Do Emotional Faces Attract Attention?

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An Investigation of the Boundary Conditions of Selection Biases in Favor of Emotional Facial Stimuli

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Zusammenfassung

Über unsere Sinne erreichen uns in jeder Sekunde unzählige Signale, deren Weiterverarbeitung durch die Kapazität unseres kognitiven Systems limitiert und deshalb nur in begrenztem Maße möglich ist. Um adaptives Verhalten sicherzustellen, muss eine sinnvolle Auswahl aus der Fülle verfügbarer Informationen getroffen werden. Aufmerksamkeitsprozesse gelten als die zentralen Mechanismen der Reizselektion. Aus evolutionspsychologischer Perspektive erscheint es sinnvoll, emotionalen Gesichtern eine herausragende Rolle für die Überlebenssicherung zuzuschreiben und aus diesem Grund einen Aufmerksamkeitsvorteil derselben anzunehmen. Diese theoretische Annahme wurde in der Vergangenheit mit unterschiedlichsten Ansätzen untersucht. Es fanden sich Belege für eine bevorzugte Verarbeitung von emotionalen Reizen, Gesichtern und im Speziellen auch emotionalen Gesichtern (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007; Mogg & Bradley, 1998). Dennoch zeigt ein genauer Blick auf die jeweiligen Studiendesigns, dass die Ergebnislage heterogen und uneindeutig ist. Viele Emotionseffekte lassen sich nicht replizieren, basieren auf sehr speziellen Stichproben oder benötigen besondere Bedingungen.

Das Anliegen der vorliegenden Arbeit ist es deshalb, zu untersuchen, ob und unter welchen Bedingungen emotionale Gesichter Aufmerksamkeit auf sich ziehen. Dazu wurden zwei experimentelle Paradigmen herangezogen: zum einen das *Dot-Probe*-Paradigma, mit dem untersucht wurde, inwiefern aufgabenirrelevante exogene Störreize in Form emotionaler Gesichter die Zielreizverarbeitung stören, und zum anderen das Flankierreizparadigma, bei dem die Zielreize zeitgleich mit den Störreizen dargeboten werden und folglich in direkter Konkurrenz stehen. Bewusst wurde eine unselektierte Stichprobe rekrutiert, bei der nicht von erhöhten Angstwerten auszugehen ist.

Eine bevorzugte Selektion emotionaler im Vergleich zu neutralen Gesichtern erfolgte nur dann, wenn die Emotionsdimension explizit aufgabenrelevant war und die Probanden gezwungen wurden, die Störreize zu verarbeiten. Die Ergebnisse zeigen, dass emotionale Reize nicht *bottom-up* und damit schnell, ressourcenfrei, unwillentlich und aufgabenunabhängig Aufmerksamkeit auf sich ziehen. Es wird diskutiert, inwiefern das Konzept der Relevanz geeignet ist, vorliegende Befunde sowie weitere Befunde in der Literatur zu erklären und bisher identifizierte Variablen zur Verstärkung von Emotionseffekten in Aufmerksamkeitsparadigmen zusammenzufassen. Anschließend wird zudem gezeigt, dass irrelevante Reize bei entsprechenden Kontextbedingungen in der Lage sind, das visuelle System auf stereotypkonforme Emotionen vorzubereiten. Dies belegt nicht nur eine kontextabhängige Aufmerksamkeitsverschiebung hin

zu irrelevanten Reizen, sondern auch eine Einflussnahme der Störreize auf basale visuelle Prozesse. Alles in allem zeigt sich, dass die Aufmerksamkeit nur dann den emotionalen Gesichtern zugewandt wird, wenn über die reinen Reizeigenschaften hinaus *top-down* die Relevanz der emotionalen Gesichter hoch eingeschätzt wird. Offen bleibt, ob diese *top-down*-Einflüsse bereits vor der initialen *attentional capture* wirksam werden, oder im Rahmen einer verzögerten Ablösung von aufgabenrelevanten Reizen nach initialer *attentional capture* entstehen. Die vorliegende Arbeit greift diese Frage im Ausblick auf und bietet einen weiteren vielversprechenden Erklärungsansatz an.

Zusammenfassend zeigt die vorliegende Dissertation, dass emotionale Gesichter nicht, wie bisher angenommen, besonderes Potential besitzen, *bottom-up* unbedingte Aufmerksamkeit auf sich zu ziehen. Stattdessen entscheidet stets ein komplexes Zusammenspiel aus Zielen, Erfahrungen und anderen Kontextfaktoren darüber, ob in einer gegebenen Situation emotionale Reize bevorzugt zur Weiterverarbeitung ausgewählt werden.

Summary

Our senses register numerous signals every second. Further processing of these signals is limited by the capacity of our cognitive system and, thus, only partly feasible. Human beings need to select a subset from the high amount of available information in order to behave adaptively. For this, attention is considered as the central mechanism of stimulus selection. From evolutionary perspective it seems plausible to ascribe emotional faces a pivotal role for survival and thus, propose a selection bias for those stimuli. This assumption was tested in various attentional paradigms. Evidence for preferred processing of emotional stimuli in general and emotional faces in particular has been shown in several studies (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007; Mogg & Bradley, 1998). However, a closer look at the respective experiments shows that the results are rather ambiguous and heterogenous. Many emotion effects could not be replicated, were based on special samples, or were contingent on very special conditions.

Therefore, the aim of the present dissertation was to investigate if and under what circumstances emotional faces capture visual attention. For this purpose, two experimental paradigms were used. In the dot-probe paradigm, on the one hand, attentional capture of two distractor stimuli, which were simultaneously presented before the target display, was measured. In the flanker paradigm, on the other hand, the target stimuli were presented simultaneously with the distractor, and thus a direct competition between distractors and top-down relevant target was present.

Furthermore, the sample was intentionally recruited in a mixed student population, where heightened anxiety is implausible. This was important because anxious people have been demonstrated to show special attention to emotional stimuli, which might indicate that the mechanism of attention to emotion is not representative for a normal population.

A preferred selection of emotional faces compared to neutral faces was found only when emotions were relevant to the task and distractor processing was mandatory. These results show that emotional facial stimuli are not capturing attention purely bottom-up, i.e. fast, resource free, involuntarily, and independently from the current task. It is discussed if and how the concept of relevance might be used to explain the present findings as well as former findings. Furthermore, it is outlined, how the concept of relevance helps to summarize already identified variables that influence attention allocation to emotional faces. Additionally, it is shown that irrelevant stimulus information is used to tune the visual system to process stereotype-matching information if and only if the context renders this information relevant. This indicates not only a context-

dependent attention allocation to irrelevant stimuli but also an influence of these stimuli on basal visual processing.

All in all, the present work shows that attention is only shifted to emotional faces if, in addition to the stimulus properties, their relevance is top-down considered high enough. It remains open whether these top-down influences manifest before the initial attentional capture or later in the form of a delayed disengagement from task-relevant stimuli after an initial task-independent attentional capture. The present dissertation discusses this question in the outlook section and offers a new promising and eventually connected account for explanation.

In a nutshell, the present dissertation shows that emotional faces have no extraordinary potential to capture attention bottom-up. Instead, a complex interaction of goals, experiences and other contextual factors determine which stimuli are selected for further processing in a given situation.

Content

1 Theory

1.1 Introduction

Our cognitive capacities are not sufficient to process all incoming sensory information. In a first pre-attentive processing stage numerous environmental stimuli are processed in parallel. Deeper conscious processing, however, proceeds serially and is strictly limited to a small number of stimuli. Therefore, humans developed mechanisms that help selecting some stimuli for further processing and reject others. The central mechanism for this purpose is attention. Following the definitions of researchers in the field, this task is mainly fulfilled by attentional selection. Katsuki and Constantinides (2014, p. 1), for example, state that

> 'Selecting the most relevant stimuli in the physical world for processing while filtering out less relevant information allows us to respond quickly to critical environmental changes and achieve behavioral goals more efficiently. This process of information selection is referred to as attention.' (Katsuki & Constantinides, 2014, p. 1)

A hotly debated question is, which stimuli are relevant. On the one hand, humans need to focus on stimuli in the environment, which are useful for their current goals and tasks, while ignoring those stimuli that are obviously not useful to this end. On the other hand, however, people still need to detect unexpected events that might be life-threatening and are in this sense evolutionary relevant. Therefore, it is assumed that, in addition to task relevant components, certain stimulus features capture attention in an involuntary fashion.

To answer the question of which stimuli elicit attention automatically bottom-up, researchers referred to experiments where bottom-up attentional capture has been demonstrated for sudden onset stimuli, stimuli that differ from the surrounding in terms of movement direction, speed, color, brightness or size (Duncan & Humphreys 1989; Jonides & Yantis, 1988; Miller, 1989; Treisman & Gelade, 1980). Chapter 1.1.1 to 1.1.3 aim at introducing different objects of attention that are believed to be selected preferentially.

1.1.1 Attention to Evolutionary Relevant Stimuli

The process of willful, resource-consuming, goal-directed stimulus selection is called top-down attention, the latter process of involuntary, automatic, fast, capacity-free, goal-independent stimulus selection is called bottom-up attention. When stimuli elicit bottom-up attentional shifts, this is called attentional capture. From a more theoretical point of view, however, not only simple perceptual characteristics are thought to define bottom-up-relevant stimuli, but also more complex but survival relevant stimuli like weapons, spiders, snakes and emotional faces. It is evolutionary relevant to rapidly detect and discriminate emotions in order to respond adequately and quickly to potentially survival-relevant stimuli, even while engaging in a current task. Therefore, it is proposed, that the cognitive system has a special threat module, that is realized through a dedicated neural circuit, in order to deal with evolutionary relevant sources of threat (Öhman & Mineka, 2001). This module is assumed to detect and process threat relevant stimuli in an automatic fashion without cognitive control. Accordingly, numerous studies were able to demonstrate an attentional bias to threat-related stimuli (; West, Anderson, & Pratt, 2009), i.e. a bias for weapons (Steblay, 1992), spiders (Devue, Belopolsky, & Theeuwes, 2011, Öhman, Flykt, Esteves, 2001), snakes (Lipp & Waters, 2007; LoBue & DeLoache, 2008, 2011, Öhman et al., 2001), and angry faces (Fox et al., 2000; Fox, Russo, & Dutton, 2002, Horstmann & Bauland, 2006). Attention to threat is important for survival. However, other stimuli in the environment should also be attended do guarantee the specie's survival.

