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A Meta-Analysis and Investigation of Attention Bias for Facial Expressions of Emotion

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A META-ANALYSIS AND INVESTIGATION OF ATTENTION BIAS FOR FACIAL EXPRESSIONS OF EMOTION

by

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DISSERTATION

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DEDICATION

It goes without saying, but my grad school journey would not have been possible without the unconditional love and support from my family. I deeply cherish the endless sacrifices they made so that I could pursue this degree. Their patience and care has kept our connection strong, which in-turn has enabled me to explore, challenge and fulfill the privileged academic existence I've come to appreciate. With their help I persevered in times of great frustration. To both my family and friends: it means so much to have you in my life, and through it all, your compassion has cemented a purpose in me.

I also dedicate this work to the inspirational writers, scientists, educators, builders, and leaders out there. These individuals moved me to pursue a deeper understanding of the world and the people that inhabit it. To that effect, here is an inspirational quote from Frederick Douglass: "*We all feel that there is something more. That the curtain has not yet been lifted. There is a prophet within us, forever whispering that behind the seen lies the immeasurable unseen"* – (Douglass, 1861)

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ABSTRACT

The progression of affective science in the last few decades has brought with it a sub-field concerned with whether task-irrelevant facial expressions of emotion guide selective attention against our will. Such attentional bias is intuitively plausible, yet numerous recent studies were unable to observe it, motivating a meta-analysis (Chapter 2). Although the overall effect of 2.4 ms from 152 cases (*g* = .0823) was significantly greater than zero, its small size indicates a barely detectable phenomenon with no practical significance. A plausible explanation for this lack of attentional bias for emotional faces was tested in Chapter 3; even infrequently presented emotions could not bias attention. Also, attended emotional faces could not further modulate spatial attention (Chapter 4). Emotional faces can be processed automatically yet are virtually unable to bias spatial attention. Potential explanations include the questionable validity of emotional face cues and the mechanisms underlying attentional bias.

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Chapter 1: Introduction

Our limited capacity to attend multiple objects in the environment means that only a subset of them survive the competition for attentional resources (Dehaene & Changeux, 2011; Desimone & Duncan, 1995). Those objects which are irrelevant to current task demands generally evade attentional selection. This even occurs for very unusual things like someone in a gorilla costume (Simons, 2000; Yantis, 1998). However, certain irrelevant objects, such as facial expressions of emotion, may out-compete other objects and influence attentional selection. Emotional faces are important objects often associated with matters of personal relevance. Thus, they may actually be worth attending to even if they are irrelevant to the task at hand.

To understand when this might occur, consider a hypothetical situation where you are locating and subsequently navigating to your car in a parking lot. If a random individual entered the parking lot from the street – while displaying a neutral face – as you were approaching your vehicle, it is unlikely that you would notice them (as shown in the top row of Figure 1). But what if instead they were exhibiting a facial expression of emotion? Would an emotional face be salient enough to impinge on your goal of getting to your car? Perhaps you would pause and ruminate on the location where you saw this individual (as shown in the bottom row of Figure 1).

The current dissertation focuses on this possibility: task-irrelevant facial expressions of emotion may cause decrements to target-related processing. Henceforth this will be referred to as attentional bias for facial expressions of emotion (or emotional faces, or emotional expressions), but it has also been referred to in previous work as

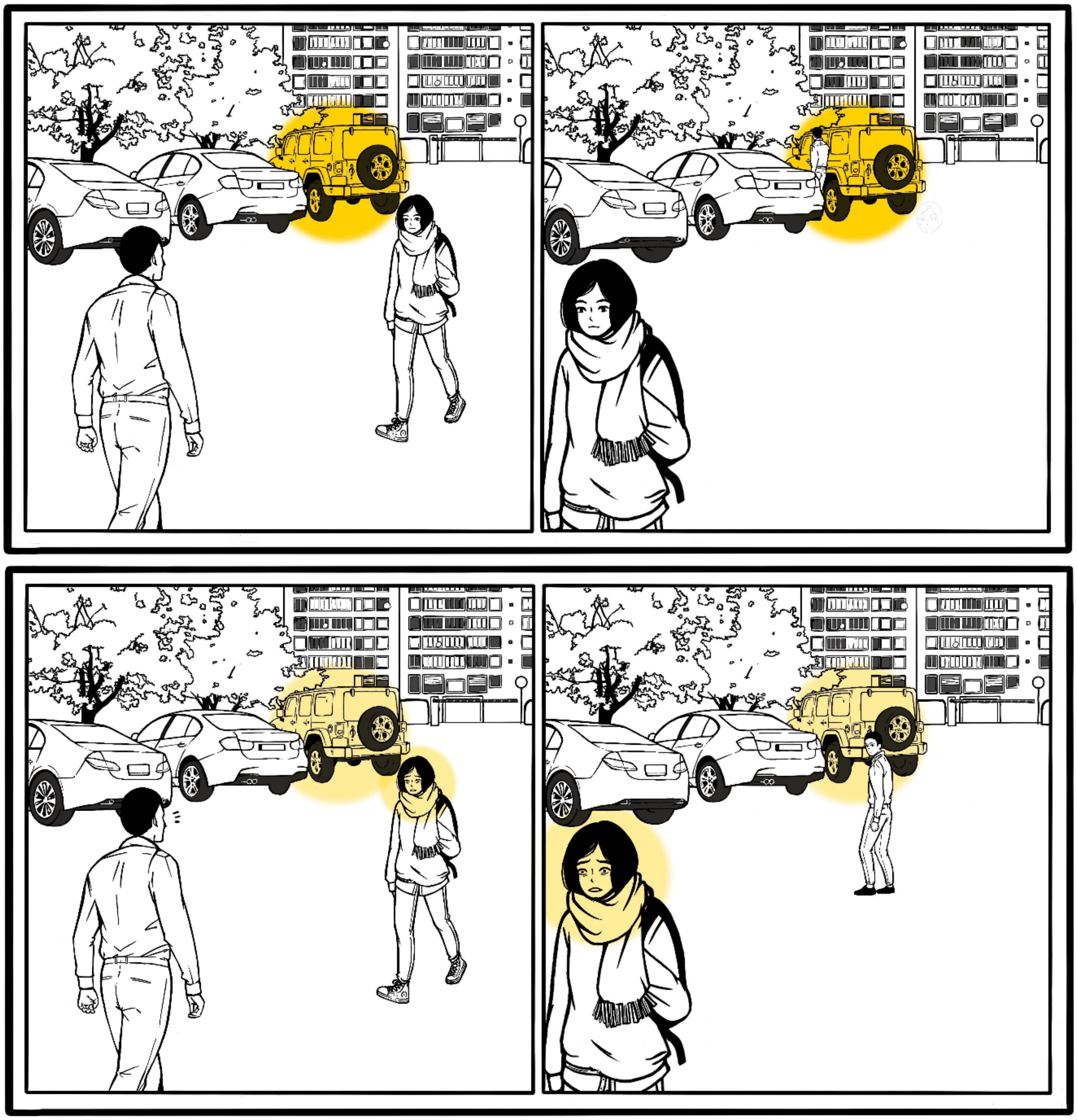


Figure 1. Example scenarios of attentional bias for a facial expression of emotion. While walking to your Jeep, an individual walks past you (events from left to right). The top row indicates what would occur if the individual was portraying a neutral expression. The bottom row indicates what would occur if the individual was portraying a facial expression of emotion. Despite the fact that faces are not part of your current goal of getting to your Jeep, an emotional face might bias your attention towards itself. The darker yellow in the top row indicates complete attentional allocation to your goal of reaching your Jeep. The lighter yellow in the bottom row indicates shared attentional allocation to your goal of reaching your Jeep and to the task-irrelevant emotional face. Drawing created by Morgan Lyphout-Spitz.

attention capture by emotion and emotional capture. Next, I will cover some relevant background and motivation to studying attentional bias for emotional faces.

The purpose of a facial expression of emotion

Facial expressions of emotion aid survival by enabling the organism to thwart potential threats (Darwin, 1872). For example, displaying a fearful expression widens the eyelids, increasing visual resolution, and flares the nostrils, thereby allowing the rapid intake of oxygen into the lungs, enabling fleeing behavior (Susskind et al., 2008). Also, an angry expression leads to a state of anger, increasing blood flow to the arms and hands, enabling flighting behavior (Levenson et al., 1990). These facial expressions and their corresponding emotional states enable quick, appropriate subsequent actions related to survival (for a review, see Shariff & Tracy, 2011).

Facial expressions of emotion are a type of nonverbal communication central to appropriate and accurate social negotiation (for reviews, see Crivelli & Fridlund, 2019; Jack & Schyns, 2015; Shariff & Tracy, 2011). As highly social creatures, humans heavily rely on communication and cooperation with others in order to co-exist. The pressure to use and perceive them very early on in life can explain their innateness and centrality to social communication. For example, a baby's usage of anticipatory smiling to engage their parents' attention at 9 months of age predicts their social competency at 30 months of age (Parlade et al., 2009).

Expression usage also corresponds to functioning later in life. For example, chronic loneliness is actually maintained by a lack of reciprocal smiling. Chronically lonely individuals experience maladaptive stress responses to social situations (Nitschke et al., 2020). Social situations require affiliative smiling in order to gain affiliation (Reed & Castro, 2021). Lonely individuals are especially in need of group affiliation. Affiliation can lead to friendships, friendships alleviate isolation, and isolation is a hallmark symptom of chronic loneliness (Hawkley & Cacioppo, 2003). And yet, those experiencing chronic loneliness show selective impairments in reciprocal smiling (Arnold, 2019) due to their maladaptive stress responses to social situations (Nitschke et al., 2020), which ultimately reduces their chances of achieving the group affiliation necessary for less loneliness. Moreover, this stress response selectively blunts the muscles necessary for reciprocal smiling, but not for frowning (Nitschke et al., 2020). So, a chronically lonely individual may very well frown in social situations, deterring others from seeking group affiliation with them (Hess et al., 2005). It is interesting to consider how something as simple as reciprocal smiling is implicated in the self-fulfilling loop of chronic loneliness.

Is emotion universal?

Based on many empirical studies, emotions are thought to be universal, equal across individuals from different cultures (Ekman, 1992). This viewpoint, known as basic emotion theory, argues that basic emotions – anger, happiness, disgust, fear, sadness, and surprise – serve similar functions and can be found in a number of different cultures (Ekman & Cordaro, 2011). Basic emotion theory gained acceptance and popularity after Paul Ekman’s seminal work in New Guinea (Ekman & Friesen, 1971). There he studied emotion recognition and perception in indigenous peoples, finding they too could identify the six basic facial expressions of emotion. Ekman also created a systematic coding system (and corresponding set of images of individuals making these posed facial expressions of emotion) for categorizing facial expressions of emotion, known as the facial action coding system (FACS, Ekman & Friesen, 1978). He has since worked as a consultant to many multi-national media companies and law enforcement agencies (*Paul Ekman Group*, n.d.), embedding himself and his work into modern culture.

Although basic emotion theory has been the prevailing view appreciated by many fields of study, we must acknowledge some of its limitations. One criticism is that the account relies entirely on the meaning of the context-less labels used to categorize images of facial expressions. Operationalizing emotions such as anger in this way is limiting because the meaning of anger in an Ekman photograph (an actor posing with a static expression) does not map onto the variety of contexts in which angry expressions arise. For example, the angry face from Serena Williams as she hits a tennis ball does not convey the same kind of anger that your significant other has towards you when you have upset them (Barrett et al., 2011). In fact, the perceived emotion from a scene with bodies and facial expressions can be determined exclusively by the visual context of the scene and not the emotional body or face information (Chen & Whitney, 2019, 2020, 2021).

Universality has also been challenged by the subtle distinctions within a single type of facial expression and the interactions between such distinctions and culture. For example, in smiling behavior, there are three independent types of smiles that correspond to separate social functions: to confer affiliation, assert dominance, or signal a reward (for a review, see Martin et al., 2017; Rychlowska et al., 2017). In western cultures, the mouth is critical for emotion perception, yet in eastern cultures the eyes are more critical than the mouth (Chen et al., 2018). This debate around universality, culture and context (Dukes et al., 2021) was recently addressed by an impressive large scale data-driven study of facial expressions of emotion (Cowen et al., 2020). By extracting patterns out of 6 million videos from 144 countries, Cowen et al. (2020) found support for 16 unique facial expressions displayed in multiple contexts and cultures. Their updated take on universality – termed the semantic space theory of emotion (Cowen & Keltner, 2020) –

asserts that many (16 of them) emotional expressions are universal, that they are influenced by differences in culture and context, and that they are more often blended than discrete (see also, Larsen & McGraw, 2011; Meaux & Vuilleumier, 2016).

These developments exemplify the nuances to studying emotion. Studies of attentional bias and automaticity for facial expressions of emotion rarely deviate from the six basic ones. This is a limitation because these categories of facial expressions do not reliability co-occur with their corresponding emotion; their correlation ranges between .13 and .3 (for a meta-analysis, see Durán & Fernández-Dols, 2021). Perhaps the six basic categories of emotion are too reductionistic and unable to fully illustrate emotions as they are experienced and used. New research shows that there are more than 25 stable categories of emotion organized in semantic space relative to one another (Cowen & Keltner, 2020). These developments pose significant challenges for future studies on emotion and facial expressions of emotion.

The brain basis of emotion

Contemporary research on emotions and feelings began with a focus on physiological responses in the body. In the late 1800's, James and Lange posited that emotion (and subsequent feelings) are characterized by a unique set of physiological responses to a stimulus. Interpretation of such physiological responses was believed to happen solely at the level of the cortex (Newman, 1995; but see Merker, 2007). However, Cannon Bard observed the critical role of mid-brain structures like the hypothalamus and periductal gray in emotional behaviors and physiological responses, contrasting James-Lange (Cannon, 1927). Subsequent debates between these two camps of thought led to the discovery of the Papez circuit – linkages between the hypothalamus and the limbic lobe (Papez, 1937) – and its role in the control over emotional expressions.

Papez's circuit was later adapted into the limbic system (Maclean, 1949), which was further broken down and studied by emotion researchers in the following years (Isaacson, 2013). Many rodent studies found that regions in the limbic system – such as the amygdala – are a necessary component of automatic threat appraisal and conditioning (for reviews, see Ledoux, 1998; LeDoux, 2000; Öhman & Mineka, 2001). But does this modular system dedicated to emotion processing in rodents (MacLean, 1990) generalize to humans?

Indeed, the limbic system in the human brain has many of the same structures as rodents. Also, these structures serve some similar functionality (Ledoux, 1998). This modular sub-cortical system is an interesting target for understanding the variety of survival (e.g., aggression) and social related behaviors (e.g., affiliation) across these two mammal species (Carter et al., 1999; but see also LeDoux, 2012). One can consider these phylogenetic similarities as the outcome of overlapping evolutionary pressures (like threat detection, see Öhman & Mineka, 2001) tied to the survival of the autonomic nervous system (Porges, 2009). Just consider for a moment how the preservation of systems dedicated to non-conscious emotion perception might be advantageous; threat and emotion detection surely aids survival. These ideas can be grouped together into what is commonly referred to as the standard hypothesis; Pessoa and Adolphs (2010) describe it on page 773 as how "ecologically important (emotional and social) stimuli are processed initially by a dedicated, modular system that operates rapidly, automatically (without the need to pay attention) and largely independently of conscious awareness".

Automatic, non-conscious emotion processing

Studies and support for the standard hypothesis in humans (for a review, see Tamietto & de Gelder, 2010) emerged in the 1990's. Since then, a variety of other terms have been used describe essentially the same thing as the standard hypothesis: threat prioritization (Carlson & Reinke, 2008), anger superiority effect (Hahn & Gronlund, 2007), fast adaptive fear system (Schubö et al., 2006), fear module (Öhman & Mineka, 2001), automatic detection of threat (Mogg & Bradley, 1999), preattentive threat-detection hypothesis (Horstmann, 2007), threat detection (Engen et al., 2017; Öhman & Mineka, 2001), threat detection advantage (Feldmann-Wüstefeld et al., 2011), threat capture (Burra, Coll, et al., 2017; Burra et al., 2016), and affective capture (Becker et al., 2017). Their commonality is that each corresponds to a piece of converging evidence for non-conscious, automatic emotion perception.

One of the most striking examples of non-conscious processing of emotional expressions comes from studies with individuals that have blindsight and spatial neglect (which results in phenomenological blindness to a hemifield). The balance between stimulus driven and goal-driven attention is lost in this region; the priority map of visual information in this area is perturbed, and perception is lost (for a review on neglect and attention, see Ptak & Fellrath, 2013). Yet, seemingly, individuals can detect the presence of an emotional face in their blind hemifield (de Gelder et al., 1999; Tamietto et al., 2007). In addition, these individuals mimicked emotional expressions (with their own faces) presented in their neglected hemifield (Tamietto et al., 2009).

Further support for non-conscious processing of emotion comes from studies of healthy individuals. For example, adults shown emotional expressions in a backward masking procedure (which makes them impossible to report) involuntarily mimic them with their own facial muscles (Dimberg et al., 2000). In another interesting example, Siegel et al. (2018) used an interocular-suppression technique, in which two different streams of visual information were presented to each eye of a participant. A target stimulus was presented to their dominant eye, and participants were instructed to select which face (from a set of five) was the most similar to the target. The five faces ranged from a slight-scowl to a slight-smile, with the middle face being neutral. Also, participants were instructed to ignore the stream presented to their non-dominant eye; this stream contained faces that were rendered invisible to the participant. Positive faces shown in the non-dominant stream caused a neutral target-face to be rated more often as smiling than neutral or scowling. Lastly, a meta-analysis revealed that angry and fearful faces can be detected when shown below conscious awareness (albeit a small sized effect, Hedger et al., 2016).

Researchers have also studied other types of automatic processing for emotional expressions. In a review of the literature, Palermo and Rhodes (2007) found evidence for three other types of automaticity: mandatory, rapid, and capacity-free. If the processing of a stimulus is mandatory, it is unavoidable and happens without intention (Wojciulik et al., 1998). Because amygdala reactivity for fearful expressions occurs without the intention to attend the emotional expression (Anderson, 2003), one can deduce they are mandatorily processed. Moreover, amygdala damage selectively impairs emotion perception when one does not intend on attending the emotional face (Anderson & Phelps, 2001; Adolphs et al., 1994). Emotion processing is also very rapid; amygdala reactivity to fearful faces begins as soon as 74 ms post-stimulus (in-vivo recording, Méndez-Bértolo et al., 2016). This is before attentional processes are believed to start taking shape (Thorpe & Fabre-Thorpe, 2001).

If emotion can be processed without central attentional resources, it is said to be capacity-free. For example, Shaw et al. (2011) found in an EEG study that spatial attention could orient to an emotional expression while central attentional resources were preoccupied (also see Maxwell, et al., 2021). Also, visually searching an emotional face embedded in an array of objects is highly efficient; increasing the number of distractors surrounding a target object does not slow a target response (Hansen & Hansen, 1988; Kennett & Wallis, 2019). High search efficiency reflects the capacity for emotion to be identified preattentively (prior to the allocation of spatial attention), guiding subsequent attentional selection (for a review, see Frischen et al., 2008). If emotional faces can be preattentively identified, perhaps their boosted priority can be passed on to downstream processes responsible for selecting which spatial locations to attend.

Conclusion

As shown by many examples, it is clear that emotional faces are processed automatically in many respects (for reviews, see Frischen et al., 2008; Hedger, Gray, Garner, & Adams, 2016; Palermo & Rhodes, 2007; Tamietto et al., 2009; Tamietto & de Gelder, 2010). Searching for and identifying an emotional face, such as an angry expression, can be done more quickly and easily than finding a neutral face (Frischen et al., 2008). When shown below conscious awareness, emotional faces have a slightly greater capacity to speed target detection (Hedger et al., 2016). Emotion, as conveyed by a facial expression of emotion, is an important feature of the environment. Evolutionary pressures to perceive and use them as a means of conveying matters of personal relevance can explain why they are automatically processed (Elam et al., 2010).

Because facial expressions of emotion are so important, one might assume they can bias attention based on just their emotionality. The purpose of emotion automaticity could be to facilitate subsequent changes in spatial attention, like orienting towards an emotional face even when it is unrelated to the task at hand. Engaging and attending to an irrelevant emotional face would lead to an understanding of its origin. If sufficiently prioritized, emotional faces might even beat out other innocuous stimuli, such as neutral faces. The next chapter systematically evaluates this possibility via a meta-analysis. The idea can be posed as a question: when an emotional face is not related to your current goals, will it attract your spatial attention?

