchrony (SOA) of 100 ms between cues and targets in the present experiments because stimulus-driven shifts in covert attention peak at 100-150 ms after stimulus onset (Müller & Rabbitt, 1989). Accordingly, various researchers have recommended to use stimulus onset asynchronies of 200 ms or less to investigate covert attention because longer SOAs possibly tap into shifts of overt attention (Cooper & Langton, 2006; Petrova et al., 2013; Stevens et al., 2011; Weierich et al., 2008).

7.1 Experiment 1

In Experiment 1, participants performed a dot-probe task either with socially meaningful targets (schematic faces) or with meaningless targets (scrambled schematic faces; see Figure 9c). According to our hypothesis, we expected to find an attentional bias towards angry face cues only when participants had to classify socially meaningful targets.

7.1.1 Methods

7.1.1.1 Participants

Seventy-seven non-psychology university students were paid 6 € for their participation. The data of four participants were excluded from all further analyses because their overall accuracy was more than 3 interquartile ranges below the first quartile of the overall distribution (Tukey, 1977). Of the remaining $N = 73$ participants, 48 were female and their ages ranged from 18 to 34 ($M = 23.4$ years, $SD = 3.1$). Their raw scores on the trait scale of the State-Trait Anxiety Inventory (STAI; Laux et al., 1981) ranged from 23 to 66 ($M = 40.6$, $SD = 9.8$). All participants reported normal or corrected-to-normal vision and provided informed consent prior to testing.

7.1.1.2 Design

We employed a 2 (*cue validity:* valid cue vs. invalid cue) × 2 (*target type:* socially meaningful target vs. meaningless target) design with *cue validity* as a trial-by-trial within-subjects factor and *target type* as a blockwise within-subjects factor. To control for possible individual differences, the trait score of the STAI (Laux et al., 1981) was entered as a continuous (centred) covariate.

Regarding power, we had the following considerations: First, we aimed to have sufficient power to detect an attentional bias in the meaningful target condition. Second, we aimed to have sufficient power to detect an interaction of cue validity and target type (i.e., to find a difference in magnitude between attentional bias in the meaningful target condition and the meaningless target condition). Third, we wanted to rule out the possibility that any potentially found attentional biases are caused by a few highly anxious participants in our sample showing extremely large biases. Therefore, we aimed to have sufficient power to detect a possible correlation between participants' attentional bias and their trait anxiety.

With regard to the first two considerations, we estimated the expected effect sizes based on Study 2 (see Chapter 6). Accordingly, we estimated the size of the cueing effect of the meaningful target condition to be between $d_Z = 0.34$ to $d_Z = 0.49$ and the size of the interaction effect to be approximately $d_Z = 0.33$. Our sample size of $N = 73$ allows to detect effects of $d_Z = 0.29$ with a probability of $1 - \beta = .80$, given an α-value of .05 (one-tailed). According to Cohen (1988), such an effect can be considered in-between "small" ($d_Z = 0.2$) and "medium" ($d_Z = 0.5$). Regarding the third consideration, our sample size allows to detect effects of $r = 0.28$ (i.e., an effect slightly below "medium" according to Cohen, 1988) with a probability of $1 – \beta = .80$, given $\alpha = .05$ (one-tailed). Calculations were done using G*Power 3.1.3 (Faul et al., 2007).

7.1.1.3 Materials

As photographic cues, we selected the same photographs of eight female and eight male individuals as in Study 2 (see Chapter 6) displaying angry and neutral expressions from the NimStim set of facial expressions (Tottenham et al., 2009). Exposed teeth are a strong perceptual confound of angry expressions that can potentially distort dot-probe effects (see Chapter 5). Therefore, we only employed angry faces with closed mouths in the present study. Using Adobe Photoshop (Adobe Systems Inc., San Jose, CA), all stimuli were cropped into a standard oval shape concealing hair and external features and were converted to greyscale (see Figure 9a). Participants' trait anxiety was assessed with a computerised version of the trait scale of the German version of the State-Trait Anxiety Inventory (STAI; Laux et al., 1981). This self-assessment scale contains 20 items, each scored between 1 (low anxiety) and 4 (high anxiety).

7.1.1.4 Procedure

The study was conducted on five PCs equipped with 17" CRT monitors using a resolution of 1,024 × 768 Pixels, a refresh rate of 100 Hz, and a colour depth of 32 bit. The experimental routine was programmed using Psychtoolbox-3 (Kleiner et al., 2007) for Matlab 2014a (Mathworks, Natick, MA).

Participants were seated in an individual testing booth approximately 65 cm from the monitor and were presented with an instruction screen explaining the experimental procedure. Figure 9 depicts a schematic illustration of a typical trial and the design of Experiment 1. Throughout the procedure, a grey fixation cross was presented on a black background to maintain participants' focus at the centre of the screen. To indicate the beginning of a trial, the fixation cross blinked for 100 ms. The fixation cross then remained on screen for a variable interval (chosen randomly from the set 1,000; 1,100; 1,200; 1,300; or 1,400 ms) to avoid any anticipatory effects. Subsequently, two photographic face cues, one angry and one neutral, were presented laterally for 100 ms. The faces had a size of 4.5 × 6.2 cm (4.0 × 5.5°) and their centre-to-centre distance was 11.1 cm (9.8°). Immediately after the offset of the cues, two white stimuli—one target stimulus and one distractor stimulus—appeared at the cue positions and remained there until a response was given. In the meaningful target condition, these stimuli were schematic faces (with a neutral expression), one open-mouthed (as indicated by a double line) target face and one closed mouthed (as indicated by a single line) distractor face. Participants' task was to indicate in which direction the nose of the schematic target face was pointing (upwards or downwards) while the schematic distractor face had to be ignored. In the meaningless target condition, scrambled versions of those schematic faces were presented. These scrambled faces consisted of the same basic features as the schematic faces, but the spatial configuration of those features was altered (e.g., the mouth was located above the nose, one eye and one eyebrow were located beneath the nose; see Figure 9c). Thus, the scrambled schematic faces conveyed the impression of a complex, meaningless pattern inside a circle. Participants' task was to find the (target) pattern that contained a horizontal double line (corresponding to the open mouth in the meaningful target condition) and indicate whether the arrow in this pattern (corresponding to the nose in the meaningful target condition) was pointing upwards or downwards. Moreover, they were told to ignore the arrow in the (distractor) pattern, which contained only a single vertical line (corresponding to the closed mouth of the distractor face in the meaningful target condition). The schematic faces / scrambled faces had a size of 2.8 × 2.8 cm (2.5 × 2.5°) and the centre-to-centre distance between them was 11.1 cm (9.8°). Nose/arrow directions of target and distractor stimuli were uncorrelated, that is, the nose/arrow of the target stimulus pointed in the same direction as the nose/arrow of the distractor stimulus on 50 % of the trials and in the opposite direction on the remaining trials (orthogonally varied in relation to the other experimental factors). Participants were asked to respond as fast as possible by pressing the "t" key for up or the "v" key for down on a standard German QWERTZ keyboard. On 50 % of the trials, the target stimulus appeared at the location of the angry face cue (valid cue) and on the remaining trials it appeared at the location of the neutral face cue (invalid cue). Each response was followed by a 500 ms inter-trial interval. If participants made an error or took longer than 1,500 ms to submit a response, they received a 1,000 Hz warning tone of 500 ms duration via headphones.

The experiment comprised 448 trials and lasted approximately 35 minutes. Trials were presented in two blocks consisting of 224 trials each—one with schematic faces as target and distractor stimuli and one with scrambled faces as target and distractor stimuli—in a counterbalanced order.[20] Within each block, a self-paced break was included after 112 trials. At the start of each block, participants were presented with 32 training trials that were not included in data analysis. At the end of the experiment, participants completed the trait-anxiety scale of the STAI (Laux et al., 1981).

7.1.2 Results

Average classification accuracy was M = 97.0 % (SD = 2.0). For the response time (RT) analysis, RTs below 150 ms were excluded, as were RTs more than 1.5 interquartile ranges above the third quartile of the individual participant's distribution (separately for both experimental blocks; Tukey, 1977). This led to the exclusion of 2.0 % of all trials with correct responses. After outlier removal, average individual RTs for correct responses ranged from M = 643 to M = 944 ms (grand mean was M = 752 ms, SD = 71).