1.1.2 **Attention to Faces**

Other human beings are central to the survival of our social species. Not only do we have to identify conspecifics for reproduction, we also need caregivers in early and late life. We need to cooperate to gather the basic goods for survival and to fight dangers. Additionally, the transmission of knowledge enabled humans to retain experiences of one generation and pass it on to the next. Cooperation, child care and reproduction necessitate a processing of social signals. Faces play a pivotal role in social interactions („Social communicative function of emotions": Bavelas & Chovil, 1997; Chovil, 1997; Oatley, 1988; Frischen, Eastwood, & Smilek, 2008; Williams, Moss, Bradshaw, & Mattingley, 2005). Shortly after birth infants are able to discriminate faces from other stimuli and prefer the former over the latter (Fantz, 1963; Johnson, Dziurawiec, & Morton, 1991; Macchi, Turati, & Simion, 2004; Mondloch et al., 1999; Valenza, Simion, Cassia, & Umiltà, 1996). Moreover, they prefer the face of their mother over unfamiliar faces (Bushnell, 2001; Bushnell, Sai, & Mullin, 1989; Field, Cohen, Garcia, & Greenberg, 1984; Pascalis, deSchonen, Morton, Deruelle, & Fabre-Grenet, 1995) and mimic facial movements (Field, 2007; Field, Woodson, Greenberg, & Cohen 1982, Nagy & Molnar, 2004). Accordingly, Brosch, Sander, and Scherer (2007) demonstrated a bias to photographs of laughing babies in adults.

Furthermore, numerous studies demonstrated face biases in adult participants (Palermo and Rhodes, 2007; Langton, Law, Burton, & Schweinberger, 2007; Neumann, Mohamed, & Schweinberger, 2011; Shah, Gaule, Bird, & Cook, 2013). Humans are experts in recognizing faces and have developed strategies for fast recognition of the most important pieces of information (e.g, Bruce & Young, 1986). However, recent studies suggest, that attention to faces is not automatic in a way, that it cannot be modulated by task demands (Bindemann, Burton, Langton, Schweinberger, & Doherty, 2007). Instead attention to task relevant objects cannot be prevented by presentation of irrelevant faces, even at very short SOAs. However, irrelevant faces slow down responses to relevant objects thereby preventing complete top-down attentional control.

1.1.3 **Attention to Emotional Faces**

In addition to the face per se, the preparedness for a preferred processing of emotional facial expressions is evolutionary beneficial. The anticipation of behaviors of other people enables a person to prepare for a potential interaction, collect information on the other person's attitudes and evaluations, cooperate, anticipate a fight, or avoid conflicts in advance by adequate social behavior. It enables parents to interpret their children's needs and worries, which is a prerequisite for caregiving. Furthermore, the detection and classification of emotional faces allows for silent communication, for example while sneaking up prey. Facial expressions are, like other threat signals, good indicators of the presence and location of threat and additionally offer information on the availability of conspecifics for cooperation or reproduction. Correctly classified, emotional faces provide information on social opportunities (happiness) and dangers (fear), interpersonal conflicts (anger), need for care (sadness), or the eventuality of contamination (disgust). In contrast to relatively stable characteristics, such as identity and gender, emotional expressions are continuously modified. The temporal transience and the high relevance of dangers, conflicts, opportunities, or the risk of contamination require a pretty fast recognition of emotional faces, which in turn necessitates early attentional mechanisms that ensure processing. Consequently, the discrimination of emotional and especially the detection of threat related facial expressions has been found to be prioritized in visual processing (Eastwood et al., 2001; Fox, Lester, Russo, Bowles, Pichler, & Dutton, 2000; Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001; Öhman & Mineka, 2001; Schupp et al., 2004; Tipples, Atkinson, & Young, 2002).

In sum, theoretical considerations suggest, that emotional faces are attended in a continuous, automatic fashion even when the actual goal is not directly related to facial information. It seems reasonable that healthy individuals developed a bias to emotional facial expressions, i.e. the tendency to preferentially process emotional facial information compared to other stimuli.

The attentional effects of emotional stimuli including emotional faces have been intensely investigated in the past. However, there is still no consensus on the mechanisms and preconditions of effects of emotional faces and it still lacks a comprehensive model that allows for reliable predictions on attentional mechanisms concerning emotional stimuli. The aim of this dissertation is to combine the extensive research on attentional mechanisms in general with the theoretical concept of attention to emotion in order to not only find but also understand attentional effects of emotional faces. Therefore, in chapter 1.2 I will introduce the basic concepts of prioritization that are relevant for the debate on attentional effects of emotional faces. In chapter 1.3 I will present evidence for prioritization of emotional faces and narrow the focus by referring to the inconsistent findings in different experimental paradigms. In chapter 1.4 I will summarize the presented inconsistencies and deduce my research question.

1.2 Mechanisms of prioritization

Several information processing mechanisms are thought to be involved in the prioritization of emotional faces. The present chapter will delineate those mechanisms and present relevant results and debates.

1.2.1 Subcortical Pathway

In line with the theoretical consideration of the pivotal role of emotional and particularly threatening facial expressions, some researchers propose the existence of a subcortical visual pathway, which quickly transmits threat signals (DeGelder, Snyder, Greve, Gerard, & Hadjikhani, 2004; Morris, Öhman, & Dolan, 1998; Tamietto & De Gelder, 2010). Empirical studies showed that processing via this path is independent of conscious perception and guides the selection process without conscious attention. (Öhman, 2005; Öhman, Carlsson, Lundqvist, & Ingvar, 2007). It is assumed that survival relevant stimuli, such as danger signals, are processed fast and unconsciously via this route, passing amygdala, superior colliculus and pulvinar nucleus of the thalamus, which allows for a rapid response (Öhman, 2005; Öhman et al., 2007; Tamietto & De Gelder, 2010). Evidence for this assumption comes from studies which demonstrate that the amygdala can be activated independently from cortical structures, is activated in the presence of affective stimuli (Breiter et al., 1996) and even without conscious perception of these stimuli (e.g. Öhman, 2005). Batty & Taylor (2003) showed differences between emotions in event related potentials (ERPs) as early as 140ms (N170) after stimulus onset. Especially fearful faces lead to increased P1. Imaging methods (fMRI) provided evidence of amygdala activation (and consecutive fusiform cortex activity) after presentation of faces (Vuilleumier & Portuois, 2007) and emotional facial expressions (Breiter et al., 1996) as well as emotional words (Isenberg, 1999). Vuilleumier, Armony, Driver, & Dolan (2001) even found that activation by fearful stimuli was independent of task and took place even when the emotional stimuli appeared in an unattended task-irrelevant location. This might suggest, that emotional stimuli automatically capture visual attention. Additionally, there is increasing evidence that amygdala activation is not only related to threat (Vuilleumier, Armony, Driver, & Dolan, 2001; Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004) but also other evolutionary relevant stimuli (Sander & Zalla, 2003). Thus, the 'fast route' might be involved in the processing of socially relevant stimuli as well.

The subcortical activations in response to emotional stimuli have been found to be integrated into cortical conflict resolution structures. Egner, Atkins, Gale, & Hirsch (2008) as well as Etkin, Egner, Peraza, Kandel, & Hirsch (2006) found evidence for two separate cortical pathways to resolve emotional conflicts vs. non-emotional conflicts. They demonstrate an association of conflict resolution in the non-emotional task with activation of the right dorsal lateral prefrontal cortex (LPFC). In contrast conflict resolution in emotional tasks was associated with activation of the rostral anterior cingulate cortex (rACC) which was directly associated with inhibition of amygdala responses to emotional distractors. Activation of LPFC to the contrary was associated to increased activation of face sensitive areas of the visual cortex but not amygdala. This replicates previous findings of other authors (MacDonald, Cohen, Stenger, & Carter, 2000; Kerns, Cohen, MacDonald, Cho Stenger, & Carter, 2000; Egner and Hirsch 2005a, 2005b). Thus, the rACC is not only activated in response to irrelevant emotional stimuli (Bishop, Duncan, & Brett. 2004) but also explicitly responsible for emotional stimuli (Bush et al. 1998; Whalen et al. 1998; Mohanty et al. 2007) in interaction with subcortical structures that are believed to provide a fast route for processing of emotional stimuli.

However, amygdala activation is also modulated by other factors, like situational variables or selection history (Huff, Wright-Hardesty, Higgins, Matus-Amat, & Rudy, 2005; Hobbin, Goosens, & Maren, 2003; Maren & Hobbin, 2007) but also task difficulty and processing resources (Bishop et al., 2007; Lim, Padmala, & Pessoa, 2008; Pessoa, McKenna, Gutierrez, Ungerleider, 2002; van Dillen, Heslenfel, & Koole, 2009,). Additionally, variations in amygdala activation have been shown to reflect top-down interpretation processes (Phelps et al., 2001).

Furthermore, it has been hypothesized, that the fast route operates with low spatial frequency components. However, Stein, Seymour, Hebart, and Sterzer (2014) found, that fearful faces were preferentially processed in the high spatial frequency spectrum. This is consistent with the findings of Smith and Schyns (2009) and casts doubt on the notion that fearful faces are processed via the subcortical fast route. However, angry faces are informative in the low spatial frequency spectrum.

In sum, neuroscientific evidence for a subcortical fast route is not clear cut. Additionally, the findings outlined above do not permit inferences on the exact behavioral outcomes. Therefore, in addition to subcortical explanations, there are also many theories that try to explain the processing of emotional stimuli on a cortical basis. A precise definition of attentional effects which are elicited by emotional faces requires an overview of the main theoretical concepts of attention in general and respective findings. Traditionally, two types of attentional control are distinguished: bottom-up stimulus-driven (exogenous) attention and top-down goal-driven (endogenous) attention.

1.2.2 **Top-Down Influences on Attention**

As 'top-down' are considered all attentional processes that are not caused by the stimulus itself but are contingent on task requirements or current goals of the observer. Top-down signals cause an increase in neuronal activity in those structures that represent the task-relevant location, shape, or color (Katsuki & Constantinidis, 2014). This facilitates target detection. In a seminal cueing study, Posner, Snyder, and Davidson (1980) presented a cue stimulus in the center of the screen (endogenous cue), that indicated one of two possible target positions. When the cue was informative for the actual target position, participants were faster to detect targets whose position was correctly cued by the central stimulus than targets whose position was either un-cued or wrongly cued. This is seen as evidence for an influence of top-down information in the allocation of visual attention above and beyond stimulus properties. Some researchers assume that top-down facilitation is the central mechanism behind attentional processes (Folk, Remington, & Johnston, 1992; Folk, Remington, & Wright, 1994).

First evidence for top-down attentional orienting came from cueing studies. Posner, Snyder, and Davidson (1980) for example found benefits in categorizing targets after valid symbolic location cues. This shows a goal dependent allocation of covered attention. A stronger debated question however, is if attention can not only be shifted to a certain *location* due to task demands but also focused on certain *characteristics*, like e.g. shape, color, or size. The classical studies that offered evidence for this claim use an additional singleton paradigm (Theeuwes, 1992). In this paradigm, a singleton search display contains an additional non-target singleton that either matches the target (e.g. red singleton, red target) or not (e.g. green singleton, red target). The typical finding is that matching singletons are attended, while non-matching singletons are not (Folk et al., 1992; Folk et al., 1994). Thus, the definition of target features or locations seems to drive attention top-down to the objects carrying relevant features only. The process is assumed to be conscious and to need cognitive capacity (Folk et al., 1992). Most researchers also consider it as voluntary (Baluch & Itty, 2011; Buschman & Miller, 2007; Connor, Egeth, & Yantis, 2004; Folk et al., 1992; Pashler, Johnston, & Ruthruff, 2001; Theeuwes, 2010a, 2010b, 2018). On a neuronal basis many studies find task dependent activation patterns in early stimulus processing (Buracas, Albright, & Sejnowski, 1996; Haenny & Schiller, 1988; Huk & Heeger, 2000; Moran & Desimone, 1985; Motter, 1993; Treue & Maunsell, 1996). However, Stothart, Simons, & Boot (2019) found in an inattentional blindness task that attentional capture follows a top-down set in the attended visual area only. Distractors presented in unattended areas captured attention irrespective of the task set.