Chapter 2: Attention Bias for Facial Expressions of Emotion: A Meta-Analysis

Attentional bias for emotional expressions

Attention bias can be defined as the capacity for an object or feature to bias the allocation of spatial attention towards itself. There are two types of attention that make up attentional bias – bottom-up salience-based attention and top-down goal-directed attention. These types of attention are the mechanisms by which competition between objects and features are resolved; incoming visual information is either filtered out, or prioritized by the attentional system (Asplund et al., 2010; Corbetta & Shulman, 2002; Desimone & Duncan, 1995; Theeuwes, 2019; Treisman & Gelade, 1980). Top-down goal directed (task-relevant) attention indicates how attention is guided against the will of the observer for objects or features that match the contents of current task-demands. For example, once you buy a new car, you might start to notice similar looking cars on the road. Attention bias for task-relevant emotion (top-down attention for emotion) is not very interesting because it is fairly straight forward that features in the world (e.g., color, shape, size, luminance) that match your current goals will bias your attention (for a meta-analysis of task-relevant attentional bias, see Büsel et al., 2018; Harris et al., 2019).

Attention bias for task-irrelevant emotion (bottom-up attention for emotion) is more interesting than attention bias for task-relevant emotion because it has wider-ranging implications. What is particularly important to note about this type of attentional bias is that the stimulus that biases attention is, by definition, completely irrelevant to current task-demands. This means that there are very few reasonable explanations as to why someone would show bias for the stimulus. One possible explanation for bias is the innate tendency to prioritize emotionally-charged stimuli (for reviews on attention by emotion interactions, see Carretié, 2014; Maratos & Pessoa, 2019; Öhman & Mineka, 2001; Pessoa, 2013; Pool et al., 2016; Yiend, 2010). Note that this type of bias is different than bias for cues with learned contingencies like conditioned reward or paired associates (Anderson & Kim, 2019; Pearson et al., 2015; Watson et al., 2019). All further references to attentional bias unless otherwise noted indicates attentional bias for task-irrelevant stimuli.

Attention bias for emotion (and therefore emotional faces) is of particular interest to neuroscientists (Vuilleumier & Schwartz, 2001). A neuro-focused model of attention bias proposed by Carretié (2014) describes how it might occur, as shown in Figure 2 (taken from Figure 7). Bottom-up sensory information from a cue (a distractor irrelevant to the current task) originating in vision, enters the preattentive evaluation network. This sensory signal exceeds a saliency threshold, leading to amplification by the visual cortex, leading to changes in dorsal and ventral network activity, which leads to the reorienting of spatial attention. The perspective here is that although both bottom-up and

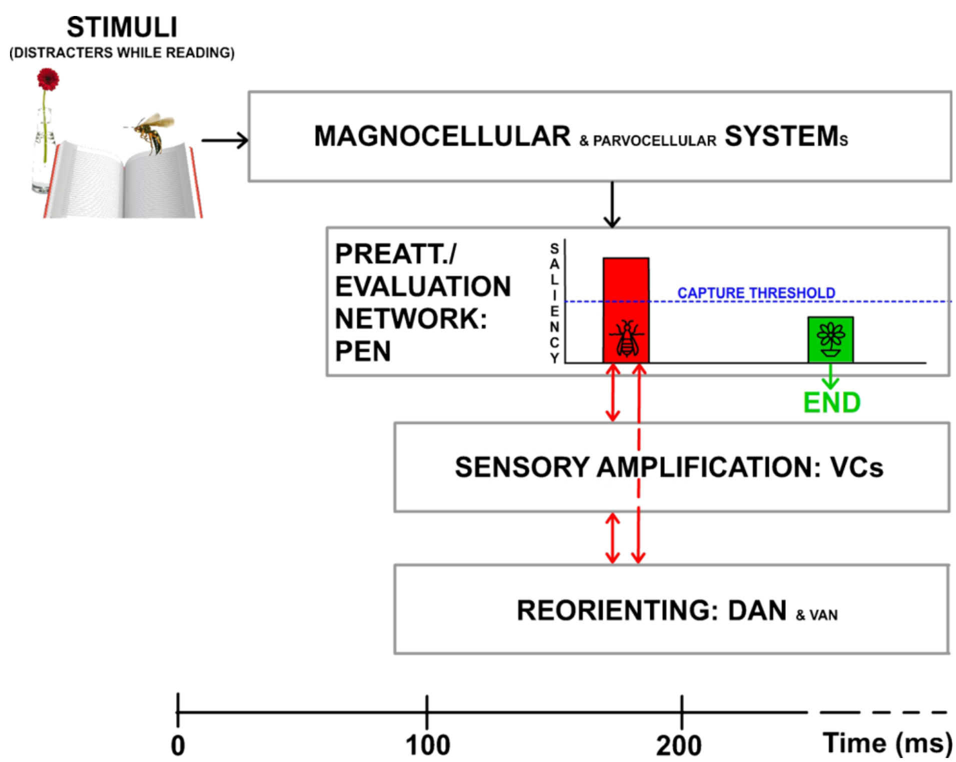


Figure 2. A conceptual model of attention bias for emotion

top-down processing of salient aspects of a stimulus contribute to attentional bias, bottom-up salience makes a greater contribution (for a review, see Pourtois et al., 2013).

Clinically-oriented researchers also find the phenomenon to be quite useful (Bradley et al., 1999; Fox et al., 2002). Unique patterns of attentional biases exist in certain populations. For example, children with autism spectrum disorder lack attentional bias for emotional expressions (Kikuchi et al., 2009), yet individuals with generalized anxiety disorder show too much of it (for a review see Bar-Haim et al., 2007; Waters et al., 2008). Attentional bias is a major component to disorders like addiction (Field et al., 2016) and is responsible in-part for its persistence (Stacy & Wiers, 2010), which makes it an ideal target for intervention (for reviews see Heeren et al., 2015; Mogg et al., 2017).

Do facial expressions of emotion bias attention?

While emotion automaticity is well-established, attentional bias for emotional faces is not. Many studies have examined the question, and the overall evidence is quite mixed. To illustrate the differing views and findings, below are several quotes indicating either support of or lack of support of attentional bias for emotional faces.

Answer: yes, they bias attention.

Several studies have argued that emotional expressions do in-fact bias attention. For example, Eimer and Kiss (2007) concluded on page 111 that “In summary, the present results provide new electrophysiological evidence for the hypothesis that task-irrelevant fearful faces can trigger attentional capture even when attention is narrowly focused.” In their abstract, Staugaard (2009) stated that “participants showed consistent attentional bias towards emotional faces in the task similar to previous research.” Also, Holmes et al. (2009) stated on page 66 that “The emergence of an early N2pc [an event related potential indicative of a shift in selective attention] to angry faces demonstrates that threat face cues captured attention rapidly". A review on attention capture by emotional stimuli, Carretié (2014) stated on page 1239 "... a conclusion can be drawn: Studies converge in indicating that emotional distractors capture attention to a greater extent than do neutral stimuli."

Even more recent work has re-iterated this conclusion. In fact, a behavioral neuroscience textbook (Breedlove & Watson, 2020) claimed that attention can be biased for emotional cues: "Important emotional cues – that look of fear on a companions face, for example – can reflexively capture attention and augment sensory processing, in order to scan for threats (Carretié, 2014)". In addition, Goodhew and Edwards (2021) state in their abstract that "Emotionally-salient stimuli can capture attention to their spatial location, even when they are not relevant to a prescribed task".

Answer: no, they do not bias attention.

However, many others have found just the opposite. For example, Puls and Rothermund (2018) stated in their abstract that "results indicate a general absence of emotional validity effects […], indicating that facial expressions of emotions do not capture attention". Also, Tannert and Rothermund (2018) echoed the same conclusion on page 230 "As our short review of the findings that were gathered with these paradigms revealed (see introduction), there is no reliable evidence for attentional biases for emotional faces…". This view is especially prominent in more recent studies (Arndt & Fujiwara, 2012; Brown et al., 2019a, 2019b; Delchau et al., 2020; Folyi et al., 2019; Glickman & Lamy, 2018; Kennett & Wallis, 2019; Lien et al., 2010; Mancini et al., 2020; Pereira et al., 2019; Raeder et al., 2019a; Victeur et al., 2019).

A resolution to contradictory findings.

It is quite difficult to ascertain a single yes or no answer as to whether attention is biased for facial expressions of emotion given the above studies. A meta-analysis is one very useful approach that can provide an answer to this question. No previous review has systematically examined attentional bias for facial expressions of emotion. One useful metric provided by a meta-analysis provides is the overall effect size. Another is the moderation of the overall effect by critical methodological factors. For example, attentional bias might be greater for certain kinds of emotional faces or images of facial expressions taken from certain databases of facial expressions. Such moderation could inform and explain these disparate findings. The next section describes one particularly promising moderator – task-relevance.

Singleton detection mode relevance

In a narrative review of the literature (for my comprehensive exam), I discovered that almost all studies that observed attentional bias used a unique procedure that (unintentionally) made facial expression of emotion task-relevant. In these studies, participants would search for a target object that was a singleton. A singleton is an object that stands out from its neighboring objects because it is unique from them. The other non-singleton neighboring objects are homogenous, which ensures the singleton object is a singleton (Lamy & Egeth, 2003). For example, consider an item that pops out at you because of its uniqueness, such as the only red apple left hanging on an apple tree. When the target is a singleton, a participant can utilize Singleton Detection Mode (SDM), which is the strategy and search process whereby targets can be located by identifying the singleton. Locating a target with SDM is very easy because the target can be found almost immediately. Finding the last remaining red apple on the tree is easy if you are looking for the odd thing out. Instead, if you located a target by looking for a specific feature, it would take you much more time and be less efficient (Wolfe et al., 2003). It would take a long time to find the last remaining red apple on the tree if you searched for it by checking each individual leaf for redness.

Participants tend to strategically adopt SDM when the target is a singleton (Bacon & Egeth, 1994; but see Irons & Leber, 2016). Critically, emotional face cues in these previous studies also happen to be singletons (for example, see Figure 3A). Targets and emotional faces have the common feature: *singletoness*. In these previous cases, the target is a singleton, and the emotional face is also a singleton, making the emotional singleton actually task-relevant. This type of relevance is referred to as SDM relevance. One cannot conclude that attention is biased for emotional faces in these cases. As mentioned previously, attentional bias is the purely bottom-up influence of emotional faces, not the bias that occurs when the emotional face is task-relevant.

One study found that attentional bias only occurs for emotional faces that have SDM relevance. Glickman and Lamy (2018) asked participants to indicate the gender of one target face shown amongst three other distractor faces. SDM was either prevented (non-SDM condition) or permitted (SDM condition). In the non-SDM condition (where SDM was prevented), participants located the oval shape with the fixed orientation of 45 degrees, and distractors were shown in randomly selected orientations (as shown in Figure 3B). In the SDM condition, participants located the uniquely oriented oval shape (the oval with a unique, singleton orientation), and the distractor ovals were shown in a uniform orientation (ensuring that the uniquely oriented oval "popped out", see Figure 3A). On half of all trials, one of the four faces that appeared was an emotional expression (distractor present trials). On the other half of trials (distractor absent trails), no emotional face was shown. This means that the emotional face was a singleton – it is the only emotional expression in the display. Critically, attention bias (as indicated by slower responses on distractor present trials relative to distractor absent) was only observed in the SDM condition (termed the unknown orientation singleton), and not in the non-SDM condition (termed the known orientation, see Figure 3C). Glickman summarized by saying on page 308 that “We conclude that capture by an irrelevant emotional face is not strictly stimulus driven and is contingent on the adoption of singleton-detection mode.”

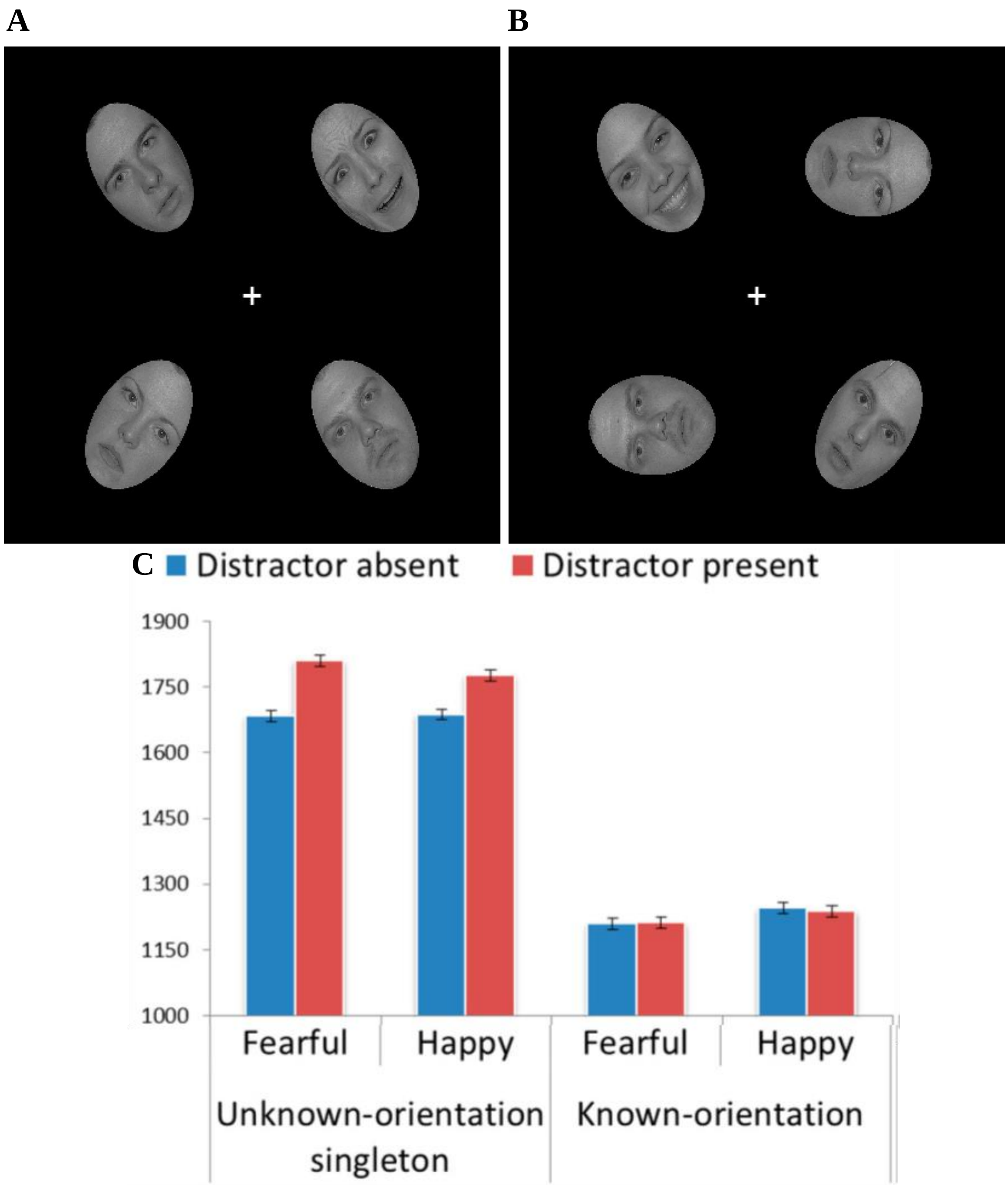


Figure 3. Conditions and results from Glickman and Lamy (2018).
A. An example of a distractor present trial in the SDM condition (shown in C as unknown-orientation singleton) where the bottom left face is the target, and the top right face is the emotional face singleton. B. An example of a distractor present trial from the non-SDM condition (shown in C as known-orientation) where the target is the bottom right face, and the top left face is the emotional face singleton. C. Response times (in milliseconds) for happy and fearful cues. Attentional bias is the difference in response times between distractor present and distractor absent trials. The y-axis is RT in ms.

Purpose of the current study

The purpose of the current chapter is to assess whether facial expressions of emotion bias attention by analyzing all relevant records in a meta-analysis. Examining the overall effect size could provide a resolution to this conflicting literature. This is especially useful because no systematic review has been conducted. Multiple types of emotional expressions (e.g., Angry, Happy) and emotional face databases (e.g., NimStim, Tottenham et al. 2009) will be examined. The timing of the stimuli and the type of dependent variable will also be examined. Only studies that required a visual search were included. The reason to is that if there is no uncertainty about the location of the target, then it is very difficult for an emotional expression to influence the focus of attention.

A much older meta-analysis also included studies with multiple target locations. However, it examined only happy facial expressions and is now out of date (Pool et al., 2016). Most importantly, it did not consider the role of SDM relevance. Nor did an even older review by Carrietie (2014). In fact, Carretie's (2014) review erroneously included cases of attentional bias that can be explained by SDM relevance (see the significant cases in Figure 4 of Carretie, 2014). In the current meta-analysis, cases of attentional bias that have emotional cues with SDM relevance are separated from cases of task-irrelevant attentional bias.

Two popular paradigms are especially well-suited to assessing attentional bias and will be included in the current meta-analysis: the spatial cueing paradigm (also referred to as the precueing paradigm; Figure 4) and the additional singleton paradigm (Figure 3A and 3B). In the spatial cueing paradigm, a participant is first shown a fixation display followed by a brief precue display (e.g., 100 ms). Participants must locate a target in the

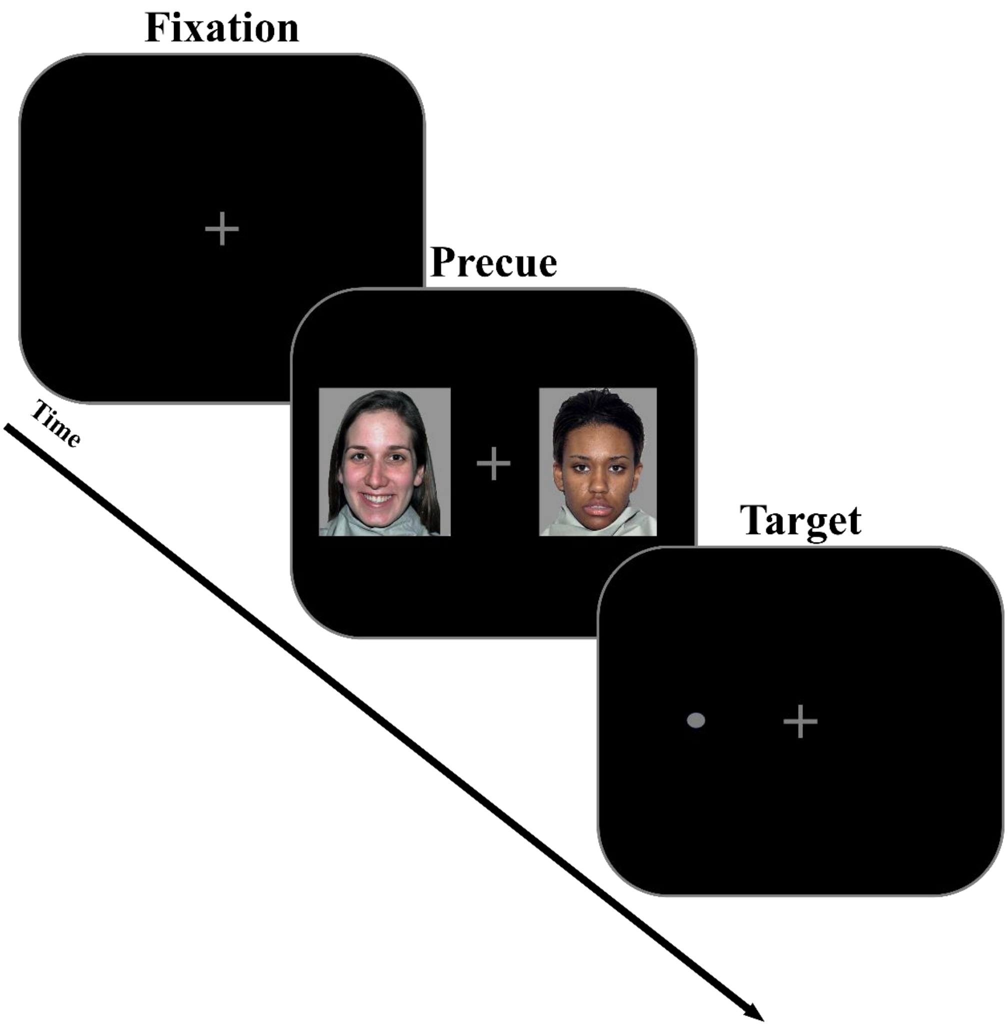


Figure 4. An example trial from a spatial cueing study.

search display (which replaces the precue display) and either indicate its location or identify something about it. When the emotional precue appears in the same location as the target, it is said to be a valid (or spatially congruent) trial. When the emotional face appears in a non-target location, it is an invalid trial. The example trial sequence in Figure 4 is a valid trial because the emotional face is shown in the same location as the target. The position of the precue and target are chosen at random, so there is no strategic reason to attend the location of emotional face in the precue display. A positive cue validity effect (RTs on invalid trials minus RTs on valid) would indicate greater attentional allocation towards emotional faces relative to non-emotional faces. In the additional singleton paradigm, only one display is shown per trial and an emotional face (cue) is either present or absent. A positive presence cost (RTs on cue present trials minus RTs on cue absent trials) indicates attentional bias for the emotional face.

Method

Inclusion Criteria.