Table 4 shows average RTs as a function of the experimental factors. We conducted a 2 × 2 within-subjects ANCOVA with the factors *cue validity* (valid cue vs. invalid cue) and *target type* (meaningful target vs. meaningless target), the participants'

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[20] Because four participants were excluded from data analysis, 35 participants completed the meaningful target block first, whereas 38 participants completed the meaningless target block first.

z-standardised (i.e., centred) STAI scores as a covariate, and (correct) RTs as the dependent variable. The analysis revealed no significant main effects, all *F*s < 1.64, all *p*s > .204, all $\eta_p^2 < .023$, but a significant *target type* × *cue validity* interaction, $F(1, 71) = 4.68$, $p = .034$, $\eta_p^2 = .062$. Neither the main effect nor any interactions of the factor STAI reached significance, all *F*s < 0.37, all *p*s > .548, all $\eta_p^2 < .006$.

Table 4. Mean RTs (in ms; Standard Deviations in Parentheses) in Experiment 1 of Study 3 as a Function of Target Type and Cue Validity.

Target type	**Cue validity**	
	Valid	Invalid
Meaningful target	747 (72)	752 (74)
Meaningless target	756 (81)	754 (79)

To clarify the meaning of this interaction, we calculated separate cueing scores for meaningful target trials and for meaningless target trials. As can be seen in Figure 10, participants showed positive cueing scores ($M = 6$ ms, $SD = 21$) on meaningful target trials that differed significantly from zero, $t(72) = 2.35$, $p = .022$, $d_Z = 0.27$. On meaningless target trials, cueing scores were slightly negative ($M = -2$ ms, $SD = 19$) and did not significantly differ from zero, $t(72) = 0.79$, $p = .435$, $d_Z = 0.09$.

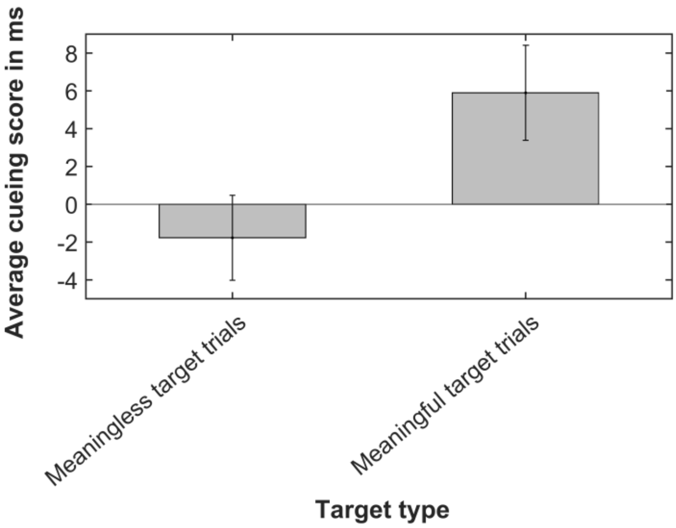

Figure 10. Average cueing scores for meaningless target trials and meaningful target trials in Experiment 1 of Study 3. Cueing scores represent the difference between the average reaction times to invalidly cued trials and validly cued trials (error bars depict ±1 standard error of the mean, SEM).

7.1.3 Discussion

In Experiment 1, we investigated whether attentional bias towards angry faces is contingent on a social processing mode in unselected samples. To induce a social processing mode, participants had to classify socially meaningful targets, namely schematic faces, in one of the experimental blocks. In the other block, targets were meaningless scrambled faces. As expected, we found a significant attentional bias towards angry faces when participants had to classify socially meaningful targets, but not when they had to classify meaningless targets. This supports the hypothesis that non-anxious individuals only show an attentional bias towards angry faces when they are in a social processing mode. At this stage, the present results suggest that target competition alone is not sufficient to explain the results of Study 2 (see Chapter 6).

However, we used scrambled faces as targets in the control condition to induce a non-social processing mode. This still leaves an interpretational ambiguity because scrambled faces are not only socially meaningless; they are, in fact, completely meaningless regarding any dimension (as already explained, scrambled faces convey the impression of a complex, meaningless pattern). Therefore, one could argue that attentional bias towards angry faces is contingent on an object processing mode, but not on a social processing mode per se. To rule out this possibility, we conducted Experiment 2 where we used meaningful (but non-social) objects as target stimuli in the control condition.

7.2 Experiment 2

In Experiment 2, we again conducted a dot-probe task with two different types of targets to manipulate social processing in participants. Again, we expected to find an attentional bias towards angry faces when participants had to classify socially meaningful targets, but not when they had to classify socially meaningless targets. In contrast to Experiment 1, we used schematic houses as socially meaningless targets (see Figure 9e). Unlike scrambled schematic faces, schematic houses are recognisable objects with semantic meaning that are nevertheless socially irrelevant.

7.2.1 Methods

7.2.1.1 Participants

Eighty-two non-psychology university students were paid 6 € for their participation. The data of two participants were excluded from all further analyses because their overall performance was more than 3 interquartile ranges below the first quartile of the distribution (Tukey, 1977). One additional participant was excluded because she accidentally did not complete the trait scale of the STAI at the end of the procedure. Of the remaining $N = 79$ participants, 58 were female and their ages ranged from 18 to 35 ($M = 23.2$, $SD = 3.5$). Their raw scores on the trait scale of the State-Trait Anxiety Inventory (STAI; Laux et al., 1981) ranged from 24 to 62 ($M = 40.4$, $SD = 9.5$). All participants reported normal or corrected to normal vision and provided informed consent prior to testing.

7.2.1.2 Design

We employed a 2 (*cue validity:* valid cue vs. invalid cue) × 2 (*target type:* social target vs. non-social target) design with *cue validity* as a trial-by-trial within-subjects factor, *target type* as a blockwise within-subjects factor, and STAI score as a continuous (centred) covariate.

Our sample size of $N = 79$ allows to detect effects of $d_Z = 0.28$ with a probability of $1 - \beta = .80$, given an α-value of .05 (one-tailed). Note that the size of the cueing effects in those conditions of Study 2 that were identical to the meaningful target condition of the present Experiment 1 was between $d_Z = 0.34$ and $d_Z = 0.49$. In Experiment 1 of the present study, the cueing effect of the meaningful target condition was $d_Z = 0.27$. The size of the interaction effect was $d_Z = 0.33$ in Study 2 and in Experiment 1 of the present study, the effect size was $d_Z = 0.25$.

7.2.1.3 Materials and Procedure

The same materials as in Experiment 1 were used. Figure 9 depicts a schematic illustration of a typical trial and the design of Experiment 2. The social target condition of Experiment 2 was identical to the meaningful target condition of Experiment 1. The non-social target condition, was identical to the meaningless target condition of Experiment 1, apart from the following exception. After the offset of the photographic face cues, instead of two scrambled schematic faces, two white schematic houses were presented, one target house with a round door and one distractor house with a rectangular door (see Figure 9e). Both houses had small lamps above the doors (represented by a small circle within an arrowhead). Participants task was to indicate whether the lamp of the target house was pointing upwards or downwards while the lamp of the distractor house had to be ignored.

7.2.2 Results

Average classification accuracy was $M = 95.5$ % ($SD = 3.4$). For the exclusion of RT outliers, the same criteria as in Experiment 1 were applied. This led to the exclusion of 2.0 % of all trials with correct responses. After outlier exclusion, average individual reaction times for correct responses ranged from 560 to 1,098 ms ($M = 767$ ms, $SD = 94$).

Table 5 shows average RTs as a function of the experimental factors. We conducted a 2 × 2 within-subjects ANCOVA with the factors *cue validity* (valid cue vs. invalid cue) and *target type* (social target vs. non-social target), the participants' *z*-standardised (i.e., centred) STAI scores as a covariate, and (correct) RTs as the dependent variable. The analysis revealed significant main effects of *target type*, $F(1, 77) = 84.35$, $p < .001$, $\eta_p^2 = .523$, and of *cue validity*, $F(1, 77) = 4.83$, $p = .031$, $\eta_p^2 = .059$. Moreover, a significant *target type* × *cue validity* interaction was revealed, $F(1, 77) = 8.30$, $p = .005$, $\eta_p^2 = .097$. Again, neither the main effect nor any of the interactions involving the factor STAI reached significance, all *F*s < 0.82, all *p*s > .369, all $\eta_p^2 < .011$.