1.2.3 **Bottom-up Influences on Attention**

Bottom-up attention is assumed to be purely stimulus-driven, i.e. certain characteristics of the stimulus itself, e.g. sudden onset, abrupt changes in luminance, differing color, movement direction, or orientation, make the stimulus pop out (Duncan & Humphreys 1989;Jonides & Yantis, 1988; Miller, 1989; Treisman & Gelade, 1980), and thus lead to an attentional shift toward the stimulus (i.e., attentional capture; Theuwes 1992, 1996, 2010a, 2010b). Theeuwes (1992, 1996, 2010a, 2010b) considers all stimulus-induced attentional processes as bottom-up when they proceed without conscious will. Consequently, when a task-irrelevant stimulus is given attention, the process would be considered as bottom-up.

The pure capture hypothesis assumes that some stimuli draw attention automatically, without binding any resources, unconditionally, fast and independent of current goals or contextual conditions (Theeuwes 1992, 1994, 2010). Proponents of this hypothesis assume that the so-called pre-attentive phase (i.e., the time interval directly preceding the overt attention shift) passes off purely stimulus driven, i.e. bottom-up (Belopolsky et al., 2010; Jonides, 1981; McCormick 1997; Mulckhuyse & Theeuwes 2010; Müller & Rabitt, 1989; Posner, 1980;

Theeuwes, 1992; 2010a, 2010b). The other end of the spectrum is a top-down mechanism, where information processing is initiated by the perceiver rather than by the stimulus.

1.2.4 Biased Competition, Additive Effects and Priority Maps

The predominant view in the bottom-up-top-down-debate is the concept of biased competition (Bundesen, 1990; Desimone & Duncan, 1995; Yantis 1996). In this line of reasoning it is assumed that selection is a result of solving the conflict of signals from both bottom-up stimulus characteristics and top-down task demands. There are several approaches concerning the exact interplay of the two mechanisms (Desimone & Duncan, 1995; Theeuwes, 2010; Lamy, 2010; Folk & Remington, 2006; Wolfe, 1994; Wolfe, Cave, & Franzel, 1989; Yantis, 1996). Brosch, Pourtois, Sander, and Vuilleumier (2011) assume at least some modulation by internal affective states, for example state or trait anxiety. They propose that attention is modulated by three main components, namely endogenous, exogenous and emotional signals. The latter two components proceed involuntarily. Recent theories suggest that top-down and bottom-up signals are integrated in so-called priority maps (Bisley, 2011; Fecteau & Munoz, 2006; Itti & Koch, 2001; Theeuwes, 2010a; Zelinsky & Bisley, 2015). Accumulated relevance signals from different sources are ascribed to the different stimuli in order to rank them for attentional prioritization within the map. The stimuli or locations with the highest values on the priority map are attended for further processing. (for a discussion of this account see chapter 5.6.2). Critically this argues against a pure bottom-up account of e.g. Jan Theeuwes (1991, 1992, 1994). Theeuwes claims, that effects of target-distractor similarity (i.e. top-down influences of task) are possible, but contingent on distractor saliency. In the study of van Zoest and Donk (2004), however, target distractor similarity had an effect, that was independent of distractor saliency, i.e. it occurred for salient but also for non-salient distractors.

Cave and Wolfe (1990) proposed in their guided search model two different search modes, a parallel stage for salient stimulus features and a serial stage for complex operations. The feature search mode is dominated by top-down processes and relies on information on the target features. The singleton search mode to the contrary is based on bottom-up stimulus features and relies on the capacity of a stimulus to pop out.

Above and beyond the findings and claims, proponents of the contingent capture hypothesis argue that even the very early phase of stimulus selection, which most theories assume to be dominated by bottom-up attentional capture, is influenced by endogenous variables, such as goals or intentions (Ansorge & Heumann, 2003; Ansorge, Kiss, Worschech, & Eimer, 2011; Bacon & Egeth, 1994; Chen & Mordkoff, 2007; Folk & Remington, 2010; Folk et al., 1992;

Gibson & Amelio, 2000; Lamy, 2010; Nordfang & Bundesen, 2011). Specifically, the contingent capture hypothesis assumes that involuntary capture is limited to stimuli that carry task-relevant features or characteristics that match the current attentional set (Bacon & Egeth, 1994; Eimer & Kiss, 2008; Folk & Annett, 1994; Folk & Remington, 1998; Folk et al., 1992; Folk, et al., 1994; Lamy, 2010; Leber & Egeth, 2006; Zehetleitner, Goschy, Müller, 2012). The authors suppose that stimuli are evaluated in the light of the current attentional set pre-attentively, i.e. before capture takes place. Thus, stimuli do capture attention when they are salient and relevant for the current task (Folk et al., 1992). In line with this, Folk and colleagues (1992, 1994) showed attentional effects of cues that incorporated characteristics of the target. Abrupt-onset distractors, for example, captured attention when the target was characterized by abrupt onset, too. The information on feature relevance is assumed to be determined top-down and to restrict the bottom-up attentional capture to a subset of task-relevant stimuli. Fittingly, Spruyt, DeHouwer, & Hermans, (2009) demonstrated in an affective priming study that the task-relevance of certain dimensions of a prime affects, which dimensions become pre-activated. Although this claim was initially based on findings in evaluative priming it is plausible to generalize it to focal attention in other paradigms (Everaert, Spruyt, & DeHouwer, 2013).

In contrast to this early influence of top-down task-constraints, proponents of the pure-capture account, explain failures to find attentional capture of task-irrelevant salient stimuli by the rapid recovery account (Belopolsky et al., 2010; Theeuwes, 2010a, Theeuwes, 2010b). This theory states that – although it seems as if task requirements influenced stimulus selection from the beginning – attention was initially captured by the salient stimulus. Subsequently, attention was rapidly disengaged at around 175ms post-stimulus due to top-down corrections (Theeuwes, 2010a, 2010b; Kim and Cave, 1999).

As can be seen, the field of attention research still lacks a consensus on a certain general mechanism that would allow for a reliable prediction concerning the effect of emotional faces. Nevertheless, research on this question has been conducted, that will be summarized and integrated in the next chapter.

1.2.5 **Mixed Theoretical Reasoning**

In sum, there is evidence for both, bottom-up capture as well as top-down influences. On the one hand side there is a theoretically plausible high relevance of emotional faces that suggests the existence of mechanisms of prioritized processing. This is consistent with the main message of models concerning the *fast route,* that assume an automatic, fast and efficient processing of emotionally relevant stimuli, especially threat signals, via a fast subcortical route. On the other hand-side it is argued that goal directed behavior necessitates mechanisms to select stimuli on the basis of task requirements. Therefore, the vast majority of researchers today argues for an interplay of bottom-up and top-down mechanisms in attentional prioritization.

However, it is questionable if natural emotional faces can elicit bottom-up capture at all. Natural emotional faces are pretty complex. Thus, a prioritization necessitates a prior processing in order to retrieve emotion category information, which seems to be in conflict with theories of feature based bottom-up capture. Consequently, a lively debate is devoted to the interplay of bottom-up attentional capture and top-down attentional control by emotional facial stimuli.

1.3 Evidence for Attentional Bias to Threat and Emotional Faces

From a theoretical perspective task independent pure attentional capture of threatening stimuli is plausible, because a fast detection of threat and initiation of appropriate behavior is an evolutionary advantage.

Not only results of studies on the subcortical pathway but also other neuroscientific investigations suggest prioritized processing of emotional faces.

The present chapter complements these neuroscientific results with behavioral data from different attentional paradigms. The paradigms are shortly described to enable the reader to understand the discussion of results and conceptual problems of the respective procedure.

1.3.1 Attentional Blink

In a rapid serial visual presentation (RSVP) paradigm (Potter & Levy, 1969) several (6-20) stimuli (originally letters) are presented in rapid succession at the same fixed location (usually centrally). When two or more targets are presented within this stream of stimuli, detection of further targets (probes) is impaired in a certain time window after presentation of the first target, (Broadbent & Broadbent, 1987; Kanwisher, 1987; Kanwisher & Potter, 1989, 1990; J. E. Raymond, K. L. Shapiro, & K. M. Arnell, 1992: Reeves & Sperling, 1986; Weichselgartner & Sperling, 1987). The time-slot of impaired processing after an attended stimulus is called *attentional blink (*J. E. Raymond, K. L. Shapiro, & K. M. Arnell, 1992). Probes that are presented in a time window between 180ms and 450ms after target presentation are typically not detected. However, when target identification was not required or when a blank screen was presented shortly after target presentation, this attentional blink effect did not occur. The idea is, that the lag, i.e. the temporal distance between attended and missed stimuli within the visual stream, is informative on the timing of target processing.

An attentional blink, that is caused by an irrelevant emotional stimulus is called *emotional attentional blink* (McHugo, Olatungi, & Zald, 2013). Most and colleagues (2005) found attentional blink effects of irrelevant negative faces that were most pronounced at lag 2, i.e. 200ms after the negative face. Additionally, the attentional blink was less pronounced for neutral faces and absent for scrambled faces. The RSVP design allows to measure if attention is captured by an emotional face and how rapidly attention can be disengaged from this stimulus. Arnell, Killmann, and Fijavz (2007) found impaired target processing after irrelevant sexually arousing distractors but not after negative, threatening, positive, or emotionally neutral distractors. Most, Chun, Widders, and Zald (2005) to the contrary found an increased attentional blink caused by negative emotional pictures compared to neutral ones at lag 2 but not lag 8. However, it remains unclear, which mechanism causes the inability to process subsequent stimuli. There are a multitude of theories, including an inhibition model (Raymond et al., 1992), an interference model (Shapiro, Raymond, & Arnell, 1994), a bottleneck model (Chun & Potter, 1995), explanations concerning attentional dwelling (Duncan, Ward, & Shapiro, 1994) and the idea of a loss of control while processing stimuli (Di Lollo, Kawahara, Ghorashi, & Enns, 2005).