A. The sample must be over the age of 18 and represent a truly random healthy sample; extreme group designs, clinical samples, or pre-selected samples – such as having high or low anxiety – were not included.
B. Studies must use cues that are whole emotional faces with forward looking gaze.
C. The emotional face cue must be a distractor to the task. For example, studies were excluded if the cue was shown in a simple free-viewing task that had no specific task instructions or goals.
D. No other types of attentional effects are included, such as flanker compatibility and face in the crowd.
E. Studies must not use pre-experimental manipulations. For example, cues could not be treated as to-be remembered information across a trial. Cues could not be shown as priming stimuli to the task or task related responses (either through explicit instruction or implicit exposure).
F. The cue location must not predict the target location.

Inclusion justification.

To ensure valid and reliable coding, Dr. Eric Ruthruff, Dr. Bob Torrance, and Joshua W. Maxwell met often to discuss, develop, and implement the final set of inclusion criteria listed above. These criteria were first applied when screening abstracts and again when screening full-text records (as shown in Figure 5). Criteria A: Only healthy adult samples were chosen so as to ensure records reflected the basic science question of whether emotional faces have the power bias attention. Other meta-analyses have already examined the relationship between attentional bias in special populations, like those with anxiety disorders (Bar-Haim et al., 2007; Clauss et al., 2022; Heeren et al., 2015), and depression (Bourke et al., 2010). Extreme group designs (e.g., sample creation by high or low anxiety assessments, in-patient groups, pre-screened samples for clinical purposes, or screening by and within certain populations) are difficult to equate with non-extreme group designs because of the high heterogeneity in extreme group designs, so they were excluded.

Criteria B: Studies that used face cues showing non-direct gaze were excluded. Gaze direction is a type of directional cue (eyes pointing to the left draw attention to the left) that could interfere with the processing of an emotional expression (for a meta-analysis on gaze cueing effects, see McKay et al., 2022). Criteria C: Studies that measure non attentional bias effects were excluded. For example, tasks that measure the overall time it takes to recognize a facial expression (e.g., Leppänen & Hietanen, 2004) or how long an emotional faces holds the eyes for (from an eye tracker) in a free viewing task (Giel et al., 2018) do not indicate attentional bias because the emotional face is not a distractor to the task. Criteria D: flanker compatibility effects (see Barratt & Bundesen, 2012) were excluded because they are the product of the combined effect of attentional bias and the benefit of shape similarity for the objects shown on compatible trials – the central target face and two flanker faces are the same stimulus. The only non-confounded effect from a flanker study is the comparison of flanker types, not flanker compatibility. These non-confounded flanker type effects do not require a visual search, so they were also excluded from this meta-analysis. In addition, studies of the face-in-the-crowd effect indicate greater search efficiency for emotional faces when they are the target stimulus (Hansen & Hansen, 1988), which means emotional faces are not a distractor but rather the target stimulus.

Criteria E: studies were excluded if the emotional face cue primed a target response or was a conditioned stimulus. For example, studies may wish to study the suppression of a cue (Dou et al., 2021) or reward attentional bias to emotion (Wentura et al., 2014). These contingencies interfere with the purely bottom-up nature of attentional bias for emotion by diminishing or boosting their salience. Criteria F: Studies with cues that predicted the target location were excluded because they elicit shifts in voluntary attention, which does not fit with my focus on studies of involuntary attention (Maxwell, et al., 2021; Prinzmetal et al., 2005, 2009, 2010).

Studies with Event Related Potentials (ERPs) other than the N2pc (e.g., visual mismatch negativity, see Stefanics et al., 2012) were excluded. The N2pc is commonly used to indicate the allocation of selective attention towards a stimulus in the left or right visual field (Eimer, 1996; Luck & Hillyard, 1994). Other ERP components, such as the N170, do not necessarily indicate attention capture, but rather might reflect the processing of a face in general (for a meta-analysis on the sensitivity of the N170 to emotional expressions, see Hinojosa, Mercado, & Carretié, 2015).

The scope of current review required further record exclusion at the stage after records were assessed for sufficient data availability (see paradigm edibility in Figure 5). Criteria G and H: Rapid serial visual presentation (de Jong et al., 2009; Maratos, 2011) and exogenous cueing studies (for examples, see figure 3 of Carretié, 2014) were excluded because they do not involve a visual search in space (as explained earlier). Criteria I: additional studies were excluded because they may not reflect attentional bias for emotion. For example, some unique studies relied exclusively on eye tracking measures such as saccadic latency or dwell time, which are not as widely accepted as indicators of attentional bias. Attention can shift covertly to an object even when the eyes do not.

Literature discovery

I used a daisy-chaining procedure and reviewed the bibliographies of several relevant reviews to gain familiarity of this literature (Carretié, 2014; Pool et al., 2016; Yiend, 2010). Between July 2019 and December 2020, roughly six iterative phases were completed to reveal an optimal systematic search for records. Further literature searching involved the exploration of subject-matter terminology specific to the database of interest (e.g., PubMed's MeSH database). The search concluded with three unique queries of Web of Science, PubMed, and UNM libraries (which includes over 40 unique sources, including PsychInfo and ProQuest), see appendix A for detailed descriptions.

To acquire gray literature (unpublished records, papers, posters, and conference materials), an email solicitation was distributed on October 7th, 2020, and a posting was made on ResearchGate December 4th, 2020. A total of 106 records were identified through this manner, in addition to those found during the initial discovery phase. Duplicate records were eliminated with DistillerSR (*DistillerSR*, n.d.). I collected and organized all records. All three coders compared abstracts against the inclusion criteria. All three coders reviewed a random 10% of records assessed for paradigm eligibility stage. Inter-Rater reliability was high; joint agreement for all moderators and decisions for exclusion was 97.1%. All disagreements were discussed among the three coders until a consensus was reached.

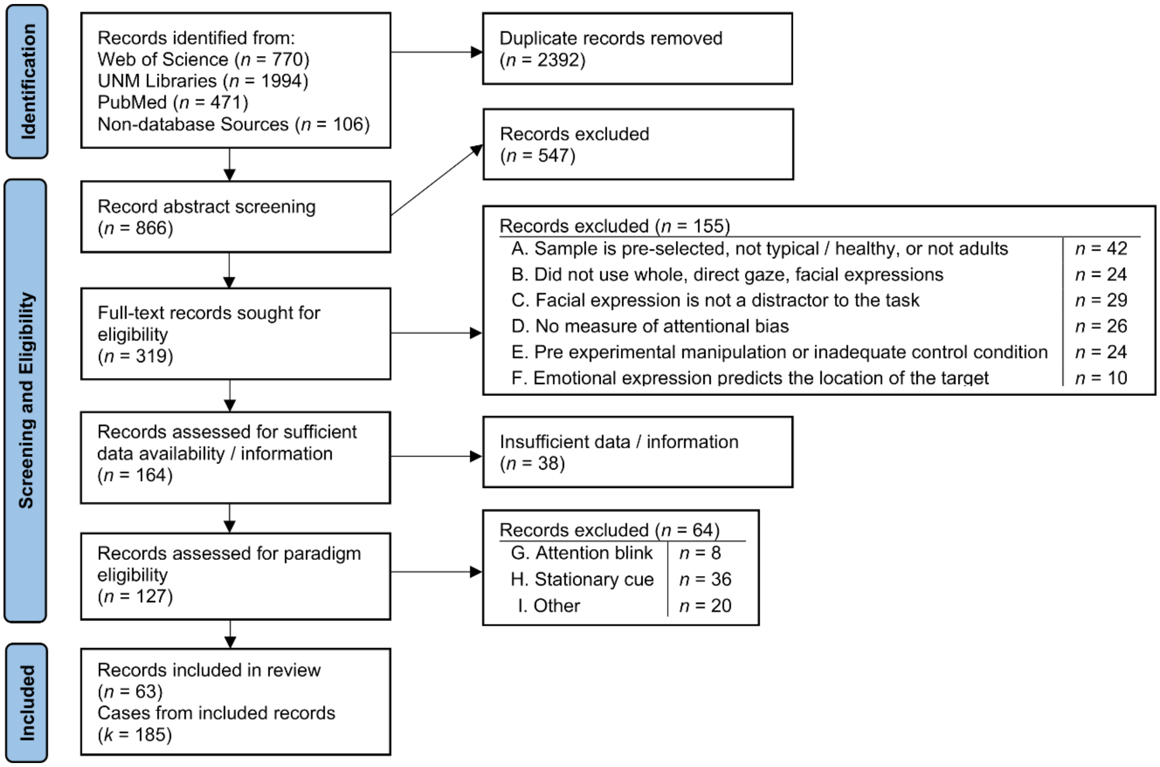


Figure 5. A PRISMA flow diagram of record exclusions.
Record exclusions by abstract screening (n = 547) was based on criteria A-F. Record exclusions by paradigm edibility (n = 64) were based on the scope of the current meta-analysis. UNM represents University of New Mexico online libraries, n represents a single source of information like an article, k represents individual cases.

Meta analytic procedure.

Hedge's g was used as the standardized mean difference (SMD) score because it corrects for positively inflated effects from small sized samples ($n < 20$, Hedges, 1981). Attention bias for emotional expressions was calculated according to what information was available in the text, figures (using web-plot digitizer, see Rohatgi, 2021), and supplementary material. Values were preferentially extracted in this order depending what information was available: condition means and variances, unstandardized difference score and variance, and standardized difference score. When multiple condition means and standard deviations were used, standard deviations were pooled using Lakens' (2013) calculator for correlated samples (see Supplementary Materials of Lakens), assuming $r = 0.75$ (Dunlap et al., 1996). Hedges g standard errors were calculated assuming a correlation of .75 (see equation 11.26 and 11.27 in Cooper et al., 2019). This follows the most closely related meta-analysis to date (Pool et al., 2016). Analyses were performed with *dmetar* (Harrer et al., 2019), *meta* (Balduzzi et al., 2019), and *metafor* (Viechtbauer, 2010) libraries. All analysis code and data can be located here: https://osf.io/pzy9g/.

Results

Study characteristics.

Of the final set of 63 included reports, 185 unique cases were identified, made up of 78 unique samples, totaling 3,589 participants. Two meta-analyses are reported sequentially below. The first covers the set of 160 cases of purely task-irrelevant attentional bias, the second covers the remaining 25 cases that were identified as having SDM relevance (both the target and the cue were singletons).

Meta-analysis of task-irrelevant attentional bias.

A random effects model (inverse variance method with a REML estimate for tau^2, Hartung-Knapp adjustment) revealed a significant overall pooled effect of attentional bias for emotional expressions, see Table 1 and the bottom of Figure 6. Between-study heterogeneity variance was estimated at $Q = 631.46$, $p < .001$, $tau^2 = .04$ [.035-.065]. The prediction interval (see formula 5.7 in Harrer, 2022) shown by a red bar at the bottom of Figure 6 indicates a range of likely effect sizes of a future study. Note that some cases may appear as duplicates, such as Gronchi et al. (2018), but are in-fact unique cases that differ on some other minority dimension, such as unique samples that differ by age. Although influential case removal is often utilized when I^2 is greater than 50%, removing 4 highly influential cases per outlier identification from a Baujat plot (Baujat et al., 2002, see Appendix B) did not change the change overall pooled effect or heterogeneity between studies (see Table 1). Therefore, no outlier or influential cases were removed.

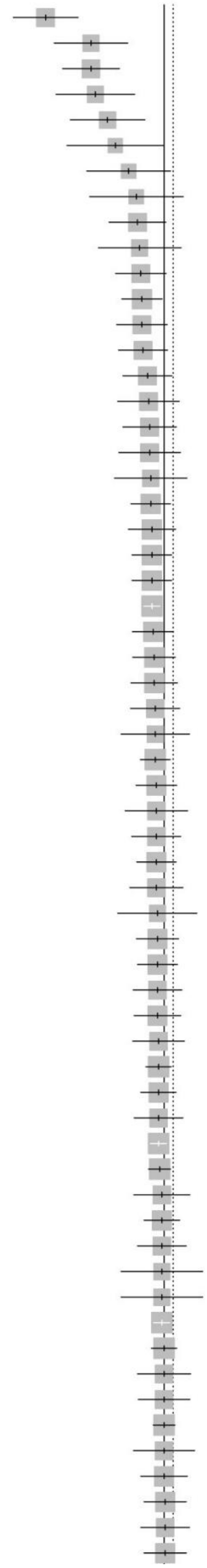
Table 1. Change in overall effects by outlier and influential case removal

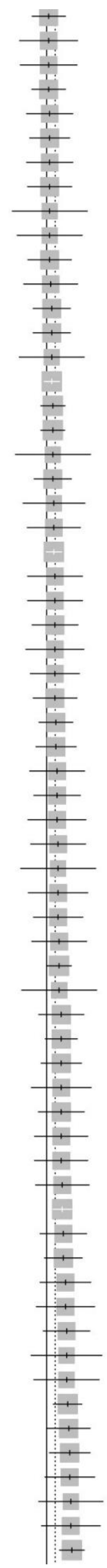
Analysis	**Hedges *g***	**95% CI**	***p***	**95% PI**	I^2	**95% CI**
Main analysis	.0823	.046 – .121	< .001	-.323 – .487	74.8%	70.7% – 08.4%
Cases removed	.0766	.038 – .115	< .001	-.319 – .472	73.8%	69.4% – 77.6%

Note: PI = prediction interval. The row labelled cases removed indicates the results of a meta-analysis with outlier and influential cases removed.

last.name.author	Exp.Num	emoType	SMD	95%-CI	Weight
Gronchi et al., (2018)	1	Fear	-1.07	[-1.36; -0.78]	0.6%
Pfabigan et al., (2014)	1	Happy	-0.66	[-0.99; -0.33]	0.5%
Gronchi et al., (2018)	1	Happy	-0.66	[-0.92; -0.40]	0.6%
Lien et al., (2013)	1	Fear	-0.62	[-0.98; -0.26]	0.5%
Joormann et al., (2007)	1	Sad	-0.51	[-0.85; -0.17]	0.5%
Krings et al., (2020)	1	Happy	-0.44	[-0.88; 0.00]	0.4%
Leyman et al., (2009)	1	Anger	-0.32	[-0.70; 0.06]	0.4%
Krings et al., (2020)	1	Sad	-0.25	[-0.67; 0.17]	0.4%
Mazidi et al., (2019)	1	Happy	-0.24	[-0.50; 0.02]	0.6%
Leyman et al., (2009)	1	Happy	-0.22	[-0.59; 0.15]	0.5%
Demeyer et al., (2013)	1	Sad	-0.21	[-0.44; 0.02]	0.6%
Puls et al., (2018)	5	Anger	-0.20	[-0.38; -0.02]	0.7%
Demeyer et al., (2013)	1	Happy	-0.20	[-0.43; 0.03]	0.6%
Puls et al., (2018)	3	Anger	-0.19	[-0.41; 0.03]	0.6%
Hunkin et al., (2014)	1	Anger	-0.15	[-0.37; 0.07]	0.6%
Zhou et al., (2015)	1	Anger	-0.14	[-0.42; 0.14]	0.6%
Bistricky et al., (2016)	1	Happy	-0.13	[-0.37; 0.11]	0.6%
Zhou et al., (2014)	1	Happy	-0.13	[-0.41; 0.15]	0.6%
Traczyk et al., (2010)	1	Anger	-0.12	[-0.45; 0.21]	0.5%
Cooper et al., (2006)	1	Anger	-0.12	[-0.30; 0.06]	0.7%
Mohammadi et al., (2015)	1	Pain	-0.11	[-0.32; 0.10]	0.7%
Puls et al., (2018)	4	Anger	-0.11	[-0.29; 0.07]	0.7%
Cooper et al., (2006)	1	Happy	-0.11	[-0.29; 0.07]	0.7%
Tran et al., (2013)	1	Sad	-0.11	[-0.18; -0.04]	0.8%
Berggren et al., (2020)	1	Happy	-0.10	[-0.29; 0.09]	0.7%
Kaiser et al., (2020)	1	Happy	-0.09	[-0.28; 0.10]	0.7%
Matusz et al., (2015)	1	Happy	-0.09	[-0.30; 0.12]	0.7%
Staugaard et al., (2009)	1	Anger	-0.08	[-0.30; 0.14]	0.6%
Glickman et al., (2018)	1	Happy	-0.08	[-0.39; 0.23]	0.5%
Garn et al., (2016)	1	Sad	-0.08	[-0.22; 0.06]	0.8%
Berggren et al., (2020)	1	Anger	-0.07	[-0.26; 0.12]	0.7%
Sigurjonsdottir et al., (2015)	1	Disgust	-0.07	[-0.35; 0.21]	0.6%
Puls et al., (2018)	3	Fear	-0.07	[-0.29; 0.15]	0.6%
Puls et al., (2018)	4	Happy	-0.07	[-0.25; 0.11]	0.7%
Puls et al., (2018)	7	Anger	-0.07	[-0.31; 0.17]	0.6%
Mueller et al., (2009)	1	Happy	-0.06	[-0.42; 0.30]	0.5%
Kaiser et al., (2020)	1	Anger	-0.06	[-0.25; 0.13]	0.7%
Puls et al., (2018)	5	Happy	-0.06	[-0.24; 0.12]	0.7%
Puls et al., (2018)	6	Happy	-0.06	[-0.28; 0.16]	0.6%
Thoern et al., (2016)	1	Happy	-0.06	[-0.27; 0.15]	0.7%
Victeur et al., (2020)	2	Fear	-0.05	[-0.28; 0.18]	0.6%
Garcia et al., (2019)	1	Happy	-0.05	[-0.17; 0.07]	0.8%
Li et al., (2019)	1	Happy	-0.05	[-0.21; 0.11]	0.7%
Puls et al., (2018)	6	Anger	-0.05	[-0.27; 0.17]	0.6%
Tran et al., (2013)	1	Happy	-0.05	[-0.12; 0.02]	0.8%
Schäfer et al., (2015)	1	Happy	-0.04	[-0.14; 0.06]	0.8%
Osinsky et al., (2014)	1	Anger	-0.02	[-0.27; 0.23]	0.6%
Wirth et al., (2020)	3	Happy	-0.02	[-0.18; 0.14]	0.7%
Puls et al., (2018)	6	Fear	-0.02	[-0.24; 0.20]	0.6%
Leyman et al., (2009)	1	Happy	-0.02	[-0.39; 0.35]	0.5%
Leyman et al., (2009)	1	Anger	-0.02	[-0.39; 0.35]	0.5%
Tran et al., (2013)	1	Anger	-0.02	[-0.09; 0.05]	0.8%
Garcia et al., (2019)	1	Sad	0.00	[-0.12; 0.12]	0.8%
Puls et al., (2018)	7	Fear	0.00	[-0.24; 0.24]	0.6%
Gronchi et al., (2018)	1	Disgust	0.00	[-0.23; 0.23]	0.6%
Schäfer et al., (2015)	1	Anger	0.00	[-0.10; 0.10]	0.8%
Marotta et al., (2020)	1	Happy	0.00	[-0.28; 0.28]	0.6%
Matusz et al., (2015)	1	Anger	0.00	[-0.21; 0.21]	0.7%
Kaiser et al., (2020)	1	Anger	0.01	[-0.18; 0.20]	0.7%
Puls et al., (2018)	1	Anger	0.01	[-0.21; 0.23]	0.6%
Mather et al., (2003)	1	Happy	0.01	[-0.18; 0.20]	0.7%