Table 5. Mean RTs (in ms; Standard Deviations in Parentheses) in Experiment 2 of Study 3 as a Function of Target Type and Cue Validity.

Target type	**Cue validity**	
	Valid	Invalid
Social target	733 (89)	734 (91)
Non-social target	805 (110)	795 (110)

The main effect of *target type* indicated faster reaction times on trials with social targets ($M = 734$ ms, $SD = 90$) than on trials with non-social targets ($M = 800$ ms, $SD = 109$). Surprisingly, the main effect of *cue validity* reflected slightly faster reaction times for invalid trials ($M = 765$ ms, $SD = 95$) than for valid trials ($M = 769$ ms, $SD = 95$).

Again, we calculated separate cueing scores for trials with social targets and for trials with non-social targets to clarify the meaning of the interaction. These cueing scores are depicted in Figure 11. Surprisingly, cueing scores for social target trials were extremely small ($M = 1$ ms, $SD = 17$) and did not significantly differ from zero, $t(78) = 0.40$, $p = .692$, $d_Z = 0.04$. In contrast, cueing scores for non-social target trials were clearly negative (M = -10 ms, SD = 29) and differed significantly from zero, $t(78) = 2.96$, $p = .004$, $d_Z = 0.33$.

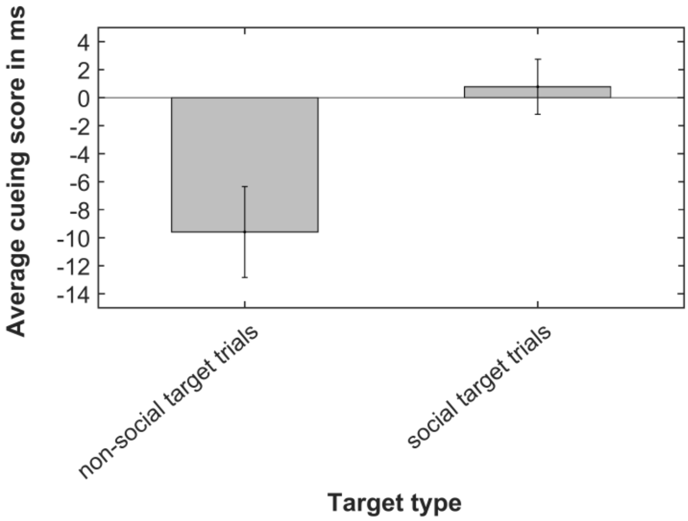

Figure 11. Average cueing scores for non-social target trials and social target trials in Experiment 2 of Study 3. Cueing scores represent the difference between the average reaction times to invalidly cued trials and validly cued trials (error bars depict ±1 standard error of the mean, SEM).

To anticipate the discussion, we looked additionally at the cueing effect for social targets in the subsample that started with the social target condition (because this was a pure replication condition, unaffected by anything that preceded this task). The cueing effect was slightly larger (M = 2 ms, SD = 17) than the overall effect, but still non-significant, $t(39) = 0.76$, $p = .450$, $d_Z = 0.12$.

We investigated whether the cueing effect in this group can be considered to reflect the same attentional bias that we found in the meaningful target condition of Experiment 1 and in identical conditions of two further experiments of Study 2 (Experiments 1 and 3). We conducted a univariate ANOVA with the between-subjects factor *experiment* and participants' cueing scores as dependent variable. This analysis showed that cueing scores were significantly above zero in the overall sample, $F(1, 258) = 23.39$, $p < .001$, $\eta_p^2 = .083$, and that the effect did not significantly differ between experiments, $F(3, 258) = 1.60$, $p = .191$, $\eta_p^2 = .018$.

7.2.3 Discussion

In Experiment 2, we again tested the hypothesis that attentional bias towards angry faces is contingent on the activation of a social processing mode in unselected samples.

As in Experiment 1, we presented socially meaningful targets (schematic faces) in one condition in order to activate a social processing mode in participants. However, we employed different target stimuli in the control condition of Experiment 2. Whereas in the control condition of Experiment 1 participants had to classify meaningless scrambled schematic faces, participants had to classify recognisable—albeit non-social—objects in the control condition of Experiment 2.

As expected, attentional bias towards angry face cues was moderated by the employed target type. Moreover, the direction of this moderation was consistent with our hypothesis. That is, cueing scores towards angry faces were significantly larger in the social target condition than in the non-social target condition. Admittedly, the absolute values of these cueing scores were rather unexpected. Whereas our hypothesis predicted significantly positive cueing scores in the social target condition and non-significant cueing scores close to zero in the non-social target condition, we found positive but non-significant cueing scores in the social target condition and significantly negative cueing scores in the non-social target condition. Thus, there are two aspects of the results to discuss: First, how grave is the failure to replicate the positive cueing effect in the social target condition? Second, what is the interpretation of the negative effect in the non-social target condition?

We postpone the discussion of the second question to the General Discussion, but will discuss the first issue here. A counter-balanced block-design always endangers the effect in the second of two blocks by possible carry-over effects. Therefore, we additionally reported the cueing effect for social targets in the subsample of those participants who completed the social target block first. Although the effect was still meagre and non-significant, meta-analytically the result corresponded to our previous results using exactly the same conditions (i.e., the social meaningful condition of Experiment 1 in the present study and the corresponding conditions of Experiments 1 and 3 in Study 2. Note, that our power was $1-\beta = .91$ for the overall sample of Experiment 2 (if we assume $d_Z = 0.34$, i.e., the effect size in the overall across-experiments sample, see section 7.2.2), but only $1 - \beta = .67$ for the subsample of those participants who started with the social target block. Thus, the probability of a Type II error was only 10 % for the overall sample (i.e., 1 out of 10 studies will fail to show a significant effect, even if it exists in the population) but 33 % for the subsample. In conclusion, we do not consider this failure to replicate a severe one.

7.3 General Discussion

In two experiments, we investigated whether the occurrence of an attentional bias towards angry faces in the dot-probe task is contingent on the activation of a social processing mode for unselected samples (i.e., for the general population as opposed to anxious individuals). In Experiment 1, participants performed a dot-probe task that used two different types of targets. In one condition, participants had to classify meaningful target stimuli (schematic faces) in a task that required social processing of these targets. In the other condition, participants had to classify meaningless target stimuli (scrambled schematic faces); thus, this condition did not require social processing of the targets. In both conditions, the target stimuli were preceded by two photographic face cues, one angry and one neutral. As expected, participants only showed an attentional bias towards the angry face cue, when they had to classify socially meaningful targets, but not when they had to classify meaningless targets. Importantly, the attentional bias in the meaningful target condition was not moderated by participants' trait anxiety. Therefore, this bias was not caused by a few anxious participants with extremely large biases. In fact, this bias was on average equally large for more anxious participants and for less anxious participants in our sample. Thus, the results of Experiment 1 support the hypothesis that attentional bias towards threatening faces is contingent on the activation of a social processing mode in the general population.

However, Experiment 1 employed meaningless non-objects (scrambled schematic faces) as targets. Therefore, it is possible that attentional bias towards angry faces in unselected samples is not contingent on a social processing mode, but on a mere object processing mode. To account for this argument, we conducted Experiment 2, which was identical to Experiment 1 apart from the following exception. In the control condition, participants had to classify houses (i.e., recognisable objects) instead of scrambled schematic faces (i.e., non-objects). The results of Experiment 2 partially support our hypothesis; however, they are more complicated than the results of Experiment 1. As expected, attentional bias towards angry face cues was moderated by the type of target stimuli. Moreover, this interaction showed the expected direction; that is, it reflected larger cueing scores towards angry face cues in the social target condition than in the non-social target condition. However, the absolute values of these cueing scores were unexpected. Whereas we expected to find a positive cueing score towards angry face cues in the social target condition and a non-significant, close-to-zero cueing score in the non-social target condition, we found a non-significant cueing score in the social target condition and a negative cueing score that was significantly below zero in the non-social target condition.