1.3.2 **Visual Search**

Especially results from visual search (Treisman & Souther, 1985) experiments suggest, that threatening stimuli are attended involuntarily and capacity-free. This paradigm is analogous to the attentional blink paradigm but operates in the spatial rather than temporal dimension. In the visual search paradigm (Treisman & Souther, 1985), participants are supposed to find and classify a stimulus that deviates from the surrounding distractor stimuli in a certain dimension, e.g. color, shape, or movement direction. These stimuli are called feature singletons. When search is inefficient, reaction time increases linearly with number of distractors (Treisman & Gelade, 1980). For efficient parallel search however, i.e. when the target pops out, search latencies are independent of the number of distractors. Bottom-up stimulus saliency is a prerequisite for a parallel search process, which is efficient because no conscious attention and only minimal cognitive capacity are needed (Belopolsky, Schreij, & Theeuwes, 2010; Jonides, 1981; McCormick 1997; Mulckhuyse & Theeuwes 2010; Müller & Rabitt, 1989; Posner, 1980; Theeuwes, 1992; 2010a, 2010b). Consequently, Öhman and colleagues (2001) not only showed faster responses to pictures of snakes or spiders between pictures of plants than to plants between spiders or snakes, but also an independence of spider search time and snake search time from the number of distractors. The search time for plants to the contrary increased with increasing number of distractors. This demonstrates a bottom-up saliency of spiders and snakes.

Processing advantages have also been shown for emotional faces in general compared to neutral ones (Eastwood et al., 2001) as well as threatening faces in particular compared to non-threatening ones (anger superiority effect: Fox et al., 2000; Horstmann & Bauland, 2006; Miller, 1991; Purcell & Stewart, 2010; for a review, see Frischen et al., 2008). However, the pop out of angry faces is not consistently found (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011). Some studies even demonstrate an advantage of neutral compared to angry faces (Juth, Lundqvist, Karlsson, & Öhman, 2005). Additionally, the findings of anger superiority in the visual search paradigm (Fox et al., 2000; Hahn & Gronlund, 2007; Horstman & Bauland, 2006, Pinkham, Griffin, Barin, Sassin, & Gur, 2010), are challenged by the notion that low level confounds of the material impede valid inferences on actual stimulus effects (Horstmann & Bauland, 2006; Coelho et al.,2010; Harms & Bundesen, 1983; Horstmann & Bauland, 2006; Miller, 1991; Purcell & Stewart, 2010; Purcell, Stewart, & Skov, 1996). Additionally, Yantis and Egeth (1999) pointed out, that the conclusion of stimulus pop-out based on bottom-up saliency from fast detected singletons in the visual search paradigm is not correct as long as the singleton is also the target, i.e. the top-down relevant stimulus. Horstmann and Becker (2008) tested attentional capture of emotional stimuli in a 1/n task and found no evidence for attentional capture as long as emotion was task-irrelevant.

In order to investigate attentional capture by a task-irrelevant distractor, the additional singleton paradigm was used (Bacon and Egeth, 1994; Theeuwes, 2004). In this special search task an additional singleton is present that is salient on another dimension, which is not relevant for the target task. It is assumed, that attention to these task-irrelevant salient singleton reflects involuntary attentional processes that cannot be overridden by top-down attentional control. However, Bacon and Egeth (1994) demonstrated that participants can override the bottom-up saliency by top-down task sets when a singleton search mode becomes less efficient. When the number of targets was increased, the additional singleton could be ignored. Theeuwes (2004) answered this critique with results from a comparable experiment. When display size was increased, participants attended the additional singleton irrespective of number of targets.

The aforementioned studies characterize salient stimuli mainly by certain physical attributes. Wentura, Müller, & Rothermund (2014) showed, that colors that had been paired with gains or losses before, boosted the additional singleton effect, i.e. increased bottom-up attentional effects through their relevance as gain or loss signals. Similarly, Schmidt, Belopolsky, and Theeuwes (2014) showed that irrelevant stimuli that had been paired with fear in a conditioning procedure, slowed down visual search. This is seen as evidence for attentional capture of fear-associated stimuli. Mulckhuyse and Dalmaijer (2016) found increased latencies of saccades toward neutral targets in the presence of fear-conditioned distractors.

Evidence for attention to threatening faces in the additional singleton paradigm is rare. Huang, Chang, and Chen (2011) found attentional capture of threatening targets as well as impaired disengagement from irrelevant threatening distractors. Additionally, when presentation time of the search display was limited to 300ms attention to irrelevant distractors was reduced, when the distractor was located outside a 100% validly cued target area. The authors argue, that this is evidence for a capacity dependent attentional capture. When resources are scarce, attention is top-down focused on the area of interest and stimuli outside of this area no longer capture attention. However, this manipulation is not unambiguous. The absence of attentional capture might be attributed to the shorter presentation of the search display to a clear top-down set that excludes the possibility of target presentation outside the cued area or to both manipulations. All in all, evidence of emotion effects in additional singleton studies is rare, especially with natural faces. In sum, visual search paradigms offer no valid clues on attentional capture of emotional faces.

1.3.3 **Stroop Interference Task**

Another example of bottom-up attentional processes is often seen in the so-called Stroop task (Stroop, 1935). Note that in contrast to the visual search paradigm the Stoop task is a non-spatial paradigm, i.e. it does not measure preferred orienting to a certain location in space but rather an attention to certain stimulus features. Participants in the experiments of Stroop (1935) had to classify the ink color of presented color-words. The color-naming was slowed when the semantic content of the word referred to a different color than the ink. However, considering the fact that the task was color-naming, the results are not convincing, because thereby color became a relevant feature. In the emotional Stroop task to the contrary, participants are asked to name the ink color of emotion-related words. Emotion effects found cannot be attributed to the fact that emotions are a relevant feature, which is solving the former problem. Since the meaning of the word does not elicit a response that is in opposition to the task-relevant response, the measured effects are no interference effects on the response level like those in the original Stroop paradigm but rather reflect a disruption of color naming by the emotional content.

Additionally, Algom et al. (2008) argued, that there is no semantic relation of the meaning of the distractors with the target relevant dimension (color) and therefore, the interference is also not comparable to the flanker paradigm, where a dimensional overlap between target and distractor can be found.

Instead, it is argued that the effects are caused by a general slowing of responses or a kind of interrupt effect in the presence of emotional stimuli rather than an attentional capture (e.g. Algom, Chajut, & Lev, 2004, Mckenna & Sharma, 2004). It was found that emotional words not only impaired color naming, but also reading and lexical decisions. Additionally, this was only the case, when emotional and neutral words were presented in blocks (Algom, Chajut, & Lev, 2004) and effects were more pronounced in the trial after the emotional distractor trial (McKenna & Sharma, 2004). This is seen as strong evidence of a slow unspecific effect opposed to a fast emotion specific attentional effect. Finally, although Stroop effects of emotional stimuli have been demonstrated (e.g. Williams, Mathews, & MacLeod, 1996), they are not consistently found in normal participants. With non-anxious participants many emotional Stroop studies fail to demonstrate effects (Williams et al., 1996) or find very short-lived effects only (Compton et al., 2003; McKenna, 1986).

1.3.4 **Conflict Tasks**

Conflict task have in common, that the relevant target and the irrelevant distractor differ on a common dimension in some trials (dimensional overlap) In these conflict trials responses to the target are impaired when attention is captured by the irrelevant distractor.

Emotional Conflict Task

In order to solve the problems of the emotional Stroop paradigm, Etkin, Egner, Peraza, Kandel, and Hirsch (2006) developed a similar paradigm with emotional faces. In this paradigm emotional facial expression (happy, fearful) needs to be classified while an emotional word (HAPPY or FEARFUL) that is printed on the target picture needs to be ignored. The difference of this task and the emotional Stroop task is the dimensional overlap of target and distractor semantics, i.e. both stimuli are emotional. This results in a stimulus interference in terms of emotion as well as a response interference. In this respect the emotional conflict task is similar to the flanker paradigm. It is found, that targets with a congruent distractor (i.e. both happy or both fearful) are classified faster than targets with incongruent distractors (Bang, Rø, & Endestad, T., 2016; Egner, Etkin, Gale, & Hirsch, 2008; Egner, Peraza, Kandel, & Hirsch, 2006). However, the same is also found for the non-emotional variant of the conflict task (gender classification with FEMALE and MALE as distractor words). Although this task creates a conflict situation with a comparable control condition and thus is well suited to measure processes of conflict, the congruency effects represent processing of a semantically relevant feature carried by an irrelevant stimulus, i.e. the results do not differentiate, if attention is captured by the emotional content or if the distractor just interferes with the target classification because it activates a relevant response.

Flanker Paradigm

The emotional conflict task (Etkin et al., 2006) that has been reported in the previous paragraph has a logic, that is similar to that of the flanker task. The flanker paradigm in its original form was designed to measure the interference of letter-distractors in a letter discrimination task (Eriksen & Eriksen, 1974). Therefore, a central target letter was presented, which was flanked by wo or more peripheral distractor letters. Typically, a 4:2 mapping is used, i.e. 4 different stimuli are mapped onto two possible responses. Thus, the flanking letters can be identical to the central target or they can be different, but activate the same response or they can be different and activate a different response. The flanker paradigm offers no direct competition of different distractors in one trial. Instead, like in the emotional conflict task (Etkin et al., 2006) distractors are presented in conflict to the target and effects are compared over different trial types. Response facilitation effects can be calculated by a difference between responses to prime-target-pairs activating the same response and those activating different responses. Additionally, a comparison of compatible trials with congruent and those with incongruent stimuli that nevertheless activate the same response offer information on the effects at the stimulus level. Fenske and Eastwood (2003) developed an emotional variant of the flanker task to investigate the impact of emotional flankers on target classification. In a typical flanker paradigm of this kind, a central target face is flanked by two distractor faces on the right- and left-hand side. Participants indicate the nature of the central target, e.g. press a key that is mapped onto a certain emotion. Fenske and Eastwood (2003) obtained flanker compatibility effects, i.e. a positive difference of target-distractor-pairs that are incompatible minus compatible with respect to the response-relevant dimension. These were more pronounced for positive targets than for negative ones, indicating a greater constriction of the attentional focus by negative targets. Emotion compatibility effects have also been demonstrated by several other authors (Barratt & Bundesen, 2012; Fenske & Eastwood, 2003; Grose-Fifer, Rodrigues, Hoover, & Zottoli, 2013; Horstmann, Borgstedt, & Heumann, 2006, exp. 1). Interestingly, most reported studies used schematic faces (Barratt & Bundesen, 2012; Fenske & Eastwood, 2003, Horstmann, Borgstedt, & Heumann, 2006). This suggests that attention to emotional faces in the flanker task might be difficult to find with natural faces. Correspondingly, Moser et al. (2008) found no significant attentional bias towards threatening natural faces in socially anxious people but a significant compatibility effect.

However, Horstmann and colleagues (2006) found evidence for the hypothesis that differences in perceptual features rather than emotional content cause the emotion effects in flanker studies (e.g. Fenske & Eastwood; 2003). Therefore they reduced the schematic faces to non-face stimuli preserving just some salient parts of the respective original schematic face stimuli. Horstmann and colleagues (2006) showed flanker effects for facial stimuli as well as non-facial stimuli, demonstrating, that low level aspects of the schematic faces are sufficient to find compatibility effects.