Standardised Mean Difference





Li et al., (2019)	1	Sad	0.02	[-0.14; 0.18]	0.7%
Marotta et al., (2020)	1	Sad	0.02	[-0.26; 0.30]	0.6%
Sigurjonsdottir et al., (2020)	1	Disgust	0.02	[-0.25; 0.29]	0.6%
Schneier et al., (2016)	1	Anger	0.02	[-0.14; 0.18]	0.7%
Staugaard et al., (2009)	1	Anger	0.03	[-0.19; 0.25]	0.6%
Kaiser et al., (2020)	1	Happy	0.03	[-0.16; 0.22]	0.7%
Puls et al., (2018)	1	Happy	0.03	[-0.19; 0.25]	0.6%
Thoern et al., (2016)	1	Anger	0.03	[-0.18; 0.24]	0.7%
Abend et al., (2019)	1	Anger	0.03	[-0.33; 0.39]	0.5%
Glickman et al., (2018)	1	Fear	0.03	[-0.28; 0.34]	0.5%
Mather et al., (2003)	2	Happy	0.03	[-0.18; 0.24]	0.7%
Waters et al., (2015)	1	Happy	0.04	[-0.22; 0.30]	0.6%
Verkuil et al., (2009)	1	Anger	0.05	[-0.13; 0.23]	0.7%
Verkuil et al., (2009)	1	Happy	0.05	[-0.13; 0.23]	0.7%
Foster (2013)	1	Anger	0.05	[-0.26; 0.36]	0.5%
Tran et al., (2013)	1	Disgust	0.05	[-0.02; 0.12]	0.8%
Garcia et al., (2019)	1	Happy	0.06	[-0.06; 0.18]	0.8%
Garcia et al., (2019)	1	Anger	0.06	[-0.06; 0.18]	0.8%
Pessoa et al., (2002)	1	Happy	0.06	[-0.30; 0.42]	0.5%
Cooper et al., (2006)	1	Anger	0.06	[-0.12; 0.24]	0.7%
Holmes et al., (2014)	1	Anger	0.07	[-0.23; 0.37]	0.5%
Tomaszczyk et al., (2014)	1	Happy	0.07	[-0.18; 0.32]	0.6%
Tran et al., (2013)	1	Fear	0.07	[0.00; 0.14]	0.8%
Osinsky et al., (2014)	1	Anger	0.08	[-0.18; 0.34]	0.6%
Osinsky et al., (2014)	2	Anger	0.08	[-0.18; 0.34]	0.6%
Puls et al., (2018)	2	Fear	0.08	[-0.14; 0.30]	0.7%
Demeyer et al., (2013)	1	Sad	0.08	[-0.20; 0.36]	0.6%
Gronchi et al., (2018)	1	Disgust	0.08	[-0.15; 0.31]	0.6%
Mather et al., (2003)	2	Happy	0.08	[-0.13; 0.29]	0.7%
Wirth et al., (2020)	3	Happy	0.09	[-0.07; 0.25]	0.7%
Mather et al., (2003)	1	Happy	0.09	[-0.10; 0.28]	0.7%
Osinsky et al., (2014)	1	Anger	0.10	[-0.16; 0.36]	0.6%
Puls et al., (2018)	3	Happy	0.10	[-0.12; 0.32]	0.6%
Zhou et al., (2014)	1	Anger	0.10	[-0.18; 0.38]	0.6%
Osinsky et al., (2014)	1	Anger	0.11	[-0.15; 0.37]	0.6%
Mueller et al., (2009)	1	Anger	0.11	[-0.25; 0.47]	0.5%
Sigurjonsdottir et al., (2015)	1	Disgust	0.11	[-0.17; 0.39]	0.6%
Gronchi et al., (2018)	1	Disgust	0.11	[-0.12; 0.34]	0.6%
Osinsky et al., (2014)	2	Anger	0.12	[-0.14; 0.38]	0.6%
Garcia et al., (2019)	1	Sad	0.12	[0.00; 0.24]	0.8%
Pessoa et al., (2002)	1	Anger	0.12	[-0.24; 0.48]	0.5%
Mohammadi et al., (2015)	1	Happy	0.14	[-0.07; 0.35]	0.7%
Wirth et al., (2020)	4	Anger	0.14	[-0.01; 0.29]	0.7%
Kaiser et al., (2020)	1	Happy	0.14	[-0.05; 0.33]	0.7%
Sigurjonsdottir et al., (2015)	1	Disgust	0.14	[-0.14; 0.42]	0.6%
Puls et al., (2018)	2	Anger	0.14	[-0.08; 0.36]	0.7%
Tomaszczyk et al., (2014)	1	Happy	0.14	[-0.11; 0.39]	0.6%
Tomaszczyk et al., (2014)	1	Anger	0.14	[-0.11; 0.39]	0.6%
Mazidi et al., (2019)	1	Pain	0.15	[-0.10; 0.40]	0.6%
Maxwell et al., (2022)	1	Fear	0.15	[0.06; 0.24]	0.8%
Staugaard et al., (2009)	1	Happy	0.16	[-0.06; 0.38]	0.6%
Cooper et al., (2006)	1	Happy	0.16	[-0.02; 0.34]	0.7%
Bistricky et al., (2016)	1	Sad	0.18	[-0.06; 0.42]	0.6%
Marotta et al., (2020)	1	Anger	0.18	[-0.10; 0.46]	0.6%
Puls et al., (2018)	1	Fear	0.19	[-0.03; 0.41]	0.6%
Holmes et al., (2009)	1	Happy	0.19	[-0.15; 0.53]	0.5%
Torrence et al., (2018)	1	Fear	0.19	[-0.12; 0.50]	0.5%
Garn et al., (2016)	1	Happy	0.20	[0.06; 0.34]	0.8%
Ferneyhough et al., (2013)	1	Fear	0.21	[0.01; 0.41]	0.7%
Kaiser et al., (2020)	1	Anger	0.22	[0.03; 0.41]	0.7%
Gronchi et al., (2018)	1	Disgust	0.22	[-0.02; 0.46]	0.6%
Pfabigan et al., (2014)	1	Anger	0.23	[-0.08; 0.54]	0.5%
Demeyer et al., (2013)	1	Happy	0.23	[-0.05; 0.51]	0.6%
Garcia et al., (2019)	1	Anger	0.24	[0.12; 0.36]	0.8%

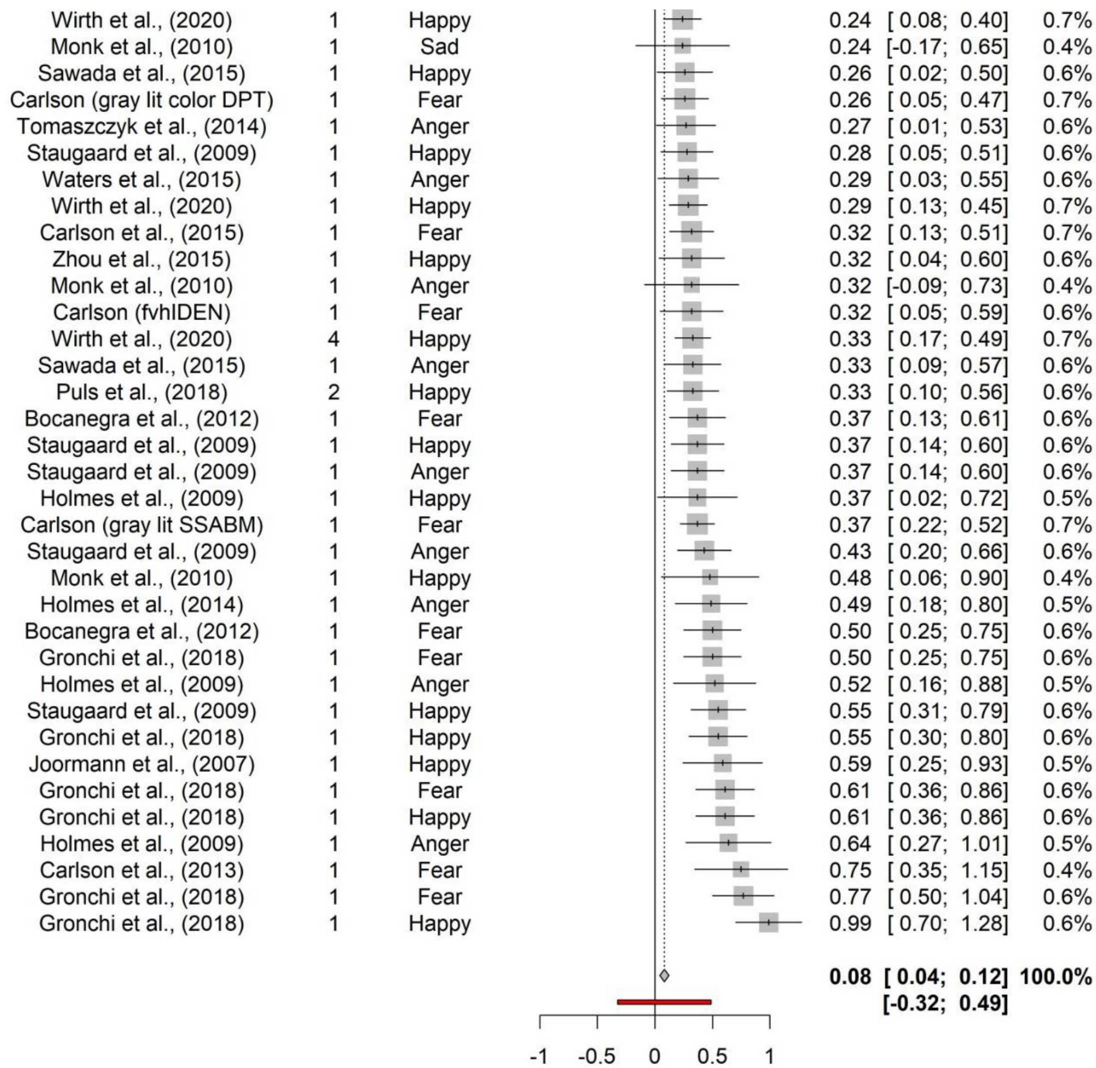


Figure 6. Forest plot of attentional bias for emotional faces.
No cases with SDM relevance were included in this meta-analysis. Gray boxes around each case indicate its weight, horizontal lines through the box are 95% CI's. The diamond, and the vertical line extending upward from it, indicate the overall pooled effect size.

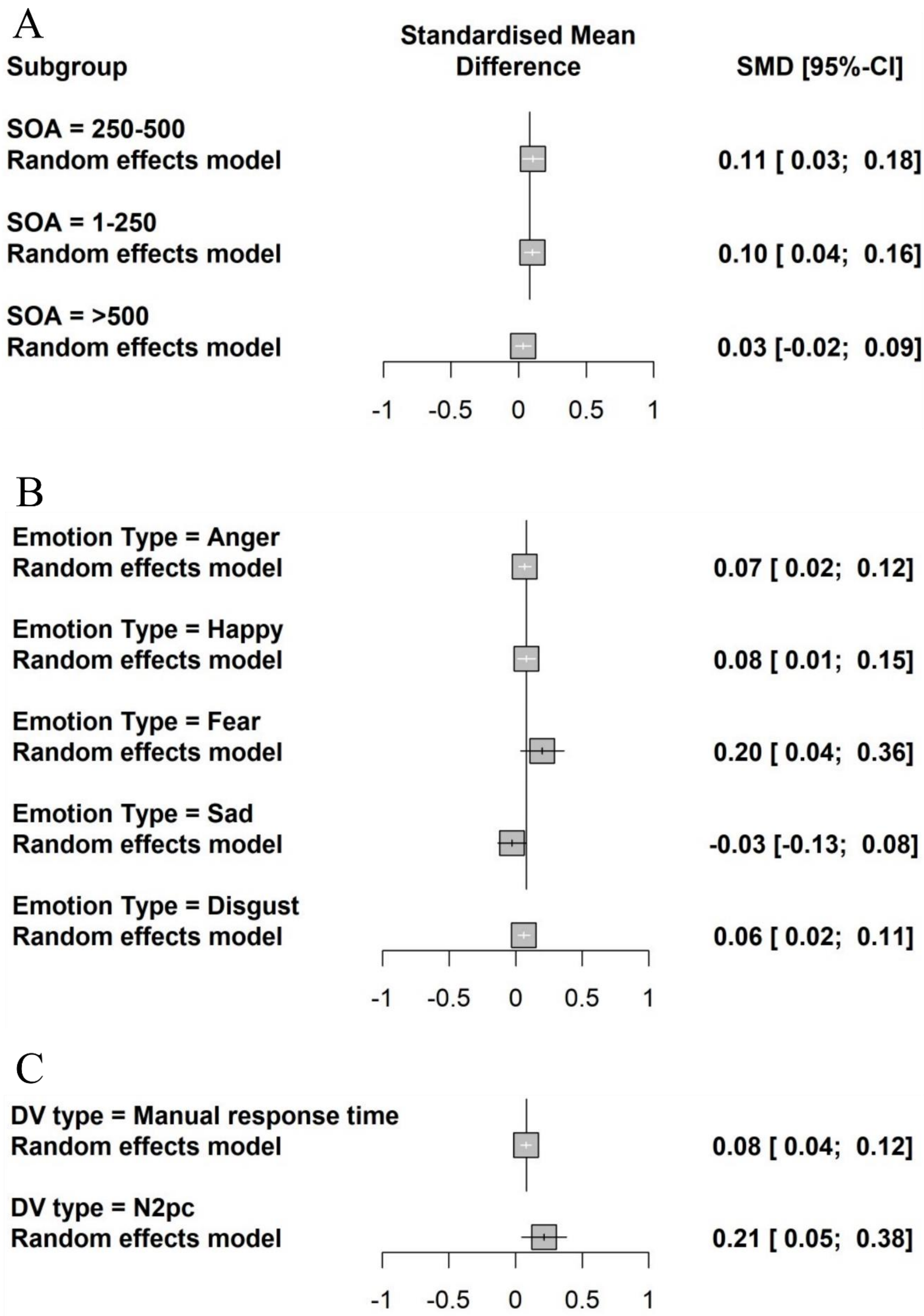
Sub-group analyses (moderators).

Mixed-effects models were used for categorical moderator analyses. Overall effect sizes for each subgroup are calculated using random-effect models and between subgroup difference were conducted with a fixed effect model (as shown in Figure 7; Borenstein & Higgins, 2013). Meta-regression was used for continuous moderators.

Table 2. Moderators of attentional bias for emotional faces.

Moderators	Q_b / Q_w	***F***	***p***	***k***	I^2
SOA	3.16		0.206	157	-
250-500	263.71			57	78.8%
1-250	299.65			65	78.6%
>500	64.61			35	47.4%
Emotion Type	5.67		0.225	158	
Anger	112.09			53	53.6%
Happy	267.09			61	77.5%
Fear	174.21			23	87.4%
Sad	28.13			12	60.9%
Disgust	3.58			9	00.0%
Cue Source	36.54		0.0003*	159	
Static STOIC	5.85			4	43.6%
Radboud	30.72			31	02.4%
Karolinska	255.58			32	87.9%
Personal set	34.49			13	65.2%
NimStim	147.07			45	70.1%
Ekman	32.81			13	63.4%
3-D models (Gur)	9.8			4	69.4%
Chinese (Lu)	7.6			6	34.2%
FACES	31.84			7	81.2%
Canada (Beaupré)	4.47			2	77.6%
Fox (2002)	0			2	00.0%
Dependent variable	3.55		0.0595	158	
Response time	600.43			151	75.0%
N2pc	8.42			7	28.8%
Proportion of trials with a cue	611.79	0.004	0.948	159	80.9%
Response time	445.43	0.037	0.848	111	79.0%
Number of search locations	616.13	0.499	0.481	159	81.0%
Publication year	536.26	0.097	0.756	144	81.1%
Sample age	568.66	0.380	0.539	129	84.3%

Note. Q_b refers the between study heterogeneity and Q_w refers to within study heterogeneity. *p* refers to the *p* value – categorical and continuous moderators were random effects models. *Indicates significant moderation at $p < .001$.


A
Subgroup
Standardised Mean Difference
SMD [95%-CI]
SOA = 250-500
Random effects model
0.11 [0.03; 0.18]
SOA = 1-250
Random effects model
0.10 [0.04; 0.16]
SOA = >500
Random effects model
0.03 [-0.02; 0.09]
-1 -0.5 0 0.5 1
B
Emotion Type = Anger
Random effects model
0.07 [0.02; 0.12]
Emotion Type = Happy
Random effects model
0.08 [0.01; 0.15]
Emotion Type = Fear
Random effects model
0.20 [0.04; 0.36]
Emotion Type = Sad
Random effects model
-0.03 [-0.13; 0.08]
Emotion Type = Disgust
Random effects model
0.06 [0.02; 0.11]
-1 -0.5 0 0.5 1
C
DV type = Manual response time
Random effects model
0.08 [0.04; 0.12]
DV type = N2pc
Random effects model
0.21 [0.05; 0.38]
-1 -0.5 0 0.5 1

D

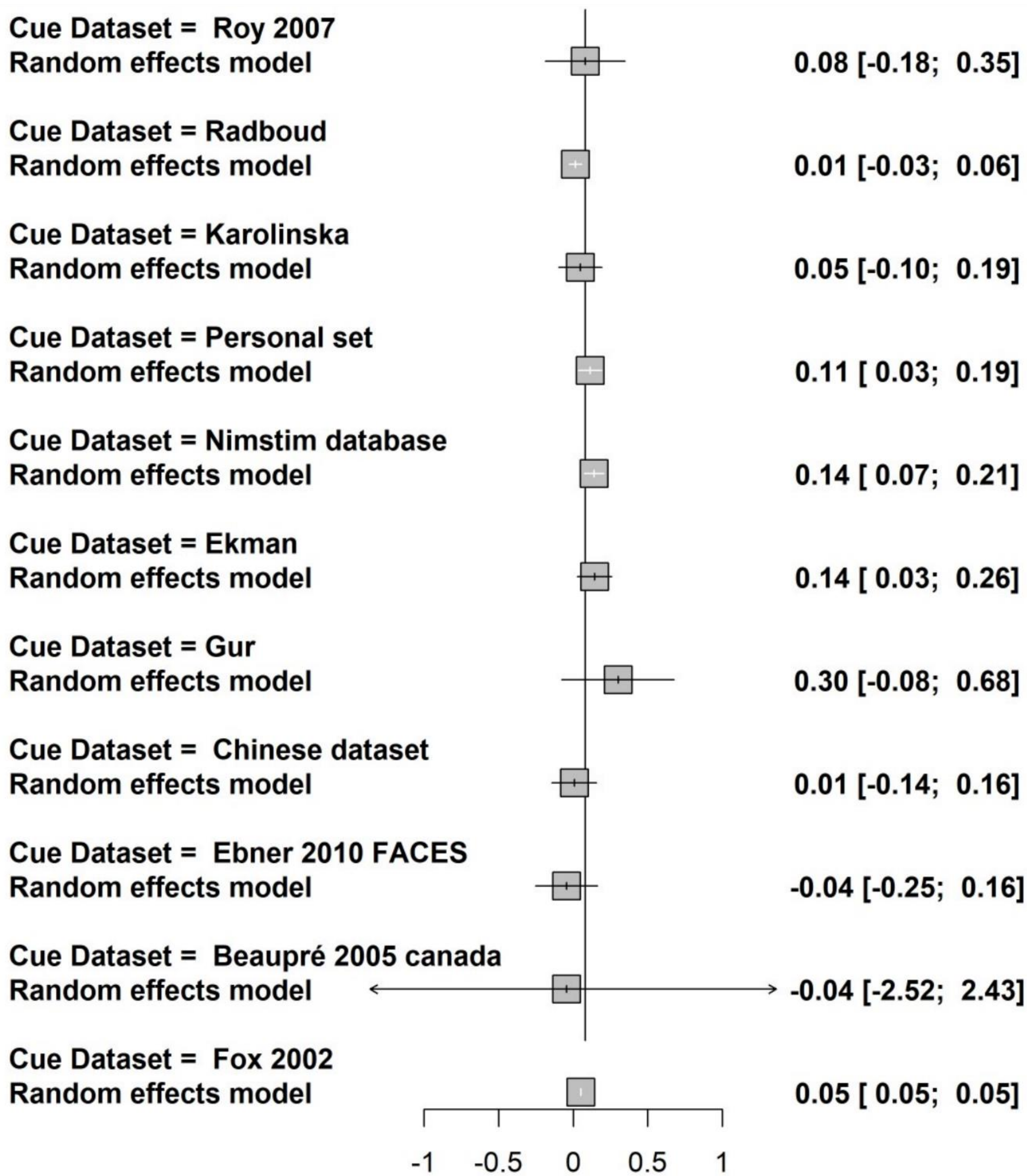


Figure 7. Sub-group effects for task-irrelevant attentional bias.
SMDs are hedges *g*, Stimulus Onset Asynchrony = SOA, Dependent Variable = DV. The solid vertical line is the overall effect. Each plot represents attentional bias towards emotional faces as a function of (A) the SOA between the cue and the target display. (B) the type of emotional expression. (C) the type of dependent variable used to measure attentional bias and (D) Dataset (database) from which the emotional faces (cues) were drawn.

Discussion.

Although the overall pooled effect was significantly greater than zero, warranting binary statements like “attention is biased for emotional faces,” such a statement would be misleading because the effect is very small. The raw overall attentional bias effect for *k* = 152 cases of RT based attentional bias was just 2.36 ms (a SMD of .0823). The hedge’s *g* in a meta-analysis that included attention bias to happy faces was .15 (Figure 5B of Pool et al., 2016), which is nearly double hedge’s *g* observed here. Upon inspection of Pool’s included cases, one especially large effect (above 2.0, Williams et al., 2005) should have been excluded because the facial expression was in fact task-relevant (it was the target object, not a distracting cue). This means that .15 is an overestimation, which is consistent with the overall effect of .08 obtained here for happy faces (and overall).

Most importantly, researchers should approach this small effect size with a practical mindset. A SMD of .0823 is much less than the recommended minimum .41 necessary to reach “practical” significance (Ferguson, 2009), meaning that the overall effect may not indicate much of anything. One perspective might be that attentional bias is not worth studying at all because it is so small. Also, studying such a small effect is not feasible for most labs because of the necessary sample size to achieve decent statistical power. A power analysis reveals that 1,161 participants would be needed to obtain the overall effect size observed here with 80% power, assuming a two-tail test of mean differences between two dependent means, and an alpha set to 0.05. The achieved power of a typical study in this meta-analysis (a sample size of 37, the median of the current meta-analysis) was just 7.7%.