As we already discussed (see section 7.2.3), the non-significant cueing score in the social target condition potentially reflects a Type II error since this cueing score was not statistically different from the cueing scores that we found under identical conditions in three previous experiments. It is more complicated, however, to explain the occurrence of a significantly negative average cueing score in the non-social target condition. Intuitively, one could argue that this negative cueing score represents an attentional bias away from the angry face cue, that is, participants avoided the angry face cue when they responded to house-like target stimuli. However, this potential explanation has one crucial shortcoming because a stimulus has to be initially attended to before it can be avoided. Thus, this explanation implies that participants were able to perform multiple shifts of attention during the presentation of the cue display. However, this seems unlikely because we applied a cue-target SOA of 100 ms and stimulus shifts in covert attention peak at 100-150 ms (Müller & Rabbitt, 1989). Thus, our SOA should only allow for one shift in spatial attention. This assumption is consistent with research findings on inhibition of return. As already discussed, the term *inhibition of return* describes the phenomenon that in spatial cueing tasks with long SOAs, participants often show negative cueing effects because after the cued location is initially attended to, it is inhibited and attention is shifted to the other location to avoid redundant scanning. However, inhibition of return occurs after approximately 200 ms at the earliest (Samuel & Kat, 2003) and usually much later, at 500-700 ms, for target classification tasks like in our experiments (Lupiáñez et al., 1997). Thus, it seems unlikely that participants in Experiment 2 initially attended to the angry face cue and then shifted attention to the opposite location.

We believe that the following approach is more plausible to explain the occurrence of a negative cueing effect in Experiment 2. It is based on three assumptions. First, in accordance with our social processing mode hypothesis, there is no attentional bias towards angry faces in the non-social target condition. Second—for the sake of the argument—let us assume that this means that attention is randomly shifted either to the angry or to the neutral face cue upon the onset of the cue display instead of being maintained at the central fixation cross.[21] Third, if attention is incidentally shifted to the angry face cue, processing of any stimulus, which replaces the angry face, is slowed due to attention-independent response slowing processes.

Consistent with the third assumption, Mogg et al. (2008) showed that attended[22] threat cues cause a general response slowing effect. This response slowing effect (often referred to as "freezing") might reflect a behavioural inhibition system that interrupts ongoing behavioural activity and thus modulates motor responses (Fox et al., 2001; Koster et al., 2004; Mulckhuyse & Crombez, 2014). Moreover, there was a larger discontinuity between the cue and target categories in the social target condition than in the non-social target condition. Whereas in the social target condition, both cues and targets belonged to a natural category (human faces), in the non-social target condition, cues belonged to a natural category, but targets belonged to an artifactual stimulus category. It is possible that after the attendance of an angry face cue, which is a socially relevant, natural stimulus, the processing of the artifactual target stimulus was inhibited.

To conclude, the present study suggests that an attentional bias towards angry faces can be detected in the dot-probe task also for unselected samples. However, the occurrence of this bias is not only, as we argued in Study 2, contingent on the presentation of distractor stimuli that compete for attention with the targets (see Chapter 6). Additionally, the activation of a social processing mode seems to be a necessary precondition. Since most previous dot-probe studies required participants to respond to arbitrary target stimuli without social meaning (usually dots or other simple

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[21] Note that this assumption is, for example, compatible with the view that spatial attention is generally biased towards the left visual field—if it is currently not affected by any other "driving force" (e.g., Nicholls & Roberts, 2002). Since cue locations and cue emotions were orthogonally varied in our experiments, the left location was randomly occupied by either the neutral or the angry face cue.

[22] Mogg et al. (2008) asked participants to respond to centrally presented target stimuli that were always preceded by a single neutral or threatening cue presented in the same position. Although participants did not have to perform any shifts of spatial attention, they were slower to respond when the target was preceded by a neutral cue than when it was preceded by a threatening cue. Thus, response times were slowed by the general presence of threatening cues independently of attentional processes. However, since cues and targets were always presented in the same location, it is plausible to assume that all presented cue stimuli were attended to by the participants.

symbols), it is consequential that these studies did not find an attentional bias to threat in non-anxious participants. Thus, our findings are inconsistent with the idea of several clinical models of anxiety that claim that only anxious individuals generally show an attentional bias towards threatening stimuli (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1988).

However, our findings also contradict the fear-module theory (Öhman & Mineka, 2001), which claims that two evolutionary processes have shaped a fear module in the human organism that cause unconditional attentional biases towards threatening stimuli: First, an efficient defence against predators made it necessary to quickly detect potentially dangerous animals and react accordingly. Second, during human evolution, aggression between conspecifics often occurred to establish a social hierarchy within a group. Therefore, it became necessary to quickly detect and decode social signals of dominance and submission. Support for the first assumed process initially came from a visual search study where participants were faster to detect dangerous animals (snakes and spiders) among non-threatening distractors (flowers and mushrooms) than vice versa (Öhman, Flykt et al., 2001). Moreover, dangerous animals seemed to be processed pre-attentively to some degree as search times for these targets were not affected by the number of simultaneously presented distractor stimuli. However, two recent studies that applied a variant of the spatial cueing paradigm showed that attentional bias towards spider stimuli only occurred when spiders were a task-relevant stimulus class, but not when they were not (Vromen et al., 2015; Vromen et al., 2016). Therefore, these studies argue that attentional bias towards spiders is contingent on top-down goals. Support for the second assumed process came mainly from face-in-the-crowd studies that found more efficient search for angry faces than for other emotional faces, that is, an anger-superiority effect (Fox et al., 2000; Hahn & Gronlund, 2007; Horstmann & Bauland, 2006; Moriya et al., 2014; Pinkham et al., 2010). In this paradigm, however, the presented face stimuli are always inherently task relevant because participants are asked to search for a specific target face among a set of distractor faces. Thus, a top-down social processing mode is necessarily activated in this paradigm. The present study suggests that attentional bias towards threatening faces is also contingent on the activation of such top-down mechanisms.

Our results are, however, consistent with appraisal theories of emotional attention. These theories claim that stimuli capture attention if they are relevant to current concerns of an individual. These current concerns comprise goals, needs, motives, and values (Brosch et al., 2008; Pool et al., 2016). Importantly, the concept of current concerns goes beyond mere task demands, that is, current concerns are assumed to be broader and more stable than task demands. In line with this idea, we showed in Study 2 that attentional bias towards angry face cues was not merely contingent on whether participants had to classify angry or non-angry target faces. As the present study shows, attentional bias towards angry faces seems to be rather contingent on a broader, more general social processing mode.

8 Comprehensive discussion

The present thesis aimed to resolve a dissent between two subdisciplines of psychology, namely cognitive psychology and clinical psychology. On the one hand, theories of emotional attention from cognitive psychology claim that all human individuals show an attentional bias towards threatening stimuli (Brosch et al., 2008; Öhman & Mineka, 2001; Russell & Fehr, 1987).[23] On the other hand clinical theories of anxiety claim that attentional bias to threat only occurs in anxious individuals, but not in the general population (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1988). As previously demonstrated, both subdisciplines have accumulated substantial empirical evidence for their respective claims, but employed mostly different experimental paradigms doing so (see Chapter 3). Whereas studies from cognitive psychology mostly applied the face-in-the-crowd paradigm and related variants of visual search, studies from clinical psychology mostly applied the dot-probe task. Thus, the aim of the present thesis was to clarify whether attentional bias towards threatening stimuli occurs only in anxious individuals or additionally in the general population and whether methodological differences between the employed paradigms can explain these inconsistent results. To this end, we conducted three studies comprising six experiments in total that investigated attentional bias towards angry faces. In these studies, we applied several variations of the dot-probe task to identify those factors which are critical for the occurrence of attentional bias in unselected samples thus explaining inconsistent results between different paradigms. In the present chapter, the results of these three studies will be summarised and discussed with regard to the aforementioned research questions. Moreover, limitations and unresolved questions, as well as directions for future research will be discussed.