However, compatibility effects do not measure the actual attentional capture but instead a response component, that develops later in time. This can be demonstrated in studies, where responses are given to a second non-emotional stimulus feature (e.g. gender). Typically, flanker effects of the second feature (e.g. gender) replace flanker effects of emotion in this condition (Zhou and Liu; 2013). As mentioned, the original flanker task adopted a classical 4:2 mapping with four different letters mapped on two response keys. This allows to investigate response compatibility effects as well as stimulus congruency effects. The 4:2 mapping of the original flanker task however, is not realized in the modified version of Fenske and Eastwood (2003).

Only few authors also analyzed so-called distraction effects, i.e. the amount of distraction in target processing by emotional distractors compared to neutral distractors, controlling for compatibility effects as well as target main effects (Barratt & Bundesen, 2012; for a detailed description of distraction effects see Tannert & Rothermund, 2018, p. 4). In a study with natural faces Grose-Fifer and colleagues (2013) showed significant interference for distractors competing with happy but not fearful target faces, i.e. attention was more captured by fearful than by happy distractors. This effect was even more pronounced in adolescents. Chen, Yao, Qian, and Lin (2016) used faces generated by the face gen software (https://facegen.com) that are more complex than schematic faces. They found distraction effects of negative compared to neutral flanker faces overall and in the high socially anxious group. Interestingly, there were no reliable emotion compatibility effects.

In sum the flanker paradigm has mainly been used to investigate response-based effects of schematic emotional faces so far. Investigations of attentional stimulus based effects of natural faces in the flanker task can rarely be found and results are not consistent.

1.3.5 **Cueing Paradigm**

As stated in the previous paragraph, the flanker paradigm has rarely been used to investigate response independent attentional effects of emotional faces. A better suited measurement of bottom-up attention to task irrelevant stimuli offers the spatial cueing paradigm

(Posner, 1980). In this paradigm targets are preceded by either centrally (endogenous cueing) or peripherally (exogenous cueing) presented distractors. The cue can pre-activate the actual position (valid) or the position opposite (invalid) to the upcoming target. After a short presentation time cues vanish and a fixation display is shown, followed by the target display. The target is presented in one of the possibly cued locations. The task is either to detect the target and indicate the side, or to discriminate and categorize certain features of the target, e.g. shape. In valid trials, attention to the cue means that the spotlight is already turned to the target location when the target appears. This leads to fast responses, while in invalid trials attention to the cue leads to a delayed response because attention is initially turned to the wrong side. The difference of response times between targets following invalid cues and those following valid cues is called validity effect. Typically, this effect is growing with the amount of attention that was directed to the respective cues. The spatial cueing paradigm enables researchers to disentangle response effects from attentional effects. Requesting a neutral response to a neutral target, a spatial cueing task allows researchers to attribute emotion effects to processes that happen before response selection (Fox, Derakshan, & Standage, 2011).

To test whether emotional stimuli capture more attention than neutral ones (i.e., dot-probe paradigm) MacLeod, Mathews, & Tata (1986) used a double-cueing paradigm, where every trial starts with the simultaneous presentation of two exogenous cues, one at each possible target position. Each trial contained an emotional and a neutral cue. In either half of the trials the emotional cue and the neutral cue was valid respectively. Enhanced attentional capture of emotional compared to neutral stimuli is assumed to produce higher validity effects for emotional stimuli. This was confirmed in a few studies using special samples (e.g. Fox et al., 2002). However, this finding is mostly limited to socially anxious participants (Bar-Haim et al. 2007; Helfinstein et al., 2008, Klumpp and Amir, 2009) and hardly replicable in the normal population with non-anxious participants (Bar Haim et al. 2007; Mogg & Bradley, 1999; Van Rooijen, Ploeger, & Kret, 2017).

Additionally, the dot-probe paradigm is not suited to disentangle engagement based-effects and disengagement-based ones. Congruency effects of emotional compared to neutral cues in the dot-probe task can be the result of two mechanisms. Attentional capture by the emotional cue leads to an orientation to the position of the upcoming target in congruent trials leading to faster responses and an orientation to the wrong side in incongruent trials leading to slower responses. However, another mechanism, namely impaired disengagement from emotional stimuli should also lead to slower responses in incongruent trials. The latter process might produce smaller effects than the former, because without directed attentional capture by one stimulus, attention would be engaged by one of the cues by chance, i.e. engagement by the emotional stimulus would occur in 50% and the probability that this stimulus is incongruent would be again 50%. This means, that the impaired disengagement should slow down on average 50% of the angry incongruent trials (25% of the total trials) while attentional orientation effects should impair responses in 100% of the incongruent trials (50% of the total trials). However, since we only see the outcomes, congruency effects could possibly be both due to engagement or disengagement or both. Especially with long cue-target intervals it is possible that several attentional shifts take place until target presentation (Cooper & Langton, 2006). This problem can be reduced when short CTIs are used (Müller & Rabbitt, 1989). Therefore, Cooper and Langton (2010) recommend to test attentional capture in the dot-probe task with a wide range of CTIs starting at 100ms or shorter and reaching up to 500ms or longer. Unfortunately, most of the results stem from studies using a CTI of around 500ms which promotes disengagement effects (Macleod et al., 1986; Mogg & Bradley, 1999; Chen, Ehlers, Clark, & Mansell, 2002; Egloff & Hock, 2003).

1.4 Attentional Capture is not Consistently and Doubtlessly Found

In sum, the empirical evidence for attentional capture of emotional faces is not fully conclusive. While singletons in the classical visual search paradigm are not independent from the task, evidence from additional singleton studies might be suited to inform about attentional capture of irrelevant distractors. However, empirical results are mixed. While some demonstrate attentional capture by irrelevant singleton (Theuwes, 2004), others show, that attentional capture of irrelevant singletons can be overridden when another search mode is adopted (Bacon & Egeth, 2003). Research on emotional additional singletons has rarely been published. Wentura, Müller, and Rothermund (2004) demonstrated attentional capture by irrelevant color-singletons that had been paired with gains or losses before. Similar results were obtained for fear-conditioned stimuli (Mulckhuyse & Dalmaijer, 2016; Schmidt et al., 2015). Huang Chang, and Chen (2011) demonstrated attentional capture of emotional faces that was eliminated, when the additional singleton was presented only briefly (300ms) and outside a pre-cued area. This casts doubt on a pure bottom-up account of attention but remains equivocal, because presentation time was also reduced. For the emotional Stroop paradigm, there is strong evidence that the effects are unspecific slow-downs rather than attentional in nature (Algom, Chajut, & Lev, 2004, Mckenna & Sharma, 2004; McKenna & Sharma, 2004). The flanker paradigm as well as the emotional conflict task did reveal attentional capture of relevant attributes carried by irrelevant stimuli. This however does not mean, that emotional stimuli also attract attention, when the emotion dimension is completely task irrelevant. In fact, it has been shown, that stimuli carrying other task relevant attributes also produce effects (Egner et al., 2006). Related to this, the classical effect in flanker studies is a response based compatibility effect. Attentional capture however should also manifest in stimulus based effects. Although it is possible to calculate stimulus based distraction effects in flanker experiments, this has rarely been done so far. Moser et al. (2008) as well as Chen, Yao, Qian, & Lin (2016) found attentional distraction in a flanker task with faces but failed to find compatibility effects. Participants of Moser et al. (2008) however, were socially anxious. Although attentional capture of emotional faces has been demonstrated in the flanker paradigm and visual search paradigms, several studies suggest, that low level features rather than emotional content cause the attentional effect (Horstmann et al., 2006; Horstmann, Lipp, & Becker, 2012).

Interestingly, there are only few studies, that demonstrated attentional capture of natural emotional faces. Bindemann et al. (2005) only found compatibility effects with natural faces, when the target was no natural face. They interpreted this as evidence for the claim, that distractor processing is reduced, when processing resources are limited.

Finally, the dot-probe-paradigm seems to be suited well to demonstrate attentional capture of emotional faces because it allows for disentangling response-effects from attentional effects. Additionally, the distractors are fully task-irrelevant. However, findings from the dot-probe paradigm are mostly relying on socially anxious samples and many studies failed to find attentional capture of emotional faces with normal participants (Bar-Haim et al., 2017; Victeur, Huguet, & Silvert, 2019) or even show a vigilance for non-threatening compared to threatening stimuli (Koster, Verschuere, Crombez, & van Damme, 2005; Mogg et al., 2000; Wilson & MacLeod, 2003). All in all, existing studies on attention to emotional faces are either not specifically designed to show pure capture effects or are conducted with special samples. Only few studies find pure attentional capture with normal non-anxious participants in a paradigm, that is suited to find them. Thus, the existence of pure attentional capture by natural emotional faces is, although evolutionary plausible and suggested by neuroscientific results, not consistently demonstrated in behavioral studies. Additionally, there are not only conflicting empirical results on the role of top-down and bottom-up influences on selection of emotional stimuli (eg. Lamy, 2010; Theeuwes, 2010) but also alternative explanations of seemingly bottom-up capture effects (e.g. Calvo & Nummenmaa, 2008; Horstmann, Lipp, & Becker, 2012; Savage, Lipp, Craig, Becker, & Horstmann). A very early influence of top-down attentional sets like goals and tasks is proposed by the contingent capture account (Folk et al., 1992), which is underlined by several empirical findings (see Victeur et al., 2019).

1.5 Current Dissertation

The previous chapter shows that, although attention to emotional faces has been investigated in the past, there is no consensus on the question, if and under what circumstances natural emotional faces capture early visual attention. The above considerations show, that the interplay of different processes in attentional selection of emotional faces is rather complex and not yet fully understood. Concrete predictions of which emotional stimuli are selected when and in conflict to which other stimuli, cannot be reliably deduced so far. Therefore, the present dissertation aims at investigating the boundary conditions of attentional capture by emotional faces. In our research, we were interested in several questions:

1. Do natural emotional faces capture attention in a purely bottom-up manner?
2. What are the boundary conditions of early attentional capture by natural emotional faces?
3. How can the identified parameters that influence attentional capture of natural emotional faces be integrated in a theoretical framework of attentional selection?

Thus, the current work sets out to investigate the most basic proposed mechanism of pure bottom-up attentional capture of natural emotional faces and continues with systematically investigating the preconditions of further top-down influences.

The first manuscript (Puls & Rothermund, 2017) was conceptualized to replicate previous findings of bottom-up attentional capture. Therefore, emotion was rendered fully irrelevant for the task. In order to rule out different alternative explanations, like inhibition of return, rapid disengagement or bottom-up influences, we implemented a wide range of different timings and also systematically varied distractor sizes, eccentricities and cue face relations.