Although some heterogeneity in the overall effect could have been explained by moderation, the only moderator to reach significance was dataset of facial expression of emotion (as shown in Figure 7D and Table 2). It is worth noting that the face dataset producing the largest effect – Gur et al. (2002) – were 3D renders of maximally expressive fearful faces. This could explain why this cue source showed the largest effect at .3 (k = 4); expressiveness is tied to arousal and ease of emotion perception (Jack et al., 2014; Lin et al., 2016, 2020). There was no moderation by paradigm. Only eight of the 160 cases used the additional singleton paradigm (g = .02), the rest used the spatial cueing paradigm (g = .09). Although the effect of SOA was non-significant (Figure 7A), cases with the longest SOA (greater than 500 ms) are nearest to zero, and the effect at the two shorter SOAs were numerically greater than the overall average effect, following the same pattern observed by Pool et al. (2016). In Figure 7B, fearful and sad faces deviated the farthest from the overall effect, but neither differed significantly. Figure 7C shows that attention bias is greater for N2pc than RTs (but non-significant). This is consistent with recent ERP reviews that find attention can be guided by task-irrelevant emotion (Y. Liu et al., 2020; Torrence & Troup, 2018).

Meta-analysis of SDM relevant attentional bias.

Cases of SDM relevant attentional bias for emotional faces (k = 25) were analyzed in the same manner as task-irrelevant attentional bias. A significant overall pooled effect of attentional bias for emotional expressions was obtained (g = .41); see Table 3 and the bottom of Figure 8. Between-study heterogeneity was estimated at Q = 110.77, $p < .001$, tau^2 = .115 [.067-.330]. This is also shown by the drapery plot in Appendix B. Although influential case removal is a rule of thumb when I^2 is greater than

50%, removing two outliers per a Baujat plot (Baujat et al., 2002, see Appendix B) did not cause a significant change in the overall effect or heterogeneity between cases (see Table 3), so no cases were removed.

Table 3. Change in overall effects by outlier and influential case removal

Analysis	Hedges *g*	95% CI	*p*	95% PI	I^2	95% CI
Main analysis	.414	.245 – .584	< .001	-.31 – 1.14	78.3%	68.5% – 86.1%
Cases removed	.374	.246 – .502	< .001	-.12 – .87	67.0%	48.9% – 78.6%

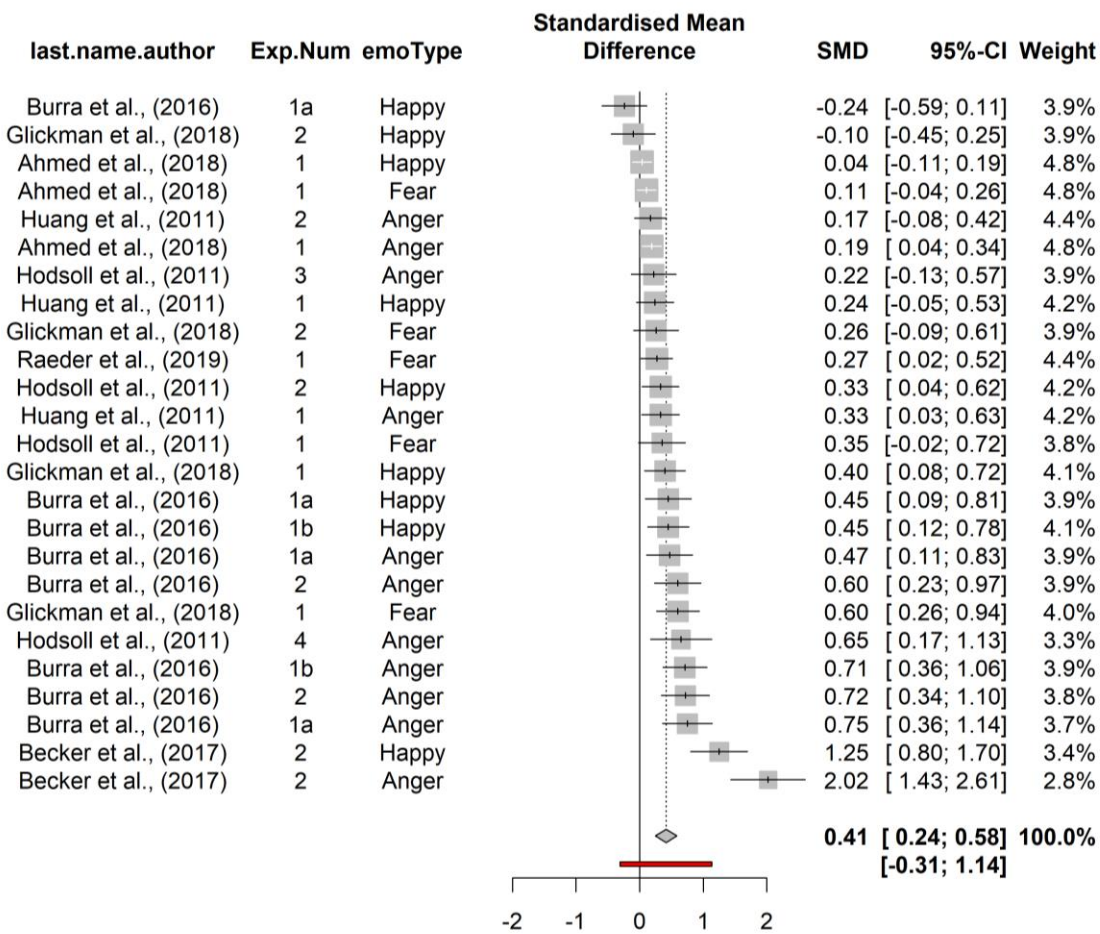


Figure 8. Forest plot of SDM relevant attentional bias for emotional faces

Discussion.

The overall effect for cases with SDM-relevance (*g* = .41) was greater than the overall effect for task-irrelevant attentional bias (*g* = .08); in fact, their 95% Confidence Intervals do not even overlap. But, given that SDM-relevant cases can be explained by their task-relevance (not just by the emotionality of the emotional face), they do not qualify as a measure of attentional bias. The same set of moderator analyses were performed on these cases. As for the meta-analysis of task-irrelevant attentional bias reported above, no moderation was observed (e.g., emotion type, $p > .05$). The overall effect (*g* = .41) is similar to the overall effect for personally relevant positively valenced cues, like bias towards food when you are hungry (hedge's *g* = .36, Pool et al., 2016). Perhaps, in general, one can expect relevant valenced cues to bias attention to roughly this degree.

Publication Bias

It is critical to examine publication bias because published records seldomly include null effects, meaning they are non-representative of an entire literature. There is high between-study heterogeneity ($I^2 > 75\%$) across all cases ($k = 185$), which means that measuring publication bias should be avoided (Peters et al., 2007). High between study heterogeneity could erroneously treat studies that deviate from the true overall effect as outliers when they may not in-fact be outliers. However, as a work-around to this issue, I used *dmetar's* (Harrer et al., 2019) *find.outlier*() as a brute force method for eliminating 45 outlier cases (based on values falling outside the 95% CI) from the original set of all cases. The heterogeneity between studies ($I^2 = 31.6\%$) for this sub-set of cases ($k = 140$) is suitable for a trim and fill analysis (a way to measure publication bias). A trim and fill analysis on this sub-set of cases produced six filled cases ($k = 146$). The original overall effect (combining both types of cases, *k* = 185) was .122, while the overall effect of the trim and fill analysis (*k* = 146) was .088 (see Table 5 and Figure 9). Such shrinkage indicates the presence of some publication bias. Note that the outlier removal used for the trim and fill analysis was quite aggressive (24% of all cases), potentially biasing the trim and fill analysis to show less publication bias than what may actually exist. The inclusion of some unpublished cases (*k* = 7) alleviates this concern some, but nonetheless publication bias estimation is an imperfect science (Harrer, 2022).

Table 4. Change in overall effects by outlier removal and trim & fill method

Analysis	**Hedges *g***	**95% CI**	***p***	**95% PI**	I^2	**95% CI**
Main analysis	.122	.081 – .163	<0.001	-.33 – .58	76.7%	73.2% – 79.7%
Trim and fill analysis	.088	.064 – .111	<0.001	-.06 – .24	36.7%	22.4% – 48.4%

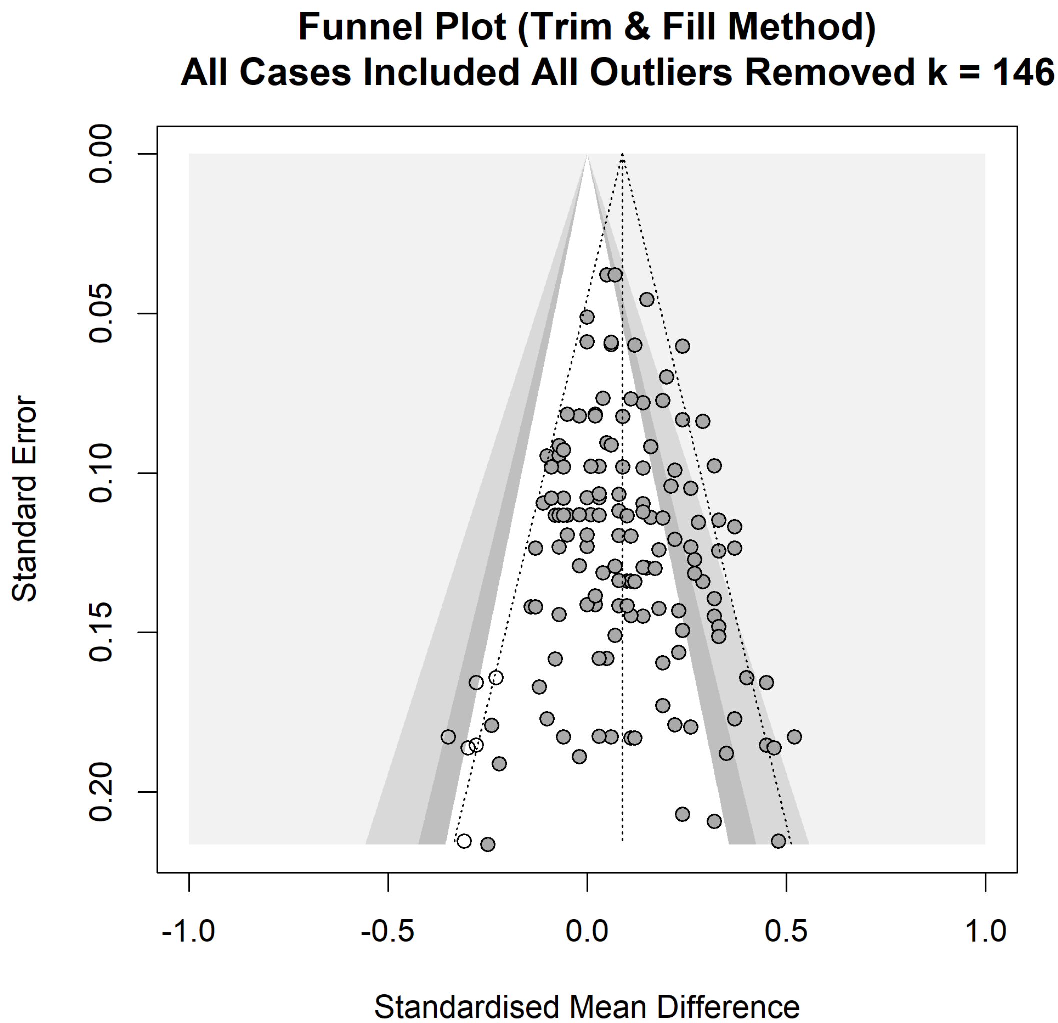


Figure 9. Funnel plot with a trim and fill procedure for all cases.
45 outlier cases were removed prior to the trim and fill procedure. Empty circles represent the six filled cases.

Conclusion

The purpose behind synthesizing studies on attentional bias for facial expressions of emotion in a meta-analysis was to assess the true overall effect size and to examine its potential moderation. I identified and removed SDM-relevant cases whereas previous reviews did not (Carretié, 2014). These cases of task-relevant attention bias were examined in a separate meta-analysis from cases of completely irrelevant emotion.

Attention bias for task-irrelevant facial expressions of emotion was significant, but the overall effect was very small (2.36 ms, g = .0823). Statistical significance for such small effect is not very meaningful because any effect can reach statistical significance when a sufficiently large sample is used (Sullivan & Feinn, 2012). Moreover, such small effects lack practical significance (Ferguson, 2009; Nakagawa & Cuthill, 2007). Some even suggest that such a small overall effect is meaningless (Sullivan & Feinn, 2012). No robust moderation of the overall effect was observed, further supporting the idea that attention is likely not biased for emotional faces.

Chapter 3: Infrequent Facial Expressions of Emotion do not Bias Attention

Although the cases of task-irrelevant attentional bias in Chapter 2 revealed a negligible overall effect, they share a common weakness that might have led to the wrong conclusion. Attentional bias can be modulated by the context in which task-irrelevant cues are presented. One factor previously shown to modulate attentional bias in a related literature is cue (scene) frequency. In a study with emotional scenes (like a car crash), Grimshaw et al. (2018) instructed participants to search for and identify a target letter (N or X) that appeared amongst several O's in a circular array. On some trials, either one erotic (positive-valance), one gruesome (negative-valance), or one landscape scene (neutral) was shown directly above or below the search array. The critical manipulation was the frequency of the scene: 25% vs. 75% of trials. Attentional bias was calculated by subtracting RTs for valenced cue (scene) trials from neutral cue trials. Grimshaw found greater bias when the cue was shown on 25% of trials than when it was shown on 75% of trials. Modulation of attentional bias by cue frequency has since been replicated (Micucci et al., 2019; but see also Zhao & Most, 2019). Similar modulation has also been observed for innocuous salient cues, such as abrupt onsets (Folk & Remington, 2015).

The modulation of attentional bias by cue frequency might explain the very small overall effect in Chapter 2. Less than 3% of all cases presented cues on less than 50% of trials. By virtue of their frequent presentation, participants likely came to expect emotional faces. Some potential mechanisms that could underly adaptation to these distracting cues are proactive control (Grimshaw et al., 2018), suppression (Gaspelin et al., 2015; Gaspelin & Luck, 2018), filtering (Kahneman et al., 1983; Micucci et al., 2019; Vecera et al., 2014; Wykowska & Schubö, 2011), and habituation (Codispoti et al., 2016;

Mazza et al., 2009). To date, no study has examined whether attention bias for facial expressions of emotion is modulated by cue frequency. In three experiments, cues were shown on an infrequent basis, making them less predictable and potentially more salient than if they were frequently shown. Perhaps the modulation of attention bias for emotional scenes by cue frequency will generalize to emotional face cues.

In each task, participants searched for a target letter. A task-irrelevant cue (one angry, happy, or neutral facial expression) was presented on only 25% of trials (the same frequency used by Grimshaw et al., 2018). On the remaining 75% of trials, no cue was shown. In Experiment 1, the cue was presented in the screen center (Figure 10). In Experiment 2, the cue was presented either above or below the search array, making its position less predictable. In Experiment 3, attention bias was assessed under different levels of task difficulty (low or high perceptual load (Lavie, 1995). Attentional bias for emotion is indicated by worse performance – slower RTs – on trials with an emotional face cue, relative to trials with a neutral face cue.

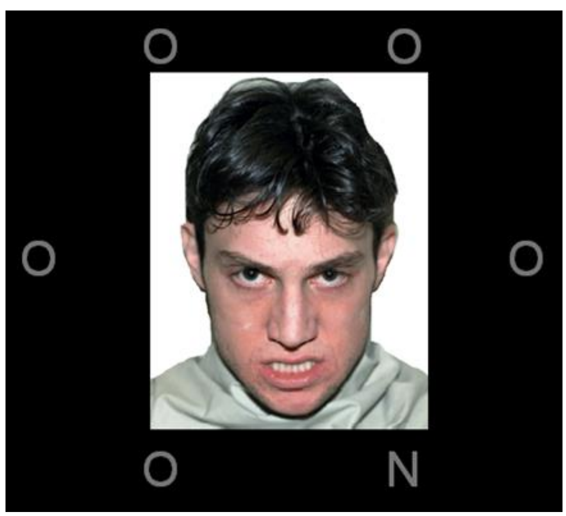


Figure 10. An example cue-present trial in Experiment 1.

Experiment 1

Methods.

31 University of New Mexico students participated in the study for course credit (10 male; mean age was 20.7 years, with a standard deviation of 4.0). This sample size was used for all of the experiments and was determined in advance based on similar studies (Experiment 7 of Puls and Rothermund, 2018). In all the present experiments, participants showed normal color vision (assessed by an Ishihara color vision test) and self-reported normal or corrected-to-normal visual acuity. The experiment was programmed in Matlab using the Psych Toolbox (Brainard, 1997) and presented on Dell M993 19-inch CRT monitors at a viewing distance of 60 cm.

Gray-colored stimulus letters were presented on a black background. Each trial began with a black screen that was presented for a randomly selected time between 200 ms and 600 ms. This blank screen was then replaced by a circular shaped search array of six evenly spaced letters (radius 5.7° based on an average viewing distance of 60 cm). Each letter subtended a visual angle of 0.85° x 1.0°. On each trial, one target (the letter X or N) was presented. The other five non-target letters in the search array were capital letter O's. The target identity and target location were randomly selected.

Participants indicated whether the target was an X or N by pressing a corresponding button ("X" or "N" on a standard QWERTY keyboard with their left and right pointer finger, respectively). The search array remained on the screen until a response was recorded or 2 seconds elapsed. On 25% of the experimental trials, a cue was presented. The cue was always a single image of a face, which had either a happy, angry, or neutral expression and drawn from the NimStim face database (Tottenham et al., 2009). Open mouth posed angry, happy, and neutral expressions for 10 different actors were chosen. Each face subtended a visual angle of approximately in 6.7° (width) x 8.6° (height). Face cues were randomly selected on each trial, with the restriction that they did not repeat from one trial to the next.

Each participant performed one practice block of 72 trials (not analyzed), then 13 experimental blocks of 72 trials (1008 trials in total). Error feedback (correct or incorrect) was provided at the end of each trial and a performance summary (average RT and error rate) was given at the end of each block.

Results and Discussion.

Every participant met our inclusion criterion of at least 85% accuracy. Trials in which the participant did not respond within 2 seconds (timeouts) were removed (less than 0.1%). For each participant and distractor type, trials with RTs greater than 3 standard deviations from the mean were removed from all analyses (1.6% of trials). Errors (4.0%) were removed from RT analyses. Mean RT and accuracy are shown in Table 1.

A repeated measures t-test confirmed that RTs were slower when a cue was present (581 ms) than when it was absent (541 ms), $t(30) = 13.78$, $p < .001$, $d_{rm} = .50$, 95% CI [.42, .57]. A corresponding cue presence cost was observed with accuracy as well; accuracy was lower when a face was present (95.6%) relative to when it was absent (96.2%), $t(30) = 2.35$, $p = .026$, $d_{rm} = 0.24$, [-.44, -.03].

Next, emotional cues were examined for cue present trials with a one-way repeated measures ANOVA, using the factor of facial expression type (angry, happy, neutral). This effect was non-significant both for RTs, $F(2,60) = 0.41$, $p = .280$, $\eta^2 p = .014$, and accuracy, $F(2,60) = 1.27$, $p = .287$, $\eta^2 p = .041$. Critically, a pre-planned t-test comparing angry and neutral facial expressions was non-significant for both RTs, $t(30) = 0.89$, $p = .383$, $d_{rm} = -.04$, [-.14, .05] and accuracy, $t(30) = -1.66$, $p = .107$, $d_{rm} = -.36$, [-.80, .09]. Similarly, pre-planned t-test comparing happy and neutral facial expressions

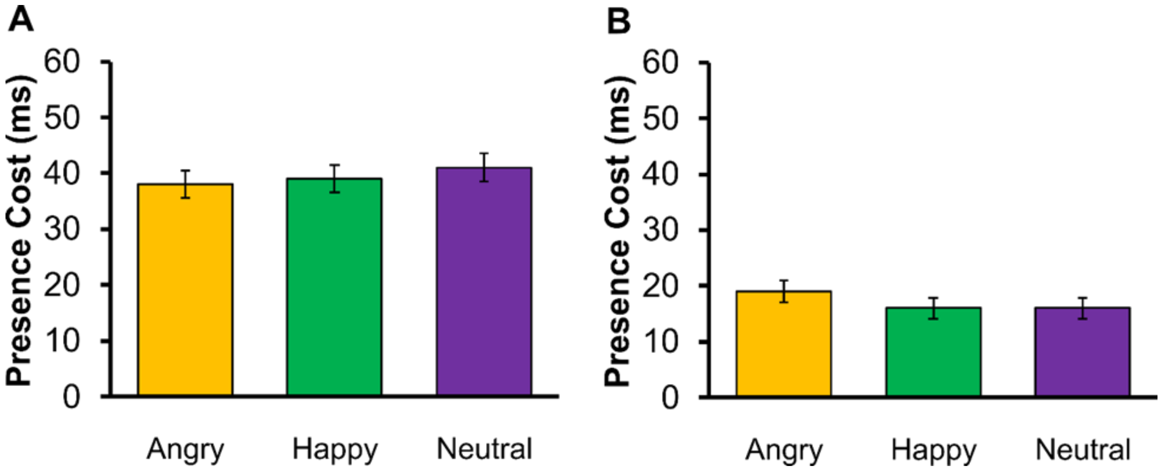


Figure 11. Results from Experiment 1 and Experiment 2.
(A) Experiment 1. (B) Experiment 2. Error bars represent ± Standard Error of the Mean (SEM).