8.1 Summary of the results

Study 1 was motivated by recent studies which suggest that the search advantage for angry faces in the face-in-the-crowd paradigm (i.e., the anger-superiority effect) is merely driven by perceptual confounds of angry faces, for example teeth-exposure (Calvo & Nummenmaa, 2008; Horstmann et al., 2012; Horstmann & Bauland, 2006; Savage et al., 2013; Savage & Lipp, 2015). Therefore, we aimed to investigate whether perceptual confounds also play a role in the anxiety-related attentional bias towards

[23] Nevertheless, these theories disagree with regard to the question whether other emotional stimuli can also capture attention (see Chapter 2).

angry faces usually found in dot-probe studies (see Bar-Haim et al., 2007; Frewen et al., 2008 for meta-analyses). Participants performed a dot-probe task with two types of angry face cues, perceptually salient faces with exposed teeth and less salient faces with concealed teeth. We did not find any attentional bias towards angry faces with exposed teeth. However, a significant bias towards angry faces with concealed teeth was found in anxious participants, but not in non-anxious participants. This resulting pattern has two implications. First, it corroborates previous dot-probe studies as the commonly found attentional bias towards threatening stimuli was replicated with those cues that were perceptually unconfounded. Second, the results of Study 1 show that perceptual confounds are not sufficient to produce a reliable attentional bias towards angry faces in non-anxious participants. Otherwise, we should have found an anxiety-unrelated attentional bias for the whole sample towards angry face cues with exposed teeth. As already discussed (see Chapter 5) it seems that perceptual confounds play a crucial role in the occurrence of the anger-superiority effect in the face-in-the-crowd paradigm because the angry face is task-relevant in this paradigm. Since participants are explicitly instructed to search for the angry face, it is likely that participants deliberately use the perceptual saliency of the mouth region in faces with exposed teeth to solve the task as fast and efficiently as possible.

Consequently, we investigated in Study 2 whether unselected samples only show an attentional bias towards angry faces when anger is a task-relevant dimension. To this end, we drew on the structural similarity between the dot-probe task and the exogeneous spatial cueing paradigm (Chica et al., 2014; Jonides, 1981). Within the spatial cueing literature, contingent-capture theory (e.g., Folk et al., 1992; Folk & Remington, 2006) claims that irrelevant cues only capture attention if they share a critical feature with the target. The theory claims, for example, that green cues only capture attention when participants are searching for green targets and that red cues only capture attention when participants are searching for red targets (Folk & Remington, 1998). The theory assumes that so-called attentional control settings are tuned to specific feature values like green or red via top-down mechanisms to help guide attention to potential target stimuli. Once an attentional control setting for a specific feature is activated, irrelevant cue stimuli sharing that feature will capture attention. It is possible that an attentional control setting tuned to detect threat is permanently active in anxious individuals, but only situationally activated in non-anxious individuals. In order to systematically manipulate the activation of an “anger control setting”, we conducted a dot-probe task with two types of schematic target faces in Experiment 1. Schematic target faces were either defined by their emotional expression (angriness; angry target condition) or by a non-emotional feature (open mouth; non-angry target condition). We expected to find an anxiety-unrelated attentional bias towards angry face cues in the former condition, but not in the latter condition. Surprisingly, we found a reliable bias that was not moderated by participants' anxiety both in the angry-target condition and in the non-angry target condition.

Thus, we conducted two further experiments to investigate why an anxiety-unrelated bias occurred in Experiment 1, given it was not due to the activation of an attentional control setting tuned to threat. In Experiment 2, we replicated typical contingent-capture effects of cues and targets of matching and non-matching colours with the same spatial and temporal parameters that were applied in Experiment 1. This result rules out the possibility that the results of Experiment 1 were obtained simply because the parameters we applied were unsuitable to detect contingent-capture effects. Therefore, we conducted Experiment 3 to test the hypothesis that another detail of Experiment 1 was the cause of the occurrence of an attentional bias towards angry faces in an unselected sample. In order to induce attentional control settings, it was necessary to present two stimuli during the target display, one target stimulus and one distractor. Common dot-probe studies, however, only present a stand-alone target during the target display (e.g., Bocanegra et al., 2012; Cooper & Langton, 2006; Jovev et al., 2012; Mogg et al., 2000; Stevens et al., 2009). In Experiment 3, participants performed a dot-probe task with two target conditions. In the onset target condition, only the target itself was presented during the target display, in the no-onset target condition, the target was always accompanied by a distractor stimulus. We only found an attentional bias towards angry face cues (that was not moderated by participants anxiety) in the condition where targets had to compete for attention with a distractor, but not in the condition where stand-alone targets were presented. All considered, the results of Study 2 led us to conclude that attentional bias towards angry faces can occur for unselected samples in the dot-probe task. This occurrence is, however, not contingent on the activation of an attentional control setting tuned to threat, but on a mode of target presentation where the target has to compete for attention with at least one other stimulus.

In Study 3, we investigated whether another critical factor was responsible for the results we obtained in our previous experiments. In all of the conditions of Study 2 where a reliable bias towards angry face cues was found, participants had to perform tasks that required social processing of the target stimuli. Thus, we conducted two experiments to test the hypothesis that attentional bias towards angry faces is not contingent on the activation of a threat control setting (as originally assumed in Study 2), but rather on the activation of a broader, more general social processing mode. In these two experiments, participants performed a dot-probe task with two target conditions. In one condition, participants had to respond to socially meaningful targets (schematic faces) in a task that required social processing of said targets. In the other condition, participants had to respond to socially meaningless targets (scrambled schematic faces in Experiment 1 and schematic houses in Experiment 2). Thus, no social processing was required in the second condition. In both experiments, we found larger attentional bias scores towards angry face cues in the condition with socially meaningful target stimuli than in the condition with socially meaningless target stimuli. These results suggest that in the dot-probe task, a target presentation mode where targets have to compete for attention is not sufficient to detect attentional bias towards angry faces for unselected samples. Rather it seems that attentional bias towards angry faces is additionally contingent on the activation of a social processing mode in unselected samples.

8.2 Reconciling cognitive and clinical psychology

The aim of the present thesis was to resolve inconsistent assumptions regarding attentional bias to threat between models of emotional attention from cognitive psychology and theories of anxiety from clinical psychology. Cognitive models of emotional attention (e.g., Brosch et al., 2008; Öhman & Mineka, 2001; Russell & Fehr, 1987) assume that attention is biased towards threatening stimuli in all individuals. In contrast, clinical theories of anxiety (e.g., Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1988) claim that only anxious individuals (both clinical and sub-clinical) show an attentional bias towards threatening stimuli, but the general population does not (at least not towards moderately threatening stimuli like angry facial expressions). What do the results of the present thesis contribute to the resolution of this inconsistency? Generally speaking, the results do not favour one side over the other. Rather, the results suggest that both claims are partly true and do have their respective merits. However, our results also suggest that claims from both sides may be too narrowly formulated and neglect specific factors that determine the occurrence of attentional bias to threat in the general population.

Some aspects of our results are rather in favour of the claims put forward by clinical theories of anxiety. For example, we did not find any attentional biases towards angry faces in the control conditions of the experiments conducted in Studies 2 and 3 even so we used a short cue-target SOA of 100 ms in these experiments. This pattern of results contradicts the hypothesis that all individuals show a bias in initial attention allocation to threatening stimuli and that anxious individuals show an additional bias in attentional disengagement from threatening stimuli (Fox et al., 2001; Jovev et al., 2012; Schofield, Johnson, Inhoff, & Coles, 2012). It seems plausible that SOAs of 500 ms or longer are too long to detect biases in attentional engagement and that dot-probe studies employing such long SOAs (which is the majority of dot-probe studies, see Bar-Haim et al., 2007) are rather sensitive to (potentially anxiety-related) biases in attentional disengagement (see section 3.2.2.1). However, the SOA of 100 ms that was employed in all experiments of the present thesis will be short enough to detect any potential biases in attentional engagement to threatening stimuli (Cooper & Langton, 2006; Yiend, 2010). Moreover, in the perceptually unconfounded condition of Study 1 (i.e., the concealed-teeth condition), we found a reliable attentional bias towards angry faces only in anxious participants, but not in non-anxious participants, thus replicating the results of many previous dot-probe studies (Bar-Haim et al., 2007; Frewen et al., 2008). Note that Study 1 was the only study where conventional target stimuli were employed. That is, in Study 1, participants had to classify a simple symbol ("×" sign or "=" sign) that was the only stimulus presented during the target display. Therefore, an attentional bias towards angry faces was found only in anxious participants under typical dot-probe conditions.