After not having found any evidence for bottom-up attentional capture in the dot-probe task, we decided to further investigate the conditions of top-down influences in attention to natural emotional faces (manuscript 2; Tannert & Rothermund, 2018). Therefore, we designed five flanker experiments. The flanker task has several advantages for our goal to progressively give rise to top-down influences in order to examine the boundary conditions of appearing effects of emotional faces. Targets and distractors in the flanker task are present simultaneously. This makes it more difficult to ignore the distractors and thereby boosts possibly present but weak effects of emotional compared to neutral distractor faces. Furthermore, the direct competition creates a far more ecologically valid situation. It has been argued in the past that a dot-probe study that lacks this direct competition does not permit for inferences about the mechanism of selection because the presentation of distractors without any relevant stimulus is not corresponding to a real selection situation (Parra, Sánchez, Valencia, & Trujillo, 2017). Additionally, the sudden onset of the target in a dot-probe task might cover attentional capture effects because of the high saliency of the onset-target. In the flanker paradigm to the contrary target and distractor presentation start simultaneously. Finally, in the dot-probe paradigm the timing is very important, because with longer times between distractor onset and target onset an attentional dwelling begins, that impedes a straightforward interpretation of the results. This often leads to difficulties in interpreting null-effects because it cannot be inferred if the effect was not present or just invisible due to other processes that happened after the capture. Due to simultaneous presentation in the flanker task, attentional dwelling should not occur. In order to allow for top-down influences we varied task relevance of emotion, including a task, that was not emotional at all, one that was valence-related and one that asked for a classification of the concrete emotion. Additionally, we varied if flanker processing was mandatory or not. Generally, the introduction of mandatory distractor processing along with goal relevance of the emotion dimension precludes the demonstration of pure attentional capture. Still it was done in order to identify and delineate conditions of attentional orientation to emotional faces. Stimuli were presented at fixed or variable positions in different studies respectively. Based on calculations of distraction effects as well as compatibility effects it is possible to differentiate and individually investigate stimulus-based effects and response-based effects.

Finally, in our third manuscript, we showed that attention to gender can be induced by a combination of task and contextual cues. Although the link to attention Is not obvious, an influence of distractor gender shows, that distractor faces have been processed. Specifically, it is demonstrated that an emotion related task, together with a context that renders gender information relevant, leads to a selective attention to gender information. This facilitates the procession of a stereotypically expected upcoming emotion.

The results of the 13 presented experiments are discussed in the light of classical and recent findings in the literature thereby focusing on the top-down-bottom-up-debate (chapter 5.2.). The concept of experience-based selection (Failing & Theeuwes, 2018; Theeuwes, 2018) is brought up as a promising account which is suited to explain the present as well as previous results.

2 Manuscript 1: Attending to Emotional Expressions - No Evidence for Automatic Capture in the Dot-Probe Task

Puls, S., & Rothermund, K. (2018). Attending to emotional expressions: no evidence for automatic capture in the dot-probe task. *Cognition and Emotion*, *32*(3), 450-463. doi: 10.1080/02699931.2017.1314932

3 Manuscript 2: Attending to Emotional Faces in the Flanker Task - Probably Much Less Automatic Than Previously Assumed

Tannert, S., & Rothermund, K. (2020). Attending to emotional faces in the flanker task: Probably much less automatic than previously assumed. *Emotion*, *20*(2), 217. doi: 10.1037/emo0000538

4 Manuscript 3: Stereotype-Based Spatial Frequency Tuning-Illustrating the Context-Dependent use of ‘Irrelevant’ Stimuli

Stereotype-Based Spatial Frequency Tuning:

Illustrating the context-dependent use of “Irrelevant” Stimuli

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Stereotype-Based Spatial Frequency Tuning

Word count: 3966

Abstract

The gender of a face biases emotion perception: Anger is more readily detected in male than in female faces whereas the reverse asymmetry holds for passive emotions like fear or sadness. We tested the hypothesis that this gender-emotion link is related to spatial frequency tuning. In line with predictions, male (female) face primes facilitated the classification of low (high) frequency Gabor patches. Arguing against a low level stimulus-based explanation, this gender asymmetry in spatial frequency tuning was found only under conditions in which gender is a relevant category (romantic context) but not in a gender-neutral context.

Key words: gender stereotypes, facial emotion, spatial frequency, face perception, priming

The decoding of emotional facial expressions is essential in almost every social interaction (Keltner & Haidt, 1999). People all over the world can identify the basic emotions when the expression is unambiguous and when there is enough time (e.g., Ekman, Sorensen, & Friesen, 1969; Izard, 1994). In real life, however, emotions must be decoded faster, under suboptimal viewing conditions, and from much less obvious expressions. People are seen from different distances and angles, under low or changing illumination, or with partly occluded faces. Especially when ambiguity is high, that is when emotions are not easily identifiable in a face, social categories are often used as cues in order to accomplish an efficient decoding of a situation, thereby guiding perception, appraisal, and action (e.g., Hugenberg & Bodenhausen, 2004; Kunda & Sherman-Williams, 1993). One easily accessible and useful category in this regard is gender. It is a well-established finding in the literature that people ascribe emotions to males and females differently (Broverman, Vogel, Broverman, Clarkson, & Rosenkrantz, 1972; Williams & Best, 1990). Specifically, anger and contempt is more readily ascribed to men, while, happiness, fear and sadness are more easily ascribed to women (Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007; Hess, Adams, Grammer, & Kleck, 2009; Plant, Kling, & Smith, 2004, Plant, Hyde, Keltner, & Devine, 2000).

There are multiple ways in which gender information can potentially influence emotion perception: The most common assumption is that gender information activates corresponding stereotypes that in turn influence emotion perception via expectancies and judgmental tendencies (e.g., Macrae & Bodenhausen, 2000). Neuronal evidence suggests top-down influences of social cognitive factors, like stereotypes. Several interconnections between brain structures that are known to be related to processing of emotional stimuli, faces, and social cognitive information have been identified to mediate processing of facial expressions based on social cognitions (Adolphs, 2003; Brothers, 1990, Haxby, Hoffman, & Gobbini, 2000; Kanwisher, 2000; for a summary see Freeman, Johnson, Adams, & Ambady, 2012). In this study, we want to test an even more subtle influence of gender categories on emotion perception that is due to spatial frequency tuning. Previous research has shown that the information that is used to identify and distinguish specific emotions is coded in different spatial frequency bands (Smith & Schyns, 2009): Anger is best recognized on the basis of information that is coded in the lower spatial frequency (LSF) bands, that is, the most distinctive information for anger consists in light/dark-contrasts comprising larger areas of a face (e.g., smooth and global changes from light to dark that are located on the forehead, the brows, or the eye regions). On the other hand, sadness and fear are better recognized on higher spatial frequency (HSF) bands, that is, the most distinctive information for these emotions consists in relatively sharp contrasts covering only very small regions of the face (e.g., wrinkles at the edges of the eyes or the mouth).

Based on these findings indicating that low vs. high spatial frequencies contain information that is diagnostic for stereotypically male and female emotions, we propose that gender categories exert their biasing influence on emotion perception via spatial-frequency tuning (Bocanegra & Zeelenberg, 2009; Hübner, 1996; Sowden, Özgen, Schyns, & Daoutis, 2003). Specifically, activating the category "male" should tune the visual system towards low spatial frequencies. Increasing the sensitivity of the LSF channel should yield an advantage in detecting typically male emotions (anger) for which the LSF band is highly diagnostic. Activating the category "female", on the other hand, should sensitize the visual system towards processing high spatial frequencies. This kind of tuning should yield an advantage in detecting typically female emotions (fear) for which the HSF band is more diagnostic.

When investigating effects of social categories and stereotypes, an important qualification has to be kept in mind: Social categorization and stereotype activation are context-dependent. Which of multiple social categories (e.g., gender, age, ethnicity) is salient and determines the classification of a person, and which aspect of a complex stereotype becomes activated and is used for person perception crucially depends on the situation (e.g., Biernat & Vescio, 1993; Blair, 2002; Casper, Rothermund, & Wentura, 2010, 2011; Diekman & Hirnisey, 2007; Gawronski & Cesario, 2013; Müller & Rothermund, 2012). We thus expect that gender biases in emotion classification and spatial frequency tuning should occur if the gender of another person is a relevant and salient social category in the respective situation (e.g., in a romantic context). For situations in which gender is irrelevant or in which other aspects of the situation dominate social information processing, we expect gender biases in emotion perception to be less pronounced or non-existent.

We tested these assumptions in a priming study in which pictures of neutral-looking male and female faces were used as primes. After each prime presentation, the neutral face either changed its emotional expression into angry or fearful, or it was replaced by a high or low frequency Gabor patch that was tilted to the left or right (see Figure 1). Depending on the type of the target stimulus in a given trial, participants either had to categorize the emotional expression or had to indicate the tilt of the Gabor patch. In addition, either a gender-relevant or a gender-irrelevant context was activated during separate blocks of the experiment by presenting the experimental stimuli in front of background pictures depicting either a romantic (gender-relevant context) or a bleak scenario (gender-irrelevant context). Our idea was that a romantic context by default implies the presence of a man and a woman and activates corresponding gender specific role models and stereotypes. In a bleak scenario lacking specific objects and information, however, there is no direct relation to gender. If at all, the bleak background might be perceived as being oppressing and might activate a generally heightened sensitivity for threat, including both anger and fear. Even if such associations might become activated, they will be unrelated to gender. We thus hypothesized gender biases in emotion classification (anger-advantage after male primes, fear advantage after female primes) and in the Gabor classification task (LSF advantage after male primes, HSF advantage after female primes) if a gender-relevant context was activated. No or only weak gender biases were expected to occur if a neutral context was activated that was not gender-relevant.

Method

Sample. Sample size was calculated on the basis of our intended power of the experiment and the likely effect. Since our study is innovative and cannot draw on a large literature reporting effects for similar studies and paradigms, we decided to assume a medium effect size for our calculations. With a medium sized effect (d=0.5; Cohen, 1992) and a proposed minimum power of β=.90, 36 participants were necessary to find the intended effect (a priori calculations of sample size were conducted with G-Power 3; Faul, Erdfelder, Lang, & Buchner, 2007). Fourty students (17 male) from different disciplines participated for monetary reward. They were recruited through advertisements on campus. Four participants with high error rates in either of the two tasks (outliers according to Tukey, 1977) were discarded from the analysis.

Stimuli and Materials. The experiment was run on a 17'' CRT Monitor (XGA resolution 85 Hz) with participants seated at a distance of 57 cm from the screen. For experiment control and data collection we used the open source software Psychopy 1.8.07 (Peirce, 2007). Ten male and ten female faces were selected as experimental stimuli from the Radboud Faces Database (Langner et al., 2010). Another four faces of each gender served as stimuli during the practice block. Each face was shown frontally with either a neutral, a fearful, or an angry expression. Faces were cut in oval and presented in greyscale in front of background context pictures that were retrieved from the Internet. Four colored photographs depicting a bleak scene (e.g., an underground station, an old factory building) were chosen for the gender-irrelevant condition; another four pictures were selected that portrayed a romantic atmosphere representing the gender-relevant condition (e.g., showing a room with a fireplace and glasses of wine). Furthermore, we used round Gabor stimuli (sinusoidals) generated by Psychopy (Peirce, 2007, 2009). Gabors were 512 pixels in diameter and had a contrast of 70% and a frequency of 3.7 cycles/deg (high spatial frequency) or 0.2 cycles/deg (low spatial frequency), respectively. The stripes were tilted by 20 degrees leftward or rightward from vertical.