Table 5. Results from Experiment 1 and 2

		Cue Type							
		Angry		Happy		Neutral		None	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Experiment 1	Response Time	582	131	583	134	585	136	544	123
	Accuracy	0.951	0.216	0.956	0.206	0.961	0.194	0.962	0.192
Experiment 2	Response Time	469	90	458	88	466	93	450	90
	Accuracy	0.945	0.227	0.934	0.249	0.947	0.224	0.938	0.241

Note. *M* and *SD* represent mean and standard deviation.

was non-significant for both response times $t(30) = -0.60$, $p = .551$, $d_{rm} = -.02$, [-.10, .05] and accuracy $t(30) = -0.90$, $p = .374$, $d_{rm} = -.16$, [-.51, .19]. Results are shown in Figure 11.

In Experiment 1, infrequently presented facial expressions of emotion were unable to bias attention. This is unlike studies with infrequent emotional scenes

(Grimshaw et al., 2018; Micucci et al., 2019). One potential explanation is that emotional face cues lack sufficient salience to bias attention.

Experiment 2

Experiment 2 extends Experiment 1 by making cues even more unpredictable, potentially boosting their salience. In Experiment 1, the face cue always appeared in the center of the search array, whereas in Experiment 2 the face cue could appear either above or below the search array. The lack of predictability of the cue's location might make them more difficult to filter out or suppress. Note that this condition is very similar to that of Grimshaw et al. (2018), who observed attentional bias from infrequent emotional scenes.

Methods.

All methods were the same as Experiment 1 except where noted. 31 University of New Mexico students participated in the study for course credit (12 male, 22.5 years of age, 7.1 standard deviation). One practice block of 48 trials was discarded from all analyses. 16 experimental blocks with 48 trials each (816 total trials) were analyzed. In the search array, the radius between the center of a letter and the center of the screen subtended a visual angle of .95°. The inside edge of the cue subtended 7.0° from the center of the screen.

Results and Discussion.

Data analysis closely followed that of Experiment 1. Trials in which the participant did not respond within 2 seconds (timeouts) were removed (0.1%). Trials with RTs greater than 3 standard deviations from the mean were removed from all analyses (1.4% of trials). Errors (6.1%) were removed from RT analyses. First, the overall presence cost of the cues on RT was examined. A repeated measures t-test confirmed that RT was indeed slower when a cue was present (464 ms) than when it was absent (450 ms), $t(30) = 9.98$, $p < .001$, $d_{rm} = .29$. No corresponding presence cost was observed on accuracy; face present trials (94.2%) were not statistically different from face absent trials (93.8%), $t(30) = 1.15$, $p = .260$, $d_{rm} = 0.14$.

Next, the presence cost of the cue across facial expression type (angry, happy, neutral) in a one-way repeated measures ANOVA. Replicating Experiment 1, this effect was non-significant both for RT, $F(2,60) = 1.37$, $p = .261$, $\eta^2 = .044$, and accuracy, $F(2,60) = 0.842$, $p = .436$, $\eta^2 p = .027$. Critically, a pre-planned t-test comparing angry and neutral facial expressions was non-significant both for RT, $t(30) = 0.39$, $p = .699$, $d_{rm} = 0.03$, [-.12, .18] and accuracy, $t(30) = 0.39$, $p = .699$, $d_{rm} = -0.09$. Similarly, a pre-planned t-test comparing happy and neutral facial expressions was non-significant for both RT, $t(30) = 1.22$, $p = .230$, $d_{rm} = -0.09$, [-.23, .05] and accuracy, $t(30) = 1.15$, $p = .258$, $d_{rm} = -0.27$. Results are shown in Figure 12.

One possibility is that participants began suppressing the emotional faces over time. Examining attention bias across blocks of the experiment might reveal this pattern. According to a one-way ANOVA, there effect of block on attention bias for happy expressions, $F(12, 390) = .60$, $p = .844$, $\eta^2 = .018$, or angry expressions, $F(12, 390) = 1.40$, $p = .163$, $\eta^2 = .041$. There was also no trend towards a decrease in attentional bias across blocks.

In Experiment 2, emotional face cues could appear in one of two possible locations, like the emotional scene cues used in Grimshaw et al. (2018). This change made the location of the cues less predictable than in Experiment 1. But, despite their infrequent occurrence and unpredictable location, no significant attentional bias effect for angry or happy facial expressions of emotion was observed.

Experiment 3

Experiment 3 further extends the two previous studies with a related study on the presence cost for angry and happy expressions shown under high or low perceptual load. In Experiment 2 of Gupta et al. (2016), participants completed a very similar task to Experiment 1 of the current study. A target letter (X or N) was presented in a circular

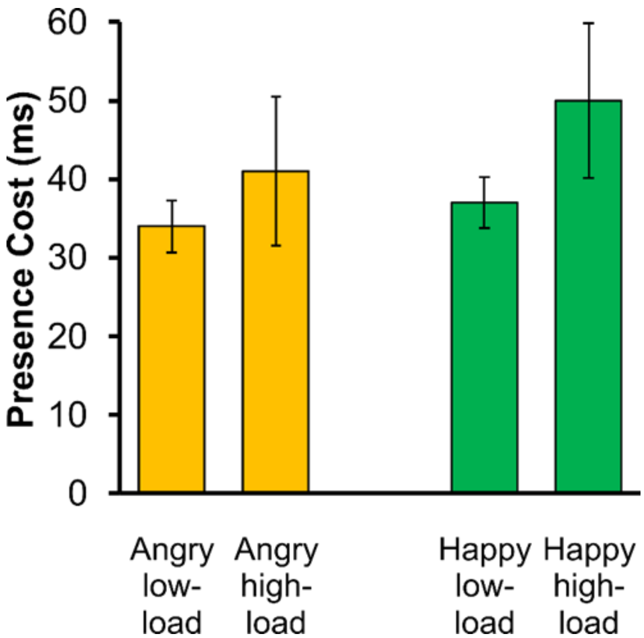


Figure 12. Results for Experiment 3. Presence cost separated by type of facial expression of emotion and perceptual load.

Table 6 Results for Experiment 3

		Cue Type					
		Angry		Happy		None	
		M	*SD*	*M*	*SD*	*M*	*SD*
Low Perceptual load	Response Time	562	121	565	122	528	117
	Accuracy	0.955	0.207	0.962	0.190	0.952	0.212
High Perceptual load	Response Time	955	324	964	330	914	321
	Accuracy	0.950	0.219	0.933	0.249	0.948	0.222

array of other distractor letters. Inside this circular array, a face appeared on 25% of all trials (making it one of the only studies with infrequently presented face cues, see also

Sigurjonsdottir et al., 2015). In the low perceptual load condition, non-target letters were capital letter O's (as they were in our experiments and others, Grimshaw et al., 2018; Micucci et al., 2019), and in the high-load condition, non-target letters were a random set of unique capital letters.

Interestingly, Gupta et al. (2016) observed a presence cost for angry faces shown under low perceptual load, but not under high perceptual load. But for happy faces, a presence cost was observed in both perceptual load conditions. The lack of a presence cost for infrequently presented angry faces shown under high perceptual load is a highly unique effect in the literature. So, in Experiment 3, we included both high and low perceptual load, closely following Gupta.

Methods.

All methods were the same as Experiment 1 except where noted. 31 participants (12 male) with 19.3 years of age (1.1 SD) completed the experiment. In the low load condition, the distractors in the search array were all capital letter "O"s (as in Experiments 1 and 2). In the high-load condition, the distractors consisted of the letters H, K, W, M, Z. Load was manipulated by block; high load trials occurred in even blocks; low load occurred in odd blocks. Following Gupta et al.'s (2016) design, no neutral face condition was used.

Results and Discussion.

Trials in which the participant did not respond within 2 seconds (timeouts) were removed (1.0%). Trials with RTs greater than 3 standard deviations from the mean were removed (1.2% of trials). Error trials (4.9%) were removed from all RT analyses, mean RT and accuracy are shown in Table 2. First, we assessed the effect of distractor presence (present or absent) and load (high and low) on mean RTs. The interaction between distractor presence and load was not statistically significant $F(1, 120) = .114$, $p = .736$. There was a significant main effect of distractor presence, $F(1, 120) = 6.69$, $\eta^2p = .05$, $p = .011$; RTs were faster when the distractor was absent ($M = 721$ ms) rather than present ($M = 763$ ms), $t(61) = 10.69$, $p < .001$, $d_{rm} = .19$. The main effect of load was also significant $F(1, 120) = 598.08$, $p < .001$, $\eta^2p = .83$; RTs were slower in the high-load condition ($M = 939$ ms) than the low-load condition ($M = 546$ ms), $t(61) = 34.21$, $p < .001$, $d_{rm} = 3.51$. A corresponding ANOVA with mean accuracy rates revealed neither a significant main effect of load, $F(1, 120) = 2.94$, $p = .089$, nor a main effect of distractor presence, $F(1, 120) = .001$, $p = .979$, nor a significant interaction between load and distractor presence $F(1, 120) = .83$, $p = .366$.

Next, we calculated the presence cost of the distractor by subtracting the distractor absent trials from distractor present trials for each participant. Presence cost was entered into a 2x2 ANOVA with the factors of load (high and low) and distractor type (happy and angry faces). A significant main effect of load was found, $F(1, 120) = 548.79$, $\eta^2p = .82$, $p < .001$. However, the main effect of distractor type was not significant, $F(1, 120) = .157$, $p = .692$; angry distractors ($M = 563$) and happy distractors ($M = 564$) did not differ significantly. $t(30) = .33$, $p = .743$, $d_{rm} = -.03$, [-.19, .14]. The interaction between load and distractor type was also non-significant, $F(1, 120) = .10$, $p = .759$. Critically, we failed to replicate Gupta et al. (2016); the presence cost for angry was not significantly different between the high and low load conditions, $t(30) = 1.26$, $p = .218$, $d_{rm} = .10$, [-.25, .06].

A corresponding ANOVA with mean accuracy revealed a non-significant interaction between load and distractor type, $F(1, 120) = 1.94$, $p = .167$. There was also a non-significant main effect of load, $F(1, 120) = 3.60$, p = .060, and distractor type. $F(1, 120) = .32$, $p = .573$. Also, the difference between angry ($M = .95$) and happy ($M = .93$) in the high load condition was non-significant, $t(30) = -1.91$, $p = .066$, $d_{rm} = .31$.

No difference in the presence cost between happy and angry facial expressions under low perceptual load was found, replicating Experiment 1. We also found no significant difference in the presence cost between angry and happy face distractors under high load, contrary to Experiment 2 of Gupta et al. (2016). Overall, the presence cost for angry and happy faces did not change based on perceptual load.

Discussion

In Chapter 3, I pursued an explanation for the lack of attentional bias found in the meta-analysis of Chapter 2: emotional faces were suppressed and therefore unable to bias attention because they were presented on the majority of trials. The salience of frequently presented cues may diminish over time because they are predictable; the representations of emotional concepts or objects like faces could become saturated, weakening the bottom-up influence of emotion. Indeed, emotional scenes show greater bias when they are infrequently presented (Grimshaw et al., 2018; Micucci et al., 2019). Grimshaw et al. argued this was the outcome of less proactive control, and Micucci et al. suggested a similar account. The assumption is that, by making emotional face cues rare, participants would be less likely to suppress them or habituate to them. Perhaps this modulation of attentional bias by cue frequency found for IAPS images generalizes to facial expressions of emotion.

Yet, across all three experiments, angry and happy facial expressions were unable to bias attention to a greater extent than neutral expressions, despite being shown infrequently (25% of trials, rather than 100%). This was the case no matter the location of the cue; cues presented inside the search array (Experiment 1) or randomly above or below it (Experiment 2) were unable to bias attention. In Experiment 3, we followed the same procedure as Experiment 1, but eliminated the neutral face condition and added a condition with high perceptual load (following Gupta et al., 2016). Some have argued that distraction is higher for cues shown under low perceptual load because unused attentional resources are naturally allocated towards them (Lavie, 1995). Yet, others have instead reported that high perceptual load increases distraction (Bretherton et al., 2020; Bunford et al., 2017; Foster, 2013; Holmes et al., 2014a; Mitchell et al., 2007). In any case, in Experiment 3, the presence cost for angry and happy faces did not differ under low or high perceptual load (for results, see Figure 12).

Conclusion

Chapter 2 revealed that task-irrelevant facial expressions of emotion are virtually unable to bias attention. However, these studies presented emotional expressions on a high percentage of trials (often 100%), which might have encouraged participants to suppress them. In the current chapter, emotional faces were presented on a small minority of trials, in predictable (Experiment 1) and unpredictable locations (Experiment 2) and shown under differing perceptual loads (Experiment 3). By ruling out the possible modulation of attentional bias for emotional faces by cue frequency, researchers can be more confident that attentional bias for emotional faces is a very small, near zero effect that is often non-existent.

Chapter 4: No Attentional Bias for Attended Emotional Faces

Chapter 2 and 3 revealed that unattended, completely task-irrelevant emotional faces are unable to bias attention. Chapter 4 addresses a slightly different research question: Can a face showing a facial expression of emotion bias attention if that face is already being attended? For example, suppose you are having a conversation with someone face to face. Maintaining the conversation requires your sustained attention towards this individual (Behrens & Kret, 2019; Jack & Schyns, 2015), which means you likely have the top-down goal to perceive and attend to their face. Suppose someone else walked past you during the conversation. Your current top-down goal for faces likely means that you would attend to this individual. If the individual was displaying a facial expression of emotion, would they bias your attention more than if they were displaying no expression (neutral)?

An easy way to ensure a face is attended is to make faces task-relevant. This is exactly what occurred in cases with SDM relevance in Chapter 2. Emotional faces were singleton objects, as were targets, making the emotional faces task-relevant. The meta-analysis of SDM relevant cases revealed that emotional faces are able to bias attention when attended. So why would I care to ask this question if there is already an answer?

The reason is that the question is actually still open. All studies with SDM relevant attentional bias in Chapter 2 were confounded. Only emotional faces were shown as singletons, so only emotional faces could have SDM relevance. Neutral faces were never shown as singletons, therefore they never had SDM relevance. Neutral faces were always non-target objects (as shown in Figure 3). The proper way to measure attentional bias is to obtain the presence cost for an emotional and neutral face separately, and then test their difference.

In Chapter 4, I accomplished this proper assessment of attentional bias for attended emotional faces (i.e., emotional faces that have SDM relevance). In two Experiments, participants searched for a singleton target, and faces (neutral or emotional) were shown as an additional singleton (as shown in Figure 13). Participants were encouraged to search for and identify targets with SDM; targets were located by searching for the uniquely oriented oval a search array (the oval tilted to the right or left). The target was the only tilted oval in the display, meaning that it had a unique (singleton) orientation relative to the non-target objects. Face singletons were either shown within the target display (Experiment 1) or in a precue display (Experiment 2). If no attentional bias for emotion is observed, it would indicate that even when faces are attended, emotion is unable to further modulate spatial attention.

Experiment 1

Methods.

31 University of New Mexico students participated in the study for course credit (12 male; mean age was 18.4 years, with a standard deviation of .8). All apparatus and participant screening was the same as the experiments in Chapter 3.

Each trial began with a black screen for 500 ms. This blank screen was then replaced by a circular shaped search array of six oval shapes. Each oval shape subtended a visual angle of 7° x 3.8°. On each trial, one of the oval shapes was oriented to the right or left by 22° from a vertical upright position. The other five oval shapes were shown in an upright vertical position (as shown in Figure 13). Participants indicated whether the target oval was tilted to the left or right with a corresponding X or N keypress ("X" or "N" on a standard QWERTY keyboard with their left and right pointer finger, respectively). The search array remained on the screen until a response was recorded. On each trial, one of the ovals (the additional face singleton) was filled with a neutral or an angry facial expression of emotion and shown in a randomly selected location. The fill of the other five ovals (the five other oval objects) were images of the same random household object. These fills were randomly selected from 8 possible household objects (e.g., a pumpkin, or a vase).

Face cues were drawn from the NimStim face database (Tottenham et al., 2009). Open mouth posed angry, happy, and neutral expressions for 10 different actors were chosen. Each face subtended a visual angle of approximately in 6.7° (width) x 8.6° (height). Face cues were randomly selected on each trial, with the restriction that they did not repeat from one trial to the next. The images of facial expressions were cropped so they would fit in perfectly with the oval shape. All images were converted to grayscale. Each participant performed one practice block of 72 trials (not analyzed), then 13 experimental blocks of 72 trials (1008 trials in total). Error feedback (correct or incorrect) was provided at the end of each trial and a performance summary (average RT and error rate) was given at the end of each block.

Results and Discussion.

Every participant met our inclusion criterion of at least 85% accuracy. Trials in which the participant did not respond within 4 seconds (0.3 % of all trials) were removed from all analyses. For each participant and distractor type, trials with RTs greater than 3 standard deviations from the mean were removed from all analyses (2.0% of all trials). Trials with an incorrect response (1.8%) were removed from RT analyses.

The overall presence cost of emotion was non-significant; a paired samples t-test on overall RTs with angry and neutral cues did not show slower responses on angry trials

(665 ms, 113 ms SD) than neural face trials (664 ms, 111 ms SD) $t(30) = 0.19$, $p = .851$, $d = .03$, see Figure 16 for results. Cue validity did not interact with cue type; cue validity scores for angry (-29 ms, 55 ms SD) were not different from cue validity scores for neutral (-34 ms, 49 ms SD) $t(30) = 0.64$, $p = .626$, $d = .12$. Note that the negative cue validity effects in Experiment 2 reflects the same location cost of irrelevant cues and targets (Folk et al., 2008).

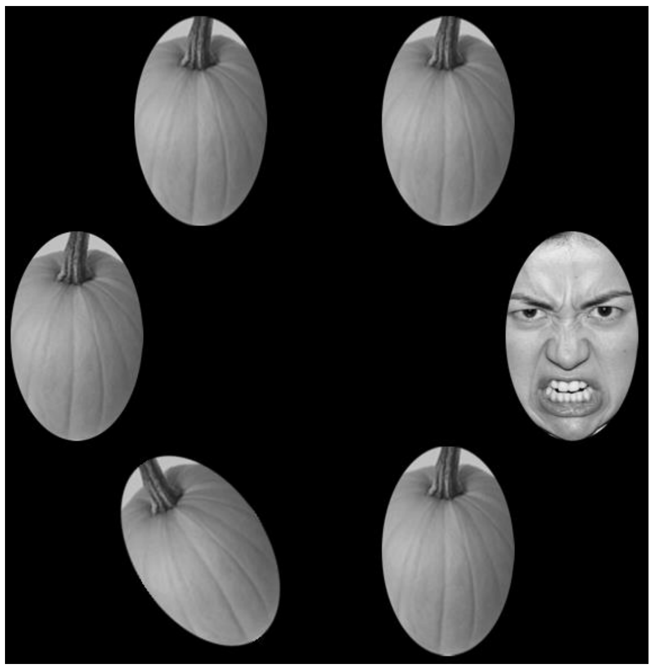


Figure 133. Example of a precue display in Experiment 1.
The example shown is an invalid angry trial. The pumpkin fill (oval) in the lower left tilted to the left is the target, the angry fill to the right is the face singleton.

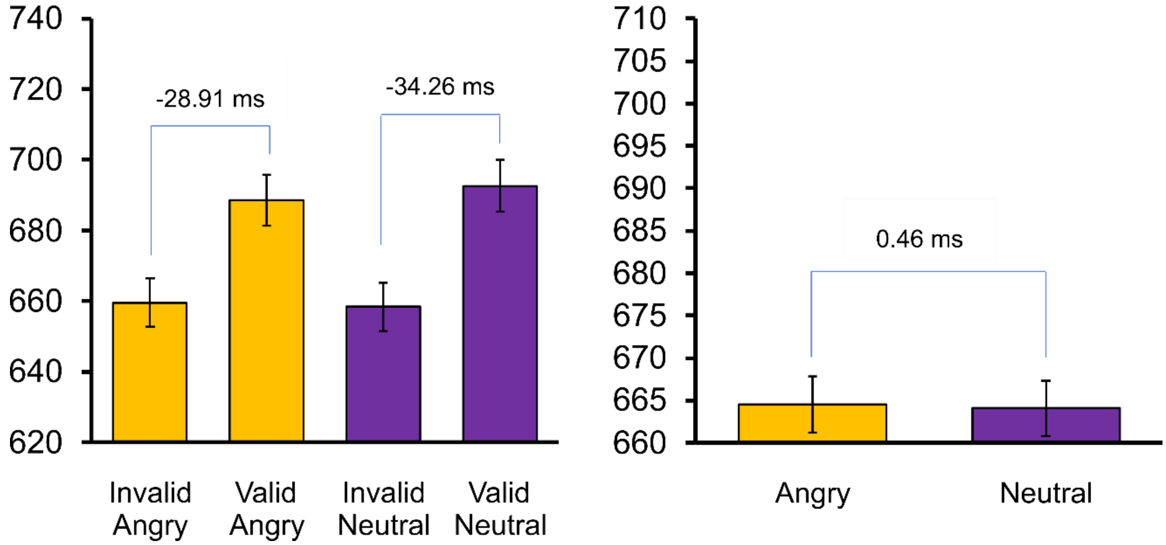


Figure 144. Results from Experiment 1.
Left: Response times in ms for angry and neutral oval filled trials as a function of cue validity. Right: the overall response times on trials with angry or neutral filled ovals.