This consistent absence of attentional bias towards angry faces in non-anxious participants under typical dot-probe conditions suggests that the general population does indeed fail to show an *unconditional* attentional bias towards threatening stimuli. Specifically, this means that attentional bias to threat is not permanent and situation-invariant in the general population. Instead, it seems that specific variable factors determine whether a non-anxious individual shows an attentional bias to threat in a given situation. This conclusion is clearly inconsistent with some models of emotional attention from cognitive psychology. For example, the fear-module theory (Öhman, Flykt et al., 2001; Öhman, Lundqvist et al., 2001; Öhman & Mineka, 2001) claims that all human individuals show an attentional bias to threat due to a hard-wired fear module that was formed by evolutionary processes. This fear module is assumed to facilitate detection of potential threats in the environment to increase the chances of individual survival. Importantly, the theory assumes that the fear module is automatically activated once a threatening stimulus is encountered and cannot be penetrated by voluntary cognitive effort. Furthermore, the theory assumes that the fear module should be most efficiently activated by threatening stimuli with evolutionary relevance. For example, it should be more sensitive to snakes and spiders than to guns and bombs. The theory explicitly considers facial expressions to be an evolutionary relevant stimulus class because aggression among human conspecifics made it necessary to quickly detect social signals of dominance and submission (Öhman & Mineka, 2001). Therefore, according to fear-module theory, facial expressions of anger (like those we used in our studies) should be particularly efficient to trigger attentional biases.

Our findings are also inconsistent with models of emotional attention based on the circumplex model of emotion (Russell & Fehr, 1987), which claim that attention is biased towards high arousing stimuli in humans (Anderson, 2005; Anderson & Phelps, 2001). One might legitimately argue that the angry faces employed in the present studies were only moderately threatening and thus simply not arousing enough to reliably capture attention in unselected samples. However, in Study 1 (see Chapter 5) we additionally used angry faces with exposed teeth as cue stimuli. These angry faces were perceived as highly intense (and therefore probably also as highly arousing). Nevertheless, we did not find an attentional bias towards these faces in an unselected sample.

Other aspects of this thesis' results, however, are rather inconsistent with the common assumption of clinical theories of anxiety that the general population does not show an attentional bias to threat (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1988)).[24] In particular, we found a reliable attentional bias towards angry faces in unselected samples across three experiments. Importantly, this attentional bias was not correlated with participants' trait anxiety in any of these

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[24] It should be noted that both the cognitive-motivational analysis of anxiety (Mogg & Bradley, 1998) and the model by Mathews and Mackintosh (1998) predict that for highly intense threat stimuli, also non-anxious participants show an attentional bias. However, the angry faces that were presented in the present experiments were only moderately threatening (at least those faces with concealed teeth that we presented in Studies 2 and 3). Thus, according to both theories, attentional biases towards these angry faces should not have occurred in unselected samples.

experiments. Therefore, this bias could not have occurred due to a few highly anxious participants in our samples showing extremely large biases and thus increasing the average bias for their whole sample. However, as previously discussed, this bias did not occur under all experimental conditions. Specifically, this bias only occurred when two specific conditions were met. One being that target stimuli had to compete for attention with other stimuli (distractors) that were presented simultaneously during the target screen. Another being that participants had to perform a task that required processing of socially meaningful target stimuli. Across all experiments of the present thesis that met these two conditions, we found an anxiety-independent bias towards angry face cues with a size of $d_Z = 0.34$ (see section 7.2.3). According to Cohen (1988), this is a moderate effect between small ($d = 0.20$) and medium ($d = 0.50$).

In conclusion, the present studies show that the general population can also show an attentional bias towards threatening stimuli, but does so only under specific conditions. Of all the theories that have been discussed so far (see Chapter 2), this finding is most consistent with appraisal theories of emotional attention, which claim that human individuals show attentional biases towards those stimuli that are currently of concern to them (Brosch et al., 2008; Brosch & van Bavel, 2012; Pool et al., 2016). According to a review article on appraisal theories of emotion, current concerns include "the individual's needs, attachments, current goals, and beliefs" (Moors et al., 2013, p. 120). Importantly, current concerns are considered to go beyond mere task demands and to be broader and more general in nature (Pool et al., 2016). This broad definition of current concerns, however, has two implications. First, it is difficult to reliably measure such broadly defined concepts. Second, it is challenging to manipulate participants' current concerns in experimental settings. Nevertheless, these assumptions are generally in line with our findings. Study 2 showed that attentional bias towards angry faces was not simply contingent on whether anger was a task-relevant dimension or not (i.e., it was not contingent on mere task demands). Instead, Study 3 showed that attentional bias towards angry faces was contingent on the activation of a broader, more general social processing mode. It is possible that this social processing mode represents a current concern or that it makes an existing current concern (e.g., the avoidance of social rejection) temporarily more salient. These conclusions are in line with a growing body of research arguing that top-down processes play an important role in the influence of emotional factors on spatial attention allocation (see Mohanty & Sussman, 2013; Sussman et al., 2016 for reviews).

Although our results are consistent with appraisal theories of emotional attention from a theoretical point of view, there is a critical difference between our results and the results of previous studies that gathered empirical support for these theories. Previous studies supporting appraisal theories of emotional attention usually showed that attention is not only biased towards threatening stimuli in human individuals, but also towards other stimulus classes that are of general relevance to the observer. For example, a recent meta-analysis showed that attention is reliably biased towards positive-valence stimuli in human observers (Pool et al., 2016). In contrast, the present results support appraisal theories of emotional attention by showing that even biases towards clearly threatening stimuli are not unconditional, but contingent on current top-down goals (see also section 8.5.2).

8.3 Potential differences in attentional bias to threat between anxious and non-anxious individuals

The present thesis shows that also the general population does show an attentional bias to threat under specific conditions. Thus, the question arises where exactly the difference between anxious and non-anxious individuals regarding attentional bias to threat lies. It should be stressed that the present thesis cannot provide a conclusive answer to this question because it only investigated attentional bias to threat in unselected samples. In order to obtain a conclusive answer, however, between-subjects designs would be necessary (e.g., comparisons between clinically anxious groups and healthy control groups or comparisons between extreme groups within the non-clinical range). Thus, the present thesis can only provide preliminary assumptions that should be examined in future studies.

In Study 1, we employed target stimuli that are typically used in dot-probe studies. Thus, participants had to respond to simple symbolic stimuli that were very salient because of their unique colour (red) and their abrupt onset (i.e., the targets were colour and onset singletons, see Bacon & Egeth, 1994; Folk & Remington, 1998). Under these conditions, we found an attentional bias towards angry face cues only in anxious, but not in non-anxious participants. In contrast, in Study 2, we employed target stimuli that were perceptually more complex (schematic faces) and that were neither onset nor colour singletons. Under these conditions, we found an attentional bias towards angry face cues for the whole sample that was not moderated by participants' trait anxiety. This finding suggests that the attentional bias to threat is stronger and more robust in anxious individuals than in non-anxious individuals. As previously discussed in the General Discussion of Study 2 (see section 6.4), an attentional activation difference between the left and the right location of the screen is created during both the presentation of the cue display and during the presentation of the target display. Furthermore, it is assumed that the activation difference created by the cue display transfers to the temporarily proximal target display and sums up with the activation difference created by the target display. This summarised activation difference then determines which of the two screen locations is attended to first during the search for the target. As already discussed in Study 2, it seems that the activation difference between the angry and the neutral face cue that is created during the presentation of the cue display is only moderate in non-anxious individuals. Thus, when the activation difference between the target location and the opposite location is too strong (because the target is extremely salient) the moderate activation difference transferred from the cue display has no effect because the target location will be attended first in any case. In contrast, if the target is not extremely salient (e.g., due to the simultaneous presentation of a similar-looking distractor stimulus in the opposite location), the activation difference transferred from the cue display can determine which location receives more overall activation and is thus attended to first. For anxious individuals, however, it seems that the activation difference between the angry and the neutral face cue is so strong (i.e. the position of the angry face cue receives so much activation) that it can override even large activation differences created by the target display. Thus, the attentional bias towards angry face cues in anxious participants can even be detected when highly salient target stimuli with an abrupt onset and a unique colour are employed (see Study 1).