Procedure. Participants were presented with two short texts, one describing a romantic situation, the other describing a dangerous incident. Participants were told to match the gender-relevant (romantic) and gender-irrelevant (bleak) background pictures to these texts during the experiment. Following the mental imagery task, participants practiced classifying the emotion expression of 32 faces by moving the mouse forward or backward (assignment of angry vs. fearful faces to upward/downward movements was counterbalanced across participants). Reactions were logged as soon as the mouse cursor reached a threshold of 200 pixels above or beyond fixation. In a second practice block, they had to indicate the tilt direction of 32 Gabor stimuli by pressing the left or right mouse-key. No context pictures were presented during the practice blocks. All stimuli were presented against a neutral gray background. The main experiment consisted of eight blocks, each comprising eighty trials. Within each block, one background picture was presented that was drawn from either the gender-relevant (romantic evening) or gender-irrelevant (bleak scene) set, that is, every block contained only one of the eight background photographs. The 320 emotion classification trials and 320 Gabor classification trials were presented in a random sequence throughout the experiment, so that the upcoming task was unpredictable at the beginning of each trial. Intermixing trials from both tasks randomly throughout the experiment was necessary in order to establish emotions as a relevant category during the entire task. Specifically, since participants did not know in advance which of the two tasks would be required in the next trial, they had to keep the emotion classification goal active also in the Gabor classification trials.

Each trial consisted of the following sequence of events (see Figure 1). A white fixation cross was shown for 300 ms and was then replaced by a neutral oval cut face that was presented for a variable duration (500 ms to 1000 ms). Varying the duration of the prime presentation rendered the onset of the target unpredictable and ensured attention allocation to the primes. In case of an emotion classification trial, the neutral face prime turned into an emotional one by replacing the neutral version of the face with either the angry- or the fearful-looking version of the same person. In case of a Gabor classification trial, the neutral face prime was replaced with a Gabor stimulus. Target stimuli remained on the screen for 50 ms and were then removed from the screen, leaving only the background picture visible until participants had responded by either moving the mouse upwards or downwards (emotion classification task) or by pressing the left or right mouse-key (Gabor classification task). Incorrect responses were signaled by a 100 ms tone of middle pitch. After each block of 80 trials, participants could take a break.

Results

Trials with erroneous responses and trials following a wrong response (11.71 %) were excluded from the RT analyses. Extreme values that were more than three interquartile-distances above the 75th percentile of the individual RT distributions for the respective task ("far out" values according to Tukey, 1977; 1.94 %) and RTs that were below 200 ms (0.02%) were removed from the RT analyses. Three people used a switched mapping of emotion responses that was opposite to instructions. Their reactions were recoded.

Gabor-Task

RT data. A 2 (gender of the face prime) x 2 (frequency of the Gabor target) x 2 (gender relevance of the context picture) analysis of variance (ANOVA) of the Gabor-classification trials revealed a significant main effect of spatial frequency, $F(1, 35) = 4.56$, $p < .05$, $\eta_p^2 = .12$, with high frequency gabors being faster classified than low frequency gabors. More importantly, we also found the predicted significant three-way interaction, $F(1,35) = 4.79$, $p < .05$, $\eta_p^2 = .12$. Following up on this interaction, we calculated planned contrasts for the gender-relevant (romance) and gender-neutral contexts. In the gender-relevant (romance) context, a significant gender x frequency interaction emerged, $F(1,35) = 6.69$, $p < .05$, $\eta_p^2 = .16$. The pattern of means for this interaction corresponded to our prediction with Gabor classifications being relatively faster for low frequency target patches after male face primes and for high frequency target patches after female face primes than for the opposite combinations of face gender and Gabor frequencies. For the gender-irrelevant context, the interaction was non-significant, $F(1,35) = 1.11$, *ns*. Participant gender did not moderate the findings in theoretically relevant ways. Only the interaction of spatial frequency x participant gender came close to significance, $F(1,34) = 3.29$, $p < .10$, $\eta_p^2 = .09$, indicating a high spatial frequency advantage for female but not for male participants. This finding did not involve the factors of interest (gender of the face prime, context) und thus did not relate to our predictions. All other effects involving participant gender were non-significant, all $F < 1.5$, $p >. 20$.

Accuracy data. Error rates were arc-sine transformed before statistical analysis. The error analysis yielded a significant main effect of spatial frequency, $F(1,35) = 7.81$, $p < .01$, $\eta_p^2 = .18$, with high frequency Gabor patches being classified less correctly. The crucial interaction of spatial frequency, gender and context did not reach significance, $F < 1$.

Emotion-Classification

RT data. The descriptive pattern of reaction times in the emotion-classification-task closely matched the pattern that was found in the Gabor task: In an analysis of variance we found a main effect of context, $F(1, 35) = 4.15$, $p < .05$, $\eta_p^2 = .11$, with faster emotion-classifications in the gender neutral condition. Planned contrasts revealed that within the gender-relevant (romance) background condition, a significant gender x emotion interaction was present, $F(1,35) = 3.34$, $p < .05$ (one-tailed[1]), $\eta_p^2 = .09$, indicating that anger and fearful classifications were faster for male and female faces, respectively. There was no hint of a gender x emotion interaction within the gender-neutral context condition, $F < 1$. However, the superordinate three-way interaction of prime gender x emotion x context failed to reach statistical significance, $F < 1$. In order to control for an influence of emotion-response mappings (fear-push/anger-pull vs. fear-pull/anger-pull), we included mapping as an additional factor into the ANOVA but found no significant effects of the factor mapping (all $F < 3.2$, all $p > .05$).

Accuracy data. Error rates were arc-sine transformed before statistical analysis. The error-data yielded a main effect of gender with more errors after female compared to male faces, $F(1,35) = 5.42$, $p < .05$, $\eta_p^2 = .13$. Even though the interaction of face-gender x emotion x context was not significant, $F < 1$, the descriptive pattern replicated the one of reaction times, indicating that the findings were not affected by speed-accuracy tradeoffs.

Discussion

The present study is the first that demonstrates an effect of gender primes on perceptual sensitivity for processing high vs. low spatial frequencies: Low spatial frequency Gabor patches were classified faster after male compared to female faces while the opposite was true for high spatial frequency Gabor patches. This finding is indicative of an emotion-specific spatial frequency tuning that prepares the organism for the identification of gender-specific emotions. Importantly, such an effect of gender primes was found only when a romantic context was activated, for which the gender-emotion link is of particular relevance. Apparently, activation of gender-stereotypical emotions – and a respective frequency tuning – is not a rigid and unconditionally automatic process. Instead, our findings suggest that gender-frequency priming is a conditionally automatic phenomenon that is triggered only by contexts in which gender is a relevant category.

Besides its theoretical relevance, the modulation of the gender-specific frequency-tuning effect by the situational context also effectively rules out alternative explanations of our findings in terms of purely perceptual priming effects that are driven by differences in low level features of the male vs. female face primes: Since the very same faces were presented as primes in both gender-relevant and gender-neutral contexts, any such difference would have resulted in a similar pattern of face-gender effects for both contexts. Since gender-specific tuning effects were obtained only for the gender-relevant but not for the gender-neutral context, however, such a purely perceptual explanation cannot account for the pattern of findings that was obtained in our study, in which gender-priming effects emerged only in the gender-relevant context condition.

The same can be assumed for the differential influence of the context pictures. Although our neutral context pictures differed from the romantic pictures in that were slightly darker, had a different frequency distribution or a different degree of pleasantness, these differences cannot explain our findings. Importantly, we did not predict or find main effects of context on the Gabor classification reactions, but instead predicted and found an interaction of background and prime gender that fits with our prediction that frequency tuning depends on combinations of gender and specific context conditions.

In combination with former findings of a stereotypical gender-emotion association on the one hand (Becker et al., 2007; Broverman et al., 1972; Plant, Kling, & Smith, 2004; Williams & Best, 1990) and emotion-frequency relations on the other hand (Smith & Schyns, 2009), our findings suggest a stereotype-dependent emotion-processing framework. When a face is shown, people draw on the most easily available characteristics to derive information about potential emotional states. In an ambiguous situation, for example, when the face is emotionally neutral or ambivalent, or when a large distance does not yet allow for an unambiguous identification of emotions from facial expressions, gender information can be utilized to automatically generate emotion-related expectations and to prepare oneself for identifying and encountering gender-stereotypical emotions in one’s interaction partner. Our study shows that an important component of this gender-emotion priming effect consists in spatial frequency tuning that sensitizes affective processing towards the detection of gender-stereotypical emotion information. Furthermore, the influence of gender on emotion processing was found to be restricted to situations in which these emotions are relevant and can be expected (romantic contexts).

Given that male/female face primes in combination with a gender-relevant context elicit both an expectation of gender-stereotypical emotions as well as a spatial frequency tuning that sensitizes the system for a fast and efficient detection of these emotions, an important follow-up question concerns the causal relation between these cognitive and perceptual mechanisms. Is spatial frequency tuning a precursor of biased emotional sensitivity that influences subsequent cognitive processes like categorization and semantic labelling via an increased sensitivity for emotion-specific diagnostic features? Or is an activation of gender-specific emotion labels and related semantic categories the first step in a subsequent cascade of biased processing that in turn influences basic perceptual processes by configuring the perceptual system in line with cognitive expectations? Our study does not allow us to investigate the time course or causal relations between cognitive and sensory/perceptual processes. Nevertheless, using variations of our priming paradigm offers straightforward solutions to answer these questions in further studies. To test for causal effects of an increased accessibility of specific emotion categories on spatial frequency tuning, one can investigate effects of emotion words as primes on subsequent Gabor classifications. The reversed causal influence can be investigated by presenting high vs. low frequency Gabor patches as primes for emotion word targets (e.g., using lexical decision or naming tasks). It should be noted, however, that the two effects need not be causally related at all – they could also reflect separate processes that independently contribute to stereotypically biased emotion processing –, nor do they necessarily have to follow a strict temporal ordering.

Finally, we would like to discuss the apparent asymmetry in the strength of the observed effects for the Gabor and emotion categorization tasks. Although the descriptive pattern of findings was highly similar for both tasks, and the predicted interaction of gender x emotion was significant for both types of tasks within the gender-relevant context condition, a significant three-way interaction was obtained only for the Gabor classification task but not for the emotion classification task. In our view, there is a straightforward explanation for this difference in findings. According to our theoretical proposition, biasing effects of gender (and context) on emotion detection and classification are assumed to be mediated via frequency tuning. Thus, whereas frequency tuning effects are an immediate consequence of specific gender/context combinations, gender biases on emotion classification represent more distal effects, and thus should be weaker than the effects that are visible in the frequency detection task. Additionally, when designing the study, we used independent response sets for the two tasks (vertical mouse movements for the Gabor classification task, horizontally arranged key presses for the emotion classification task). Using different sets of responses that are orthogonal with regard to spatial orientation and motor codes prevents cross-talk between the two tasks and rules out any influence of spatial frequency priming on emotion classifications and vice versa. However, introducing a second set of responses for the second task goes along with a reduced reliability for the second non-standard form of RT measurement (mouse movements). Determining a criterion for what constitutes a "movement" in the respective direction is somewhat arbitrary (200 pixels), in addition, movement measures always reflect a combination of two components: response onset and response speed. Being aware that mouse movements are a less reliable RT indicator, we decided to use this measure for the replication part of our study: the effect of gender primes on emotion categorization, for which evidence already has been reported in the literature (e.g., Becker et al., 2007). This allowed us to reserve the highly reliable key presses for the innovative Gabor classification part of our study. The expected difference in reliability of the two response measures was confirmed in our study and became evident in the much larger RT variance for the mouse movements (SD = 168ms) than for the key presses (SD = 119ms), which explains the somewhat lower reliability of the statistical results for the emotion classification task. Another possible explanation for the difference in findings may relate to the difference in difficulty between the two tasks. As can be seen in the absolute RTs, emotion classifications of the face pictures took much longer than classifying the direction of simple stripes. Accordingly, subtle context influences may have been harder to detect with this more complex and demanding task.