Experiment 2

Experiment 2 followed up on Experiment 1 by presenting face singletons in a precue display (as in the dot-probe paradigm), not in the search display as an additional singleton. Precue displays have the benefit of presenting cue objects in an array that is sperate from the target array, diminishing the competition between the cue and the target. This could boost the capacity for the emotional face singletons to bias attention towards itself.

Methods.

31 University of New Mexico students participated in the study for course credit (9 male; mean age was 19.5 years, with a standard deviation of 3.3). Everything was the same as Experiment 1 except for the following.

Each trial began with a black screen for 500 ms, followed by a precue display containing a circular shaped array of six ovals. On each trial, one of the ovals was filled with a neutral or an angry facial expression of emotion. The location of the filled oval was randomly selected. The five other ovals were filled with the same random object, all six ovals had the same upright orientation (as shown in Figure 15). After 100 ms, the precue display disappeared and was replaced by a search array of six oval objects. Each of the oval objects were filled with the same random object. The random object fill in the precue display was always different than the random object fill used in target display. One of the ovals in the search array was tilted to the right or the left by 22° – this was the target. Each participant performed one practice block of 144 trials (not analyzed), then 9 experimental blocks of 144 trials (1440 trials in total).

Results and Discussion.

Every participant met our inclusion criterion of at least 85% accuracy. Trials in which the participant did not respond within the timeout period of 4 seconds (0.2 % of all trials) were removed from all analyses. For each participant and distractor type, trials with RTs greater than 3 standard deviations from the mean were removed from all analyses (1.9% of all trials). Trials with an incorrect response (2.0%) were removed from RT analyses.

To assess the overall presence cost of emotion, a paired samples t-test was conducted on overall RTs. Angry and neutral cues significantly differed from each other; responses were slower on angry face trials (M = 703 ms, SD = 160 ms) than neutral face trials (M = 696 ms, SD = 158 ms), $t(30) = 2.27$, $p = .031$, $d = .41$, see results in Figure 14. The location of the singleton was randomly selected, which means that it was the target on 1/6 of trials. Attentional bias for attended emotional faces can also be measured by the interaction between cue validity (invalid vs. valid) and type of singleton (angry vs. neutral). Like the spatial cueing studies in Chapter 2, cue validity scores (invalid RT minus valid RT) were computed for each cue type and compared in a paired t-test. Angry cue validity scores (*M* = 71 ms, *SD* = 51 ms) were not larger than neutral cue validity scores (*M* = 71 ms, *SD* = 50 ms) $t(30) = 0.05$, $p = .959$, $d < .01$.

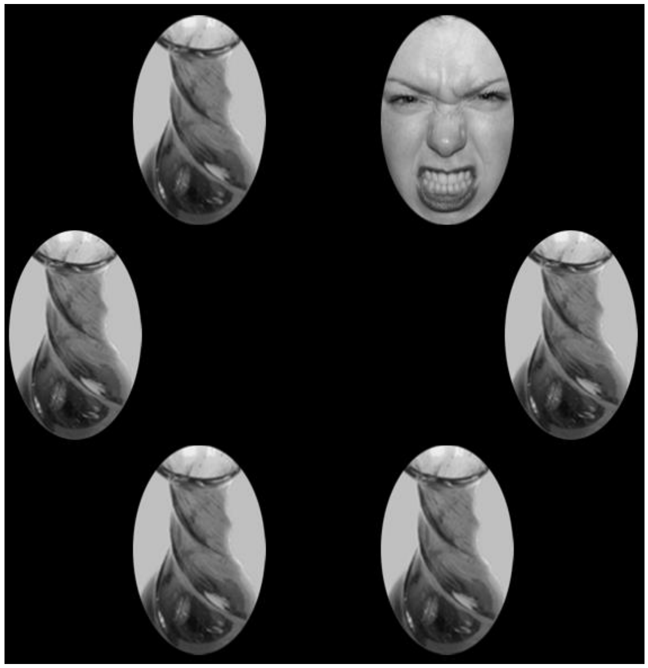


Figure 155. An example search array from Experiment 2.
This display would appear for 100 ms and be replaced by a search array that looks like Figure 13, except with no face singleton.

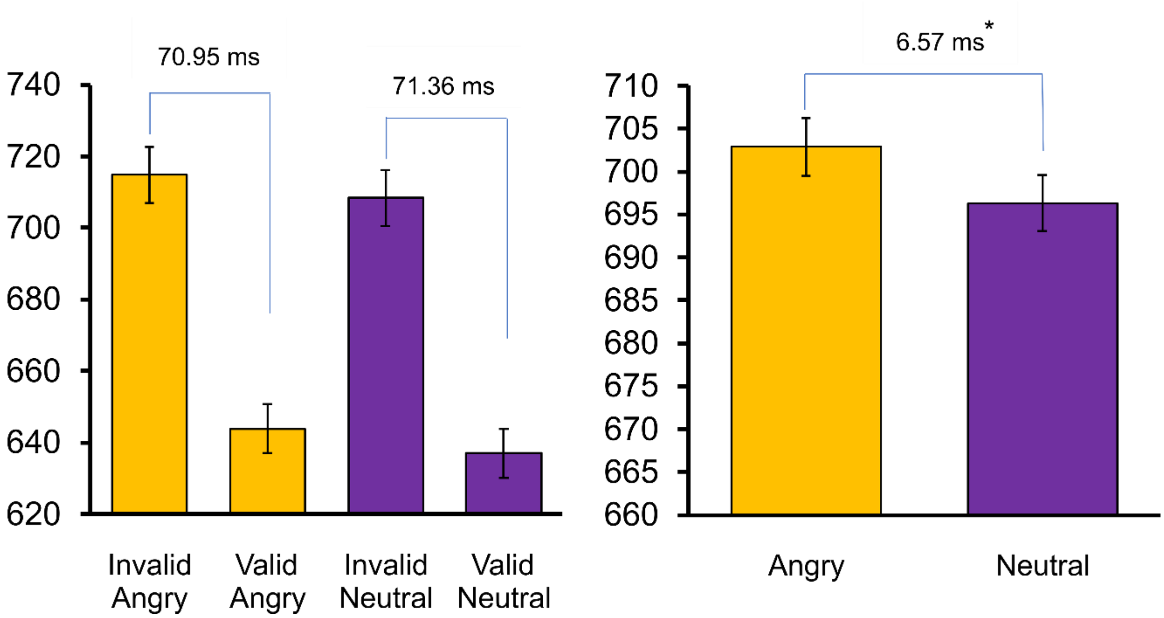


Figure 166. Results from Experiment 2.

Left: Response times in ms for angry and neutral oval filled cues as a function of cue validity. Right: the overall response times on trials with angry or neutral face singletons. Error bars represent standard error of the mean, *= $p < .05$.

In conclusion, there was an overall presence cost for emotional faces (6.57 ms), indicating attentional bias for attended emotional faces. But there was no cue validity by face type interaction, indicating that attention was not specifically drawn to the location of the emotional face and unable to bias attention (see the General Discussion for more information).

Conclusion

Cases of SDM relevant attentional bias for emotion in Chapter 2 assessed attention bias by examining the cost of emotional cue presence. However, these studies did not have a proper control condition for measuring attentional bias because the neutral faces were never SDM relevant. The studies in the current chapter addressed this issue; emotional face singletons were compared to neutral face singletons (as shown in Figure 13).

In two Experiments, attention bias was measured by the overall presence cost of emotion and its interaction with cue validity. Only one out of these four tests of attentional bias reached significance, indicating that SDM relevant attentional bias for emotion is unreliable One conclusion from the current chapter is that even attended emotional faces are unable to bias attention. But there are several plausible explanations for null attentional bias for attended emotional faces.

It is typical for an additional singleton study to present additional singletons (cues) only on half of all trials. Here, additional singletons were shown on every trial, which could have attenuated the salience of the singleton and consequently the level of attentional bias (see the General Discussion for more details on salience and attentional bias). Another explanation is that these studies were underpowered. The true effect size of attentional bias for attended emotional faces is likely to be small (as shown in Chapter 2 and 3); all attentional bias effects are the outcome of an interaction (see the General Discussion). Also, it is hard to predict the expected effect size because this study is a first of its kind. Note that this issue of power applies to Chapter 3 as well. In sum, although emotional faces with SDM relevance were presumed to bias attention, here we did not find that to be the case.

Chapter 5: General Discussion

Important, salient emotional events can guide attention and evoke emotional responses from those who are subjected to them. Such events are often accompanied by facial expressions of emotion, such as anger or happiness. The act of producing an emotional expression is in itself a signaling mechanism wielded by humans for the purpose of survival (Cowen & Keltner, 2020; Darwin, 1872; Susskind et al., 2008), and pro-social communication (Cowen et al., 2020; Jack & Schyns, 2015). There is a high degree of importance placed on perceiving emotion in another individual's face; emotional faces are often accompanied by matters of personal importance. Researchers have therefore assumed that task-irrelevant emotional faces should override ongoing goal-directed thoughts and actions (for reviews, see Carretié, 2014; Pool et al., 2016).

It is surprising, then, to find the literature to be so contradictory. Many authors observed support for the idea (e.g., Eimer & Kiss, 2007), yet many others did not (e.g., Puls & Rothermund, 2018). In hopes of finding a resolution to this issue, I conduced a systematic review of the literature on attentional bias for emotional faces in Chapter 2 and found a significant yet very negligible overall raw effect of just 2.36 ms (*g* of .0823). Furthermore, in Chapter 3, I could not find attention bias even with infrequent cue presentation. In Chapter 4, I found that even emotional cues with SDM relevance are unable to reliably bias attention more than neutral cues with SDM relevance.

The standard hypothesis and emotion automaticity

The lack of attentional bias for emotional faces can be better understood by more closely examining the ideas and the research behind the standard hypothesis (Pessoa & Adolphs, 2010) and emotion automaticity (Palermo & Rhodes, 2007). These topics are intertwined and are often used as the logical basis for assuming that attention should be biased by emotional faces. Critical viewpoints of the standard hypothesis and emotion automaticity could inform how and why attention is not biased for emotional faces.

Support for the standard hypothesis.

According to the standard hypothesis, there exists an innate, universal *perceptual knowledge* of valenced information (Compton, 2003; Pourtois et al., 2013). Such cemented information is caused by survival-related adaptations to process emotion faster and with greater accuracy (Mobbs et al., 2015). Over time, a dedicated sub-cortical threat module was shaped by the need to parse coarse low-level valence related information (Burra, Hervais-Adelman, et al., 2017; Koller et al., 2019; Öhman & Mineka, 2001; Tamietto & de Gelder, 2010). This sub-cortical module enables fearful faces shown below conscious awareness to be located faster than neutral ones (for a review, see Hedger et al., 2016). It also may explain other forms of emotion automaticity like how emotional expressions can be processed in parallel with ongoing task demands (Maxwell, et al., 2021; Shaw et al., 2011). It can also explain how searching for emotional faces is highly efficient; an emotional face target guides preattentive search (e.g., face in the crowd effects; see Frischen et al., 2008 for a review).

Further support for the standard hypothesis comes from studies of differential processing within the sub-cortical threat module (circuit). For example, in one study, Cushing et al. (2019) instructed participants to identify face images of neutral and fearful expressions with direct or averted gaze. Images were biased to either magnocellular or parvocellular pathways based on their visual characteristics. The magnocellular pathway is more sensitive to fearful faces with averted gaze (a "clear threat" signal) than the parvocellular pathway is to fearful faces with direct gaze (a "ambiguous threat" signal).

In sum, at very early stages of visual processing, the meaning of a fearful facial expression can be comprehended (note that fearful faces were not used in Chapters 3 and 4). This is quite remarkable – the retina can detect threat related information (Cushing et al., 2019).

Opposition to the standard hypothesis.

However, the standard hypothesis encourages an overly simplistic viewpoint that emotion automaticity is caused by the sub-cortical module. Newer perspectives can explain more of the nuances to emotion-related processing in the brain. Take the Multiple Attention Gain Control (MAGiC) model (Pourtois et al., 2013) for example. MAGiC is based on the premise that non-overlapping amplification mechanisms such as voluntary attention to emotion and involuntary attentional bias are influenced by emotional faces. These systems subsequently modify perception, biasing subsequent actions like the allocation of spatial attention. Since these mechanisms work through similar sensory pathways, they can interact. One critical place in which such interactions occur is in the amygdala.

The amygdala's role in the processing of emotional information is nuanced. According to the standard hypothesis, the amygdala is the centerpiece of the modular system for emotion automaticity (Tamietto & de Gelder, 2010). Yet that perspective has been slowly replaced by studies that detail the unique functions of the many sub-components (nuclei) of this region. To quote a review on the amygdala, Whalen (2009) said on page 500 that "Higher amygdala activity can precipitate, but might not necessarily dictate, a change in your emotional state".

The amygdala is sensitive to many different types of input, like reward learning (Murray, 2007), and even innocuous object perception like direct gaze from neutral faces (Burra et al., 2013). Yet reactivity in this region to incoming information does not always indicate a causal relationship. Self-organized activity and input from other networks relay information to the amygdala at different stages of processing. So, although emotional stimuli shown below awareness reliably evoke amygdala activity, the origin of such responses is not straightforward (as shown in Figure 1 of Diano et al., 2017). Also, the temporal dynamics of amygdala reactivity can be split into early and late stages of processing. In the early stage, activation begins as soon as 74 ms post-stimulus onset (of a fearful expression, measured in-vivo, see Méndez-Bértolo et al., 2016). In a later stage, activity begins around 500 ms post-stimulus onset (Rothstein, 2010). An alternative view of the amygdala – and its 12 nuclei – is that it works as a coordination hub for emotion processing (for reviews, see Gothard, 2020; Pessoa, 2005, 2008; Pessoa & Adolphs, 2010; Pourtois et al., 2013). A more appropriate viewpoint is that the dedicated sub-cortical module cannot by itself explain emotion automaticity. The cortex has a powerful role in enabling and preventing emotion automaticity (Maratos & Pessoa, 2019; Müri, 2016).

Careful considerations for emotion automaticity.

It is challenging to delineate the contributions of automaticity versus non-automatic processing in non-conscious emotion perception (for reviews on automaticity, see Moors & De Houwer, 2006; Posner & Petersen, 1990). For example, fearful faces shown under conscious awareness often "breakthrough" and become consciously perceived. This challenges the idea that only non-conscious processing has a role in speeded threat detection of fearful faces (see awareness checks in Hedger et al., 2016). Also, non-conscious processing in individuals with spatial neglect come from studies with very small samples sizes (e.g., *n* = 1, Tamietto et al., 2007), meaning they may not even replicate.

Another challenge to emotion automaticity is that it is not observed in certain circumstances (Cave & Batty, 2006; Kim & Cave, 1995). For example, threat automaticity relies on the presentation of threatening information as the target (or parts of the target), making it task-relevant; if threatening information is instead shown more often as a distractor, less or no threat automaticity occurs (Cave & Batty, 2006). Based on fMRI research, Straube concluded there is no support for strong automaticity of emotional faces (Straube et al., 2011). Emotional automaticity for faces and voices depends on the salience and perceived relevance of the emotional information (for reviews, see Straube et al., 2011; Vuilleumier & Righart, 2011). This explains why attentional bias is also modulated by the salience and relevance of the stimulus.

Automaticity for emotional faces is modulated by a number of different factors. For example, the low-level features of the face modulate its automaticity (Hedger et al., 2019; Horstmann, 2009; Horstmann et al., 2010; Horstmann & Becker, 2019; Kennett & Wallis, 2019). The salient white eyes of an emotional expression moderate target search efficiency (Horstmann, Lipp, & Becker, 2012). More whiteness increases the degree of automaticity. Other factors that modulate facial emotion automaticity include the spatial frequency of the face (Cushing et al., 2019), teeth exposure (Wirth & Wentura, 2018, 2018), how it is actually searched for in space (Smilek et al., 2006), and the clarity (or intensity) of the facial expression of emotion (Lin et al., 2016; Maxwell, et al., 2021;

Wang et al., 2017). The highly conditional nature of automaticity questions how often an emotional face is actually identified automatically.

Explanations for the lack of attentional bias for emotional faces

Emotion automaticity and the standard hypothesis offer an appealing ground truth that may have inadvertently created some incorrect implicit assumptions that attentional bias for emotion was a "sure thing". Misleading assumptions can go uncorrected for long periods of time. One source of this assumption comes from the title of a highly cited paper (458 citations according to google scholar) by Vuilleumier and Schwartz (2001): "Emotional facial expressions capture attention". In their study, patients with spatial neglect indicated the location of an emotional expressions (in their blind hemifield). Their results cannot be taken as evidence of capture (attention bias) because they only measured identification accuracy for emotional faces (no neutral face condition), and also, the emotional expressions were task-relevant (the target finding property). A colloquial explanation of this assumption is that attentional bias was never thought of as being much different from emotion automaticity, which is a widely accepted idea (for reviews, see Frischen et al., 2008; Palermo & Rhodes, 2007; Yiend, 2010).

Emotional face cues

Another potential explanation as to why emotional faces do not bias attention is that floating faces displaying emotional expressions in a typical laboratory study lack ecological validity. Emotional faces in real-life scenarios are dynamic and embedded elements in a rich and meaningful environment. Emotional face perception is carried out in highly contextualized situations; non-verbal cues, like body expressions and elements of the surrounding environment are necessary features for comprehending the meaning of a facial expression of emotion (Aviezer et al., 2012; Aviezer & Hassin, 2017; Barrett et al., 2011; Z. Chen & Whitney, 2020; Gendron et al., 2013; Shaham & Aviezer, 2020). In fact, the non-face and non-body context by itself is sufficient for accurate emotion perception (Z. Chen & Whitney, 2019, 2020, 2021). This context is entirely missing in laboratory studies.

The pictures that researchers use of actors making posed, static expressions (e.g., Lundqvist et al., 1998; Tottenham et al., 2009) are excellent for establishing accurate separations between categories of emotion, and between emotional faces and non-emotional faces. But, in practice, using them as a proxy for a desired underlying physiological state of emotion (Vytal, 2011) may be flawed (Cowen et al., 2020, 2020). In fact, a meta-analysis of studies of basic emotions found that the six different categories of basic emotions do not reliably co-occur with their respective facial expression; their correlation ranges between .13 and .3 (Durán & Fernández-Dols, 2021). If not a categorical emotion, what do images of basic facial expressions actually represent? Also, neutral faces showing forward facing gaze actually facilitate target processing (Framorando et al., 2016) and elicit amygdala reactivity (Burra et al., 2013), which suggests neutral faces can actually convey emotion, depending on the circumstances. Faces are often categorized using the FACS or a procedure that generates subjective ratings of the a-priori emotional label. Perhaps these approaches are flawed. A more accurate conclusion to make based on Chapters 2-4 is that static images of emotional faces shown in the absence of any context cannot bias attention.

Perhaps emotional faces are not salient enough to elicit sufficient arousal to bias attention. A meta-analysis of attentional bias for positively valenced cues reported a positive relationship between cue arousal and attentional bias (Pool et al., 2016). In particular, Pool found greater bias for erotic scenes than happy faces (as shown in Figure 5B in Pool et al., 2016). One explanation could be that erotic scenes produce greater levels of arousal than do happy faces. This was indeed a reported trend; Pool found that the average arousal was 39 for happy faces and 66 for erotic scenes. Studies with emotional faces rarely pre-select cues based on their arousal, whereas this is common practice in studies with IAPS images (Most & Wang, 2011). Relatedly, decreasing the intensity (arousal) of an emotional face eliminates its capacity to be perceived automatically (Maxwell, Joseph, et al., 2021), which could be due to a reduction in amygdala reactivity to the emotional face (Lin et al., 2016, 2020). Carretié's (2014) model of attentional bias (as shown in Figure 2) indicates that valenced stimuli must pass a threshold of salience in order to bias attention. Emotional faces might simply lack the salience necessary for attentional bias.