Furthermore, the results of the present thesis suggest that attentional bias towards angry faces is permanent in anxious individuals, but situation-specific in non-anxious individuals. Study 3 shows that attentional bias towards angry faces is contingent on the activation of a social processing mode in the general population. In this study, the activation of a social processing mode was manipulated by asking participants to classify socially meaningful or socially meaningless targets. However, in Study 1, anxious participants showed an attentional bias towards angry face cues even so they were searching for socially meaningless, symbolic target stimuli. What do these results mean for real-life situations? For example, a non-anxious individual might show an attentional bias towards threatening faces during an oral exam because it is crucial to scan the examiners' faces for signs of approval and rejection in this situation. However, the same individual probably does not show an attentional bias towards angry faces during a walk through a crowded park on a sunny day. In contrast, anxious individuals might also show an attentional bias in the latter situation although it is not functional to scan the entire environment for specific social signals in this given situation.

8.4 Methodological challenges in the measurement of attentional bias to threat

As discussed in the introduction of the present thesis (see Chapter 3), cognitive psychology and clinical psychology commonly use different paradigms to investigate attentional bias to threat. While cognitive research on emotional attention frequently applies the face-in-the-crowd paradigm, clinical anxiety research heavily relies on the dot-probe task. The present studies show that methodological differences between these two paradigms can indeed explain why both subdisciplines reach different conclusions regarding the occurrence of attentional bias to threat in the general population.

Moreover, the results of the present studies suggest that the dot-probe task might be a more promising paradigm for the investigation of attentional bias towards threatening stimuli than the face-in-the-crowd paradigm for two reasons. First, numerous recent face-in-the-crowd studies showed that the anger-superiority effect (i.e., a relative search advantage for angry faces compared to other facial expressions) is largely dependent on natural perceptual confounds of angry expressions (e.g., Calvo & Nummenmaa, 2008; Horstmann et al., 2012; Horstmann & Bauland, 2006; Savage et al., 2013; Savage & Lipp, 2015). In contrast, Study 1 showed that the anxiety-related attentional bias towards threatening stimuli usually found in the dot-probe task is not contingent on perceptually confounded stimuli. In fact, perceptually confounded angry faces (with exposed teeth) eliminated the anxiety-related attentional bias that occurred for unconfounded angry faces (without concealed teeth).

Second, the emotional expressions of the stimuli in the face-in-the-crowd paradigm are always task-relevant because participants intentionally search for a face with a specific or a discrepant emotion. Thus, the paradigm is not able to assess unconditional (i.e., purely bottom-up driven) biases towards threatening faces because top-down processes can potentially play a role in the search for the target face. Horstmann and Becker (2008) addressed this issue in a series of experiments with schematic faces as stimuli. In some experiments (Experiments 1A, 2A, and 3A) participants performed a standard face-in-the-crowd search where the target face was defined by its emotional expression. However, in the remaining experiments, participants performed a 1/*n* task where the target face was defined by the orientation of the nose (Experiment 1B), by a conjunction of colour and orientation (Experiments 2B and 2C) or by a colour singleton (Experiments 3B and 3C). Although the target in this task was not defined by its emotional expression, a schematic face with a discrepant expression (i.e., an expression singleton) was presented on each trial. This expression singleton could either coincide with the target face (valid expression singleton) or it could be one of the distractor faces (invalid expression singleton). If a negative-face singleton embedded in a positive crowd captures attention, then search should be more efficient with a valid negative-face singleton than with an invalid negative-face singleton, or with either a valid or an invalid positive- face singleton. In conclusion, the authors consistently found a search advantage for negative faces in the standard face-in-the-crowd paradigm where emotional expression was the target-defining feature. In contrast, the authors found little evidence for attentional guidance by negative faces in the 1/*n* task where emotional expression was not task-relevant.

This result is consistent with Study 3, which suggests that attentional bias towards angry faces is contingent on the activation of a social processing mode in unselected samples. It seems plausible that such a social processing mode is always activated in the standard face-in-the-crowd paradigm due to the fact that finding a face with a specific or discrepant emotional expression is an essentially social task. In contrast, the face cues presented in the dot-probe task are completely task-irrelevant and participants are usually asked to ignore these stimuli. Thus, the dot-probe task seems preferable to the standard face-in-the-crowd paradigm for the measurement of unconditional biases towards threatening stimuli.

Generally speaking, the dot-probe task has recently become a very popular paradigm, with a strongly increasing number of dot-probe studies being published each year according to Web of Science (Clarivate Analytics, London, England). This popularity is most likely at least partially caused by research on *attentional bias modification*. This research has shown that a training variant of the dot-probe task can be used to reduce the attentional bias towards threatening stimuli in patients with anxiety disorders. Importantly, this reduction of attentional bias to threat also results in an amelioration of the patients’ symptoms (see Browning, Holmes, & Harmer, 2010; Hakamata et al., 2010 for reviews on attentional bias modification).

However, despite its popularity and relevance in therapy contexts, the dot-probe task has several potential pitfalls that should be carefully considered by future research. As already discussed (see section 3.2.2.1) the dot-probe task cannot disentangle biases in attentional engagement from biases in attentional disengagement. This issue is particularly problematic because the majority of dot-probe studies use long cue-target SOAs of 500 ms and more, which allows participants to perform multiple shifts in covert and even overt attention (Cooper & Langton, 2006; Petrova et al., 2013). In the present experiments, we addressed this issue by employing a cue-target SOA of 100 ms. This SOA would allow participants to perform only one shift in covert attention between cue and target onset (Müller & Rabbitt, 1989). However, even the application of a short cue-target SOA cannot entirely rule out the possibility that disengagement processes played a role in the found result patterns (see Chapter 4).

Moreover, a methodologically disconcerting trend has recently emerged within the dot-probe research community. Although dot-probe studies usually employ target-detection (e.g., Brosch et al., 2011, Experiment 1; MacLeod et al., 1986; Salemink et al., 2007) or target-categorisation tasks (e.g., Bocanegra et al., 2012; Brosch et al., 2011, Experiment 2; Cooper & Langton, 2006; Holmes et al., 2005; Murphy et al., 2008; Putman, 2011), a growing number of dot-probe studies that employed target-localisation tasks has recently been published (e.g., Everaert et al., 2013; Vogt et al., 2013; Vogt & De Houwer, 2014). Mogg and Bradley (1999b) conducted a dot-probe study with a target-localisation task and found similar results (and similar effect sizes) to previous dot-probe studies with target-categorisation tasks. Therefore, the authors concluded that target localisation and target categorisation are equally viable tasks for the application in dot-probe studies. Since target localisation is usually easier than target categorisation (as indicated by shorter RTs and fewer errors), the authors even suggest that target-localisation tasks might be preferable in studies with error-prone samples (e.g., children or patients with severe disorders). However, it is an erroneous inference that two similar result patterns which are obtained with different experimental tasks necessarily reflect the same cognitive processes. As already discussed (see sections 3.2.3.1 and 6.4), when a target-localisation task is applied in a dot-probe study, the response alternatives (usually “left” and “right”) are identical to the potential target locations. Thus, faster RTs on valid trials than on invalid trials might not reflect attentional processes, but instead response priming effects. Consequently, future dot-probe studies should avoid the application of target-localisation tasks (see also Weierich et al., 2008 for a review recommending the application of categorisation tasks).