Conclusion

Our study provides first evidence for a relation between gender information and spatial frequency tuning. Based on previous research that established a link between spatial frequencies and diagnostic features of specific emotions (Smith & Schyns, 2009), we predicted a specific pattern of gender priming effects that was confirmed in our data: Whereas male face primes facilitated perceptual processing of low spatial frequencies, which are diagnostic for typically male emotions (anger), female face primes were followed by a perceptual tuning towards high spatial frequencies, which are diagnostic for typically female emotions (fear). Corresponding with recent accounts of a context-dependent activation of stereotypes (Casper et al., 2010, 2011; Müller & Rothermund, 2012; see also Blair, 2002), such a matching effect of gender primes on spatial frequency tuning was obtained only when the face primes were combined with gender- and emotion-relevant context primes.

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Footnotes

Fn. 1: Methodologically, the *F*-test for the interaction is equivalent to a one sample *t*-test that tests whether the mean for the difference variable (($RT_{female\text{-}angry} - RT_{male\text{-}angry}$) – ($RT_{female\text{-}fearful} - RT_{male\text{-}fearful}$)) is larger than zero. Thus, given our specific predictions, a one-tailed test is recommended in order to increase the power of the test (see Maxwell & Delaney, 1990, p. 144).

5 Figures

Figure 1 Experimental procedure. Following a background picture depicting the context, an emotionally neutral face prime was presented that changed unpredictably into either an emotional face (anger vs. fear; emotion categorization task) or into a tilted Gabor patch of high or low spatial frequency (left vs. right tilt; spatial frequency categorization task). Responses were given with vertical mouse movements for the emotion classification task, and with horizontally arranged mouse key presses for the frequency classification task. (face photographs have been obtained from Radboud faces database; Langner et al., 2010)

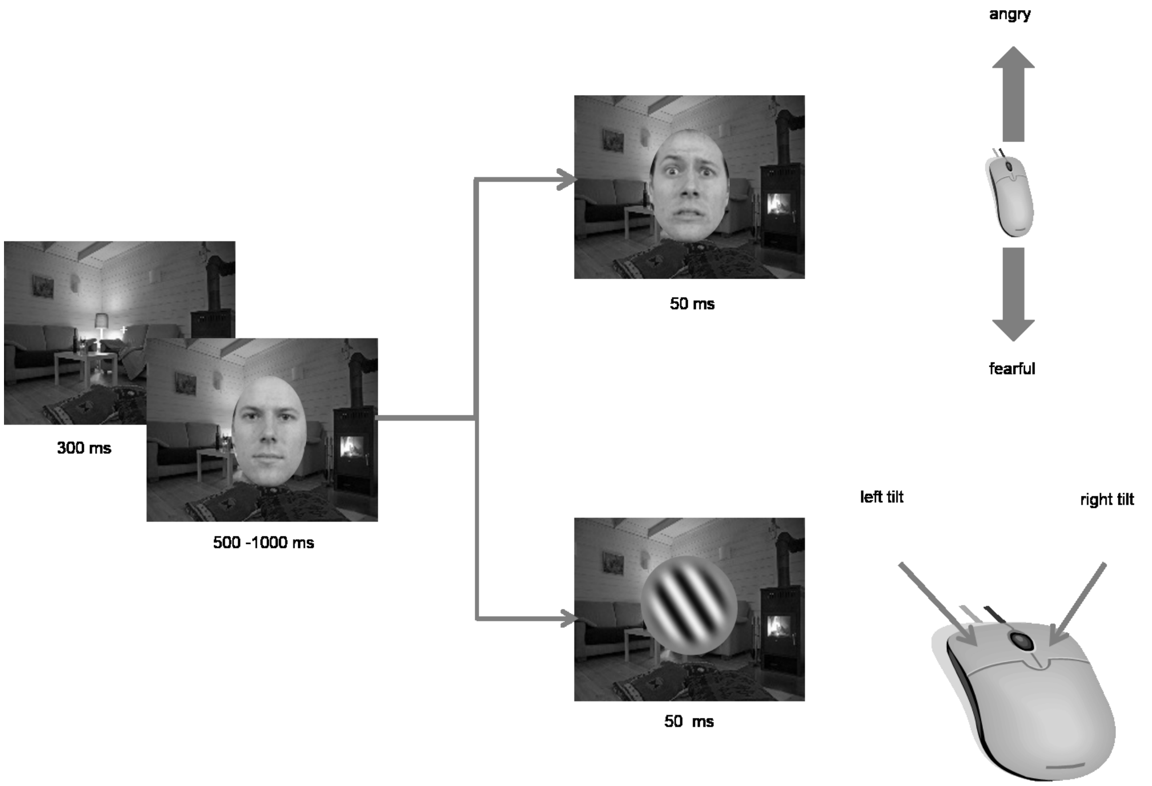
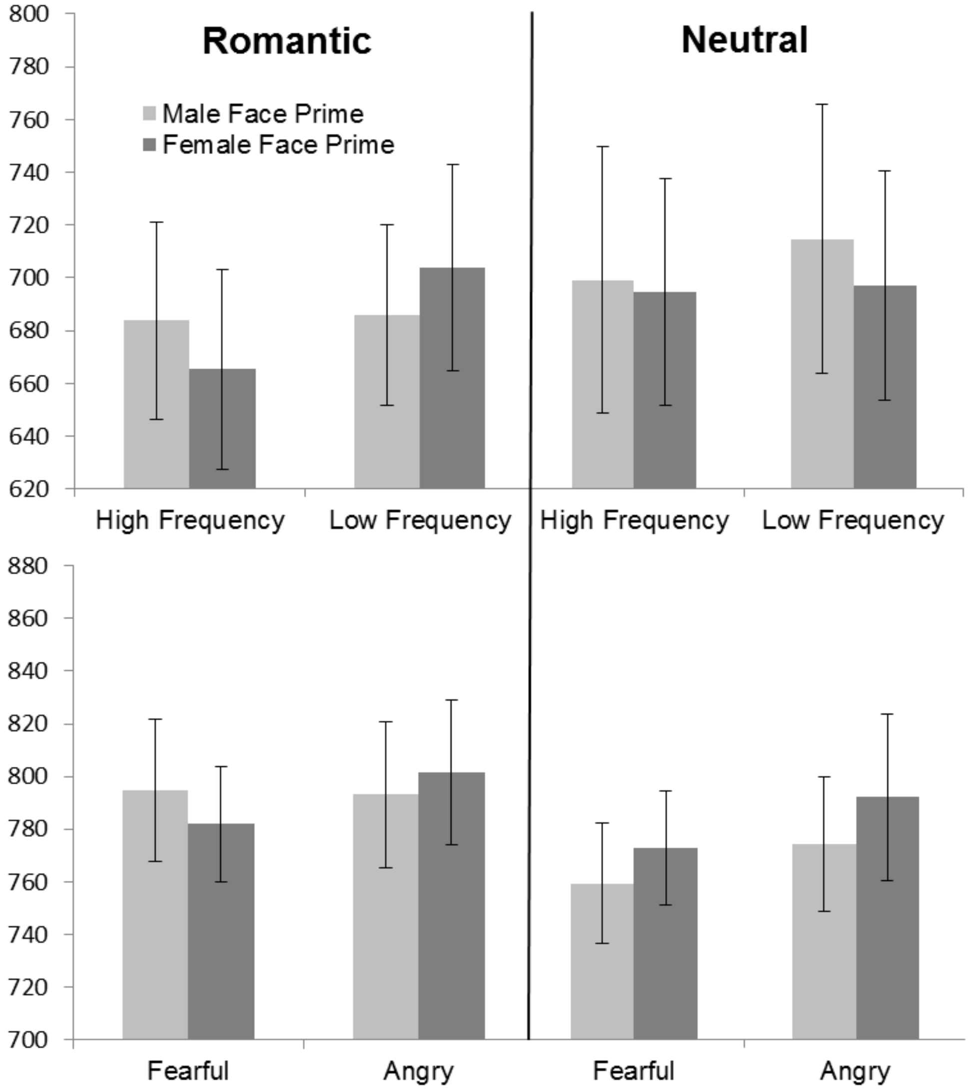


Figure 2 Mean response times in the Gabor classification (upper part) and emotion classification (lower) tasks. Error-bars indicate standard errors of the mean.



5 Discussion

The present dissertation systematically investigated, if and under what conditions emotional facial stimuli capture visual attention. For this, we conducted a series of seven experiments using the dot-probe paradigm (Puls & Rothermund, 2017), a series of five experiments using the flanker-paradigm (Tannert & Rothermund, 2018), and one experiment using a dual task paradigm (Tannert & Rothermund, submitted). None of the overall 12 experiments showed a pure bottom-up attentional capture of emotional faces.

In the seven dot-probe experiments, several relevant parameters (CTI, cue-duration, stimulus size, subliminal vs. supraliminal presentation) were systematically varied in order to address previously criticized weaknesses in experimental design and apparatus that might have led to overlooking potential effects of emotional faces. Neither a supraliminal nor a subliminal presentation led to a higher interference of emotional compared to neutral distractors. This suggests an absence of pure attentional capture by emotional faces.

In the second manuscript the effect of emotional expressions in the flanker task, in which distractors and targets were presented simultaneously (in contrast to the procedure in the dot-probe-paradigm) is investigated. This led to direct interference and increased the chance to find attentional capture effects. However, experiment one and experiment two (Tannert & Rothermund, 2018), which were composed as a classical version of the flanker task (Eriksen & Eriksen, 1974), showed neither response-compatibility effects nor distraction effects. Only after extensive modifications that made emotions a relevant dimension and made distractor processing mandatory (experiment three, Tannert & Rothermund, 2018), did attentional capture effects emerge in the form of delayed responses in the presence of emotional distractors. Additionally, an absence of emotion effects in E4a and E4b (Tannert & Rothermund, 2018) suggests that relevance of emotional faces is important for their selection. This is underlined by the fact that we found compatibility effects for the respectively relevant dimension (age, gender).

Additionally, manuscript three indicates that, given certain contextual factors, task-irrelevant stimuli are used to tune and prepare the visual system so that matching emotional expressions based on stereotypes are quickly