Erotic scenes may have elicited greater arousal than emotional faces because they are richer stimuli that are more difficult to suppress. There is much more heterogeneity in the features across multiple examples of negatively valenced emotional scenes (e.g., spider and snakes from the IAPS dataset (Lang, 2008) than across multiple examples of negatively valenced emotional expressions, such as anger (yet they are often treated similarly, see Hedger et al., 2016). Angry faces are much more consistent; each angry face has similar individual facial features (e.g., furrowed brow), and the same arrangement of individual features (e.g., the furrowed brow is always above the eyes). Given that the arousal of an expression is intertwined with its features (Liu et al., 2022) participants capable of directly suppressing the arousing feature(s) of an emotional face will thereby suppress the arousal it can elicit. Suppressing IAPS images in the same manner is not possible; there is no consistent landmark feature across multiple images of guns, eye surgery, spiders, and car accidents to suppress.

Measures and mechanisms of attentional bias.

Measuring attentional bias is difficult because it relies on a weak manipulation. Attentional bias often relies on a second-order effect of the interaction between cue type (emotional vs. non emotional) and another manipulation such as cue validity (valid vs. invalid). The manipulation of emotion is also weak because no matter the expression of the face, faces in general are already salient enough to bias attention to a greater extent than non-face objects (Devue et al., 2012; Devue & Grimshaw, 2017; Langton et al., 2008). Also, attentional bias for emotion may depend on the visual competition between that exists when an emotional face is presented alongside a neutral face (Mathews & Mackintosh, 1998). However, the 17 cases where emotional faces were presented in isolation show nearly the same effect (g = .07) as cases where emotional faces were not isolated (g = .08). If the bias caused by faces is strong, then this creates a ceiling effect leaving little room for emotion to have additional influence. Also, the salience of an emotional expression is likely to be absorbed (shared) by the salience of the face itself because the expression is an embedded element of the face (Young, 2018).

Perhaps the small overall effect can be explained by the type of dependent variable. RT studies are the most common – RTs were used in 152 of the 160 cases in Chapter 2. So, the conclusions drawn here might be limited to studies with RTs. But even other measures like ERPs show the same pattern. For example, no attentional bias was observed in a study with a variety of ERPs – N170, N2pc, P3 and Visual Awareness

Negativity (Qiu et al., 2022). A review of ERP studies reveal mixed findings as well (Torrence & Troup, 2018). Although the N2pc effects in the current study were larger (g = .21) than RT effects (g = .08), the overall effect for N2pc studies (a lateralized ERP, k = 7) was still small and non-significant. While ERPs are perhaps a bit more sensitive than RTs, they are also more indirect than measures of RT (Bridwell et al., 2018). Studies that use eye tracking measures, such as first saccades to the cue (Devue & Grimshaw, 2017) also tend to find no attentional bias to the emotional faces. In addition, no attentional bias for emotional faces is observed with accuracy in the rapid serial visual presentation paradigm (Brown et al., 2019a). The pattern also holds true in nontraditional paradigms, like how reaching motions are not so biased towards task-irrelevant emotional faces (with the arms, see Ambron & Foroni, 2015). In sum, the small overall (often non-significant) effects of attentional bias for emotional faces seems unlikely to depend strongly on the type of dependent variable.

Studies of attention capture (similar to attentional bias) for innocuous cues can help to explain why task-irrelevant emotional faces are not able to bias attention. For example, in one spatial cueing study (see Figure 4 for an example of a precuing study), cue validity effects were found for innocuous suddenly appearing task-irrelevant digits (see Figure 1 of Maxwell, Gaspelin, et al., 2021). A cue validity effect could be taken to indicate attentional bias for the suddenly appearing digit, yet these digits were not processed for meaning, which is a telltale marker that it was not attended (Craik, 2002; Craik & Lockhart, 1972). The target in this task was a number word, so attention to the precue digit “7” should facilitate responses to the target “seven”, but this was not observed. One explanation offered by this study and others (Zivony & Lamy, 2018) is that task-irrelevant cues influence where attention points, but do not trigger engagement or selection (similar to pointing a camera but not taking a picture). The meaning of a task-irrelevant cue is not comprehended because its identifying features are never submitted to the deeper stages of processing necessary for identification.

If the meaning of a task-irrelevant cue is never comprehended (inaccessible), and if an emotional face is a task-irrelevant cue, then the meaning of a task-irrelevant emotional face cue is never comprehended. If the meaning of an emotional face cue is not comprehended, how can it bias attention based on its meaning (emotionality or label of angry)? The lack of attentional bias for task-irrelevant emotional faces described in the current dissertation further supports the idea that task-irrelevant cues are not submitted to deeper stages of processing and go virtually unidentified.

Another explanation could be that attention is only biased for emotional faces when doing so is optimal for the current circumstance. Participants in laboratory studies may not exhibit any attentional bias because avoiding attentional bias is the most appropriate decision. After all, there are no consequences or incentives related to attending to the task-irrelevant emotional expressions portrayed by strangers on a computer screen.

There is neuroscientific evidence of such flexible cognitive control over spatial attention that could be implicated in the lack of attentional bias for emotional faces. The two primary types of attention mentioned previously – bottom-up and top-down – are employed by the parietal and temporal lobes, which communicate with the thalamus via thalamocortical networks (Asplund et al., 2010; Corbetta & Shulman, 2002; Halassa & Kastner, 2017; Young, 2018). Together, these areas form a priority map that can down-weight certain regions in space (suppressing them, see Gaspelin & Luck, 2018) or upweight them (Ptak & Fellrath, 2013). Perhaps the bottom-up salience from the task-irrelevant emotional face fails at the level of the priority map.

Emotional faces likely cause some degree of feedforward change in the thalamocortical networks involved in attentional sampling of the environment (for a review of the dynamics of spatial attention, see Fiebelkorn & Kastner, 2020). Priority maps operate in a rhythmic manner, sampling for bottom-up and top-down information at a rate of 4hz (Fiebelkorn & Kastner, 2019). So perhaps attentional bias is most likely to occur in the troughs of such sampling because coordination is lowest in these periods. Or perhaps the lateral prefrontal cortex adjudicates the bottom-up signal from task-irrelevant emotional faces, preventing or enabling its influence over how spatial attention is guided (Asplund et al., 2010). Further research is necessary to pinpoint how and where emotional faces can or cannot bias attention.

Conclusion

The current dissertation examined whether facial expressions of emotion bias attention. A meta-analysis of previous studies (Chapter 2) revealed that they do not, even though they are capable of automatic processing (Chapter 1). This was the case in a new set of experiments; no attentional bias occurred no matter how often they were shown (Chapter 3). Even when emotional faces possess featural relevance to current task demands, they were still unable to bias attention (Chapter 4). One explanation is that the salience of the emotional faces used in these studies is not great enough to guide selective attention against an individuals' will. Future studies may try to use dynamic facial expressions of emotion or cues that have greater ecological validity.

Appendices

Appendix A: Literature Search Queries

UNM Libraries

The query or database search performed on all of University of New Mexico's library sources on December 2020 was done with this hyperlink: UNM Libraries Query. The syntax of this query is: ((("emotional capture" OR "emotional dot probe" OR "emotional dot-probe" OR "attention bias" OR "attentional bias " OR "emotional distraction" OR "attention capture" OR "attentional capture" OR "EIB" OR "exogenous attention" OR flanker OR "oculomotor capture" OR "n2pc" OR "attentional disengagement" OR "automatic attention") AND ("emotional face" OR "emotional faces" OR "angry face" OR "angry faces" OR "ANGRY FACE" OR "fearful face" OR "fearful faces" OR "happy face" OR "happy faces" OR "facial expression of emotion" OR "facial expressions of emotion" OR "negative face" OR "negative faces" OR "threat face" OR "threatening face" OR "threatening faces" OR "threat faces" OR (facial n3 emotional) OR "threat-related face" OR "threat-related faces") AND attention) NOT SU (school age (6-12 yrs) OR adolescence (13-17 yrs) OR childhood (birth-12 yrs) OR children OR adolescent) NOT TI (child OR adolescent OR children) NOT AB (child OR adolescent OR children).

PubMed

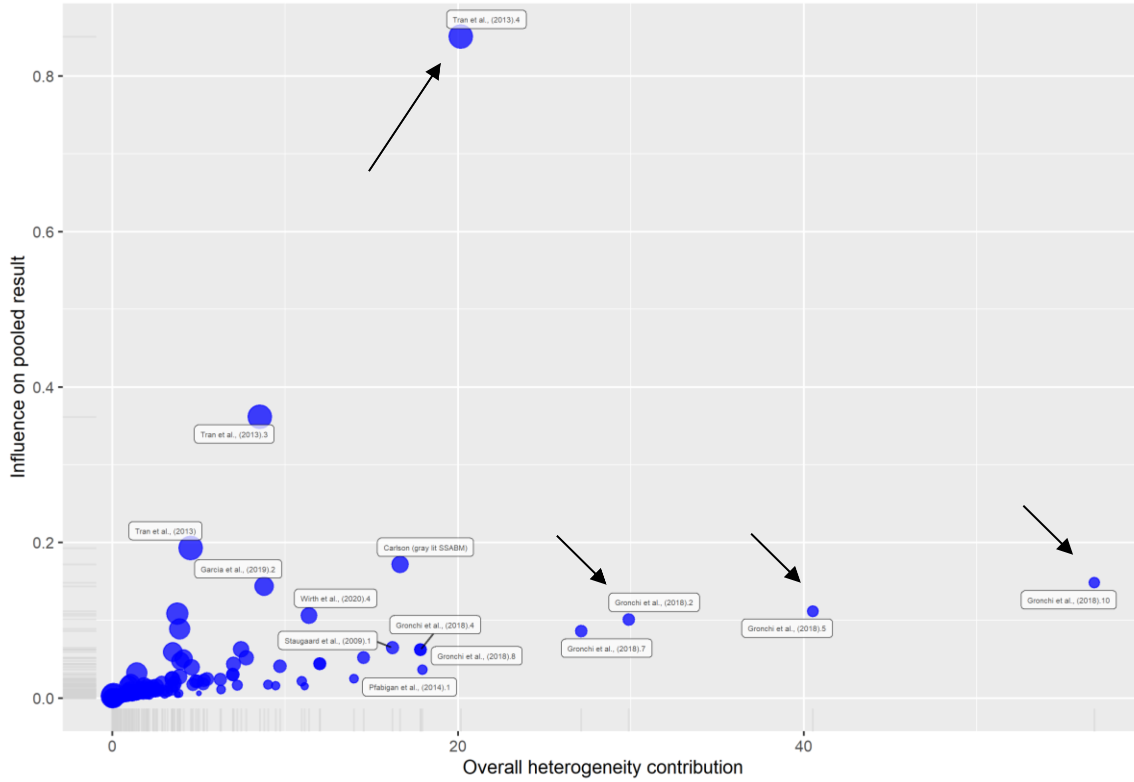
The database search performed on all of PubMeds' resources on December 2020 was done with this syntax: ("emotional capture" OR "emotional dot probe" OR "emotional dot-probe" OR "attention bias" OR "attentional bias " OR "emotional distraction" OR "attention capture" OR "attentional capture" OR "EIB" OR "exogenous attention" OR flanker OR "oculomotor capture" OR "n2pc" OR "attentional disengagement" OR "automatic attention") AND ("emotional face" OR "emotional faces" OR "angry face" OR "angry faces" OR "ANGRY FACE" OR "fearful face" OR "fearful faces" OR "happy face" OR "happy faces" OR "facial expression of emotion" OR "facial expressions of emotion" OR "negative face" OR "negative faces" OR "threat face" OR "threatening face" OR "threatening faces" OR "threat faces" OR "threat-related faces") AND attention

Web of Science

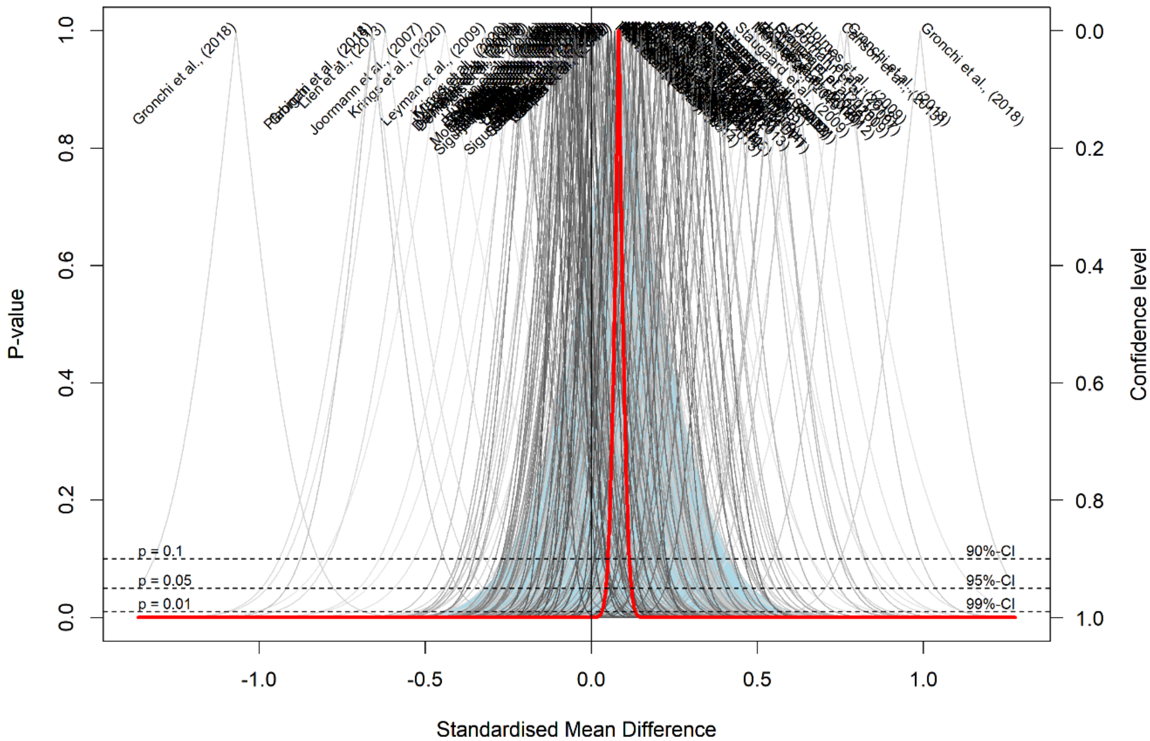
The database search performed on all of Web of Sciences' resources on December 2020 was done with this syntax: Web of Science Query. The syntax of this query is: ("emotional capture" OR "emotional dot probe" OR "emotional dot-probe" OR "attention bias" OR "attentional bias " OR "emotional distraction" OR "attention capture" OR "attentional capture" OR "EIB" OR "exogenous attention" OR flanker OR "oculomotor capture" OR "n2pc" OR "attentional disengagement" OR "automatic attention") AND ("emotional face" OR "emotional faces" OR "angry face" OR "angry faces" OR "ANGRY FACE" OR "fearful face" OR "fearful faces" OR "happy face" OR "happy faces" OR "facial expression of emotion" OR "facial expressions of emotion" OR "negative face" OR "negative faces" OR "threat face" OR "threatening face" OR "threatening faces" OR "threat faces" OR "threat-related faces") AND attention

Appendix B: Meta-Analysis Supplementary Materials

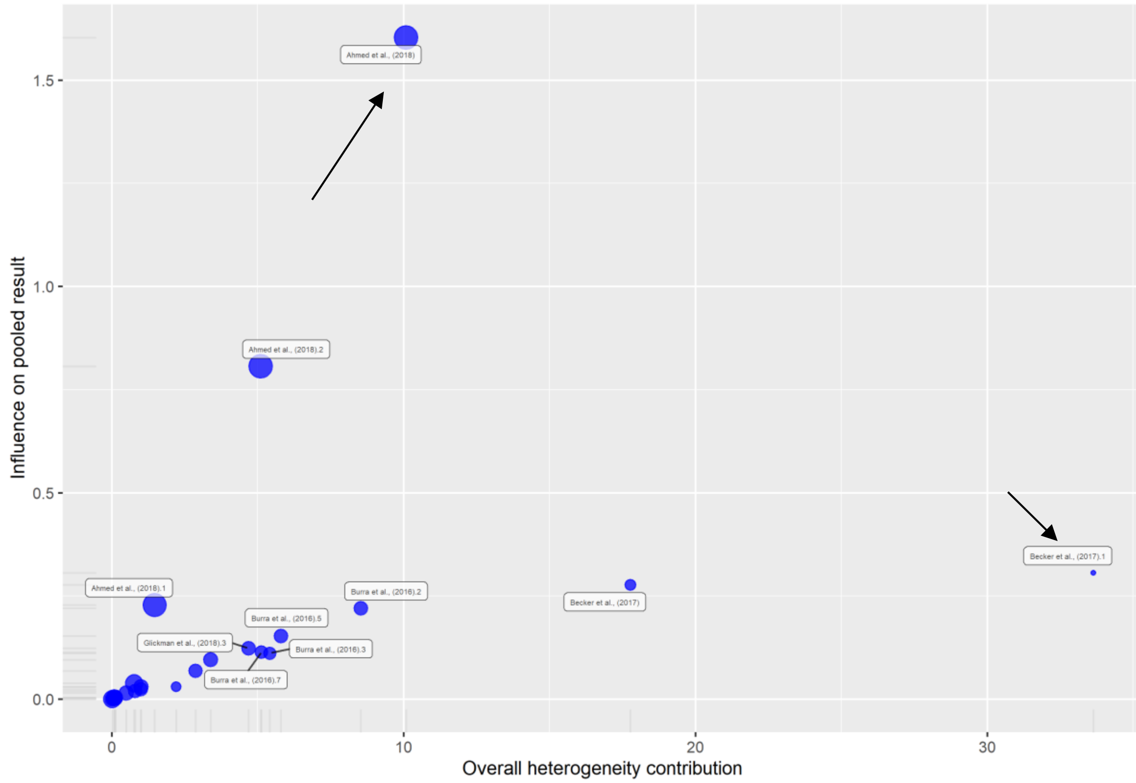
Below is the Baujat plot for task-irrelevant attentional bias cases (Baujat et al., 2002). 4 cases (signified with arrows) were selected as potential outliers. But ultimately no cases were excluded because their removal had no meaningful impact on the overall heterogeneity of the overall effect or its size.



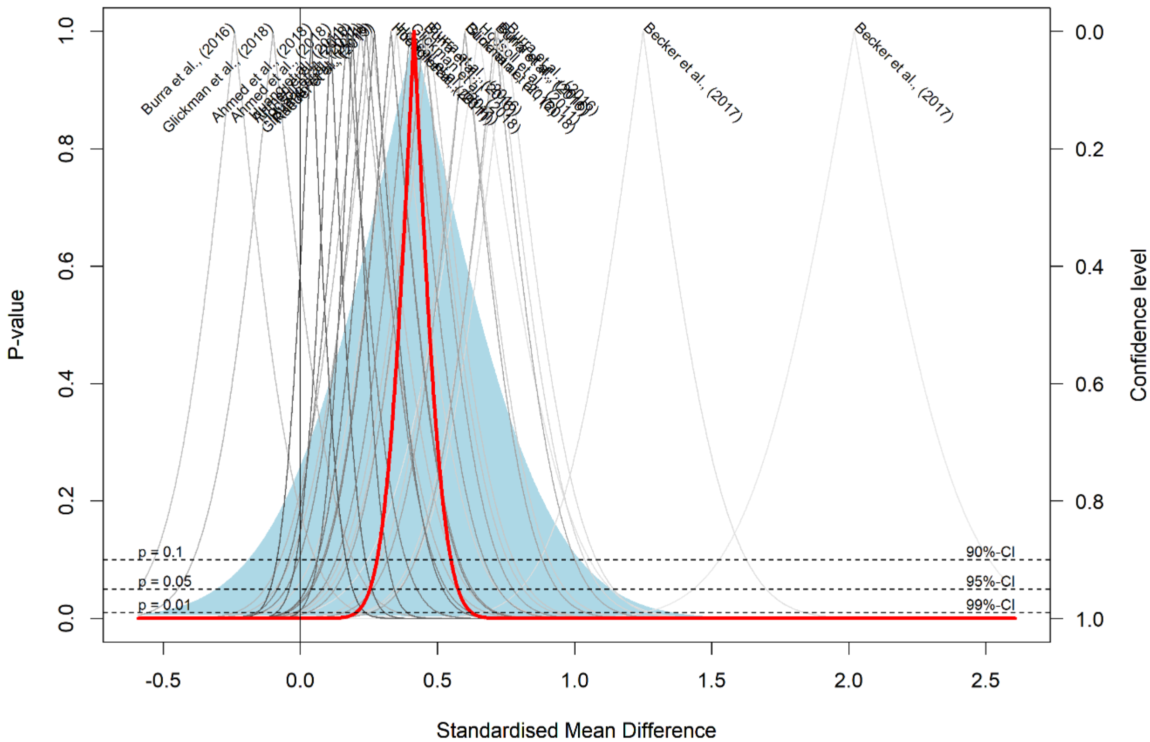
Below is a drapery plot for task-irrelevant attentional bias (Rücker & Schwarzer, 2021).



Below is the baujat plot for only SDM relevant cases. Again, when the two outliers were removed, no meaningful changes were observed, so no cases were removed.



Below is a drapery plot for SDM relevant cases of attentional bias.



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