In summary, the dot-probe task seems to have several advantages over the face-in-the-crowd paradigm for the assessment of attentional biases to threat. Nevertheless, the dot-probe task has some shortcomings that should be considered when conclusions are drawn based on this paradigm. Thus, future research should develop new paradigms that (1) allow to investigate unconditional biases to threat that are independent from top-down mechanisms (2) can disentangle biases in attentional engagement and disengagement (3) are unconfounded by non-attentional processes (e.g., response slowing). Presently, none of the spatial paradigms for the investigation of attentional bias to threat (i.e., the face-in-the-crowd paradigm, the dot-probe task, and emotional spatial cueing) meet all three criteria.

8.5 Limitations and open questions

The reported studies suggest that the general population can show an attentional bias towards angry faces. Moreover, the studies identified necessary preconditions for the occurrence of this bias. However, some aspects of the studies' results and limitations in the applied methods raise specific questions that are discussed in the following sections.

8.5.1 The absence of correlations between attentional bias and individual anxiety in the control conditions of Studies 2 and 3

In Studies 2 and 3, we consistently found an anxiety-independent bias towards angry face cues in those experimental conditions where (1) targets competed for attention with distractor stimuli and (2) the task required social processing of the targets. In those conditions where one of these criteria was not met, one would expect to find an anxiety-related attentional bias towards angry faces (i.e., a significant bias in anxious, but not in non-anxious participants). These conditions were the onset target condition of Experiment 3 in Study 2, the meaningless target condition of Experiment 1 in Study 3 and the non-social target condition of Experiment 2 in Study 3 (see Figure 9). However, a significant correlation between participants' trait anxiety (as assessed by the STAI; Laux et al., 1981) and their attentional bias scores was not found in any of these conditions. This is particularly unexpected because we found a significant correlation of that kind in Study 1 (see Chapter 5).

What could be the reason for the absence of a correlation between participants' trait anxiety and their attentional bias scores in those conditions of Study 2 and Study 3?

First, there might be a test-theoretical reason for this result. It has been shown that the attentional bias score calculated in the dot-probe task has poor internal reliability (Kappenman, Farrens, Luck, & Proudfit, 2014; Kappenman, MacNamara, & Proudfit, 2015). Since, the internal reliability of a measure places an upper limit on its ability to correlate with another measure, we might not have been able to detect a correlation between participants' trait anxiety and their attentional bias scores.

However, there might also have been a methodological reason of the absence of a correlation between participants' trait anxiety and their attentional bias scores. Study 1 (and previous dot-probe studies) employed simple and salient symbols as target stimuli. Thus, the target-categorisation task in Study 1 was very easy, as indicated by short RTs ($M = 487$ ms, $SD = 49$). In the aforementioned control conditions of Study 2 and Study 3, however, the task was more difficult. In Study 3, average RTs were much longer in the meaningless target condition of Experiment 1 ($M = 755$, $SD = 79$) and the non-social target condition of Experiment 2 ($M = 801$, $SD = 109$). This is not surprising since target stimuli were presented simultaneously with distractor stimuli throughout this study. Thus, participants first had to select the correct stimulus (i.e., the target) before they could categorise it. In contrast, only one target stimulus was presented during the target display in the onset target condition of Experiment 3 in Study 2. Nevertheless, RTs in this condition ($M = 610$, $SD = 56$) were also clearly slower than in Study 1, most likely because targets in this condition (schematic faces) were perceptually more complex than targets in Study 1 ("×" and "=" symbols). Thus, it most likely took participants longer to process and categorise the targets. Consequently, it is possible that a correlation between participants' trait anxiety and their attentional bias scores only occurs in the dot-probe task, when an easy task with simple target stimuli and short average reaction times is performed.

8.5.2 Attentional bias towards other emotional expressions

In the present studies, we consistently presented angry faces (alongside neutral faces) during the cue display. As already discussed (see Chapter 4), we chose angry faces as cues because they convey a clear impression of impending threat for the observer and because anger expressions are not more salient than neutral faces due to natural perceptual confounds (if angry faces with concealed teeth instead of exposed teeth are used; see Chapter 5). However, since our results suggest that attentional bias towards angry faces is contingent on currently activated top-down processes and not purely driven by bottom-up characteristics of angry faces, it seems likely that other facial expressions also have the potential to capture visual attention under specific conditions. This assumption is consistent with appraisal theories of emotional attention (e.g., Brosch et al., 2008; Brosch & van Bavel, 2012), which claim that attention is biased towards all stimuli that are of general relevance to the observer. For example, happiness is another facial expression that might capture visual attention because a happy expression signals affiliation and acceptance. Thus, facial expressions of happiness are primarily relevant to the observer. In line with this assumption, a recent meta-analysis shows that the general population shows an attentional bias towards positive stimuli (Pool et al., 2016). However, numerous dot-probe studies employing happy face cues did not find a reliable attentional bias towards happy expressions in the general population (e.g., Cooper & Langton, 2006; Mills et al., 2014; Mogg & Bradley, 1999a; Murphy et al., 2008; Reinecke et al., 2011). However, these dot-probe studies could have obtained non-significant results because attentional bias towards happy faces might also be contingent on a social processing mode (similarly to attentional bias towards angry faces). To return to the example given above, one’s attention might not be captured by every happy face in the environment during a walk through a park on a sunny day. In contrast, during an oral exam, an examinee’s attention might be biased towards even the faintest smile in the faces of the examiners because it could signal approval of the examinee’s answer to a question. It should be noted however, that happy faces might have less potential to capture visual attention than angry faces because happy faces are usually characterised by lower arousal (Russell & Fehr, 1987).

Although many previous dot-probe studies used fearful faces to investigate attentional bias to threat (e.g., Holmes et al., 2005; Murphy et al., 2008; Reinecke et al., 2011), predictions under which specific conditions fearful faces might capture attention in the general population are rather complicated. While expressions of fear are characterised by extremely high levels of arousal (Russell & Fehr, 1987), the social message conveyed by fearful faces is highly dependent on the context. On the one hand, fear might signal the expresser’s submission to the observer. On the other hand, a fearful expression can also indicate that the expresser has detected a threat in the environment that might also be dangerous for the observer (see also (Paulus & Wentura, 2014). Thus, whether an expression of fear signals threat or not is highly contextual. Consequently, it seems plausible that the general population shows an attentional bias towards fearful faces when situational context factors suggest that the fearful expression signals a threat that is also dangerous for the observer of the expression.

8.6 Conclusions

The present thesis aimed to investigate whether the general population shows an attentional bias towards angry faces. To this end, we conducted three studies comprising six experiments in total. In these studies, we applied several variants of the dot-probe task to identify potential determinants for the occurrence of such a bias in unselected samples. In sum, we found reliable attentional biases towards angry faces that were not correlated with participants' trait anxiety across several experiments. This result pattern suggests that the general population can show an attentional bias towards angry faces. However, the results of these studies also suggest that this bias is not unconditional. That is, it does not occur by default in the general population—as it seems to be the case for anxious individuals.

More specifically, the results of the present studies suggest that attentional bias towards angry faces is contingent on two determinants in unselected samples. First, Study 2 (see Chapter 6) suggests that non-anxious individuals must be in a search mode where one object must be selected from a set of at least two objects (i.e., the target has to compete for attention with at least one distractor). Second, Study 3 (see Chapter 7) suggests that non-anxious individuals must be in a social processing mode. It is important to note that this social processing mode seems to be broader than a mere threat-detection mode. That is, non-anxious individuals do not simply show an attentional bias towards angry faces when they are in a mere threat-detection mode, but rather when their current goals generally require social processing of the environment. Furthermore, the results of Study 1 (see Chapter 5) suggest that salient bottom-up characteristics of angry faces (i.e., exposed teeth) do not determine whether unselected samples show an attentional bias towards those faces.

To conclude, in the general population, attentional bias towards angry faces seems to be contingent on top-down processes that are flexibly activated according to current situational demands and goals. The ability to situationally activate or deactivate attentional biases towards angry faces seems functional as it allows an individual to focus on current goals in non-social situations in addition to being able to quickly process potential threats during social interactions. In contrast, high trait anxious individuals seem to have a permanent, inflexible, and therefore dysfunctional bias towards angry faces.

9 References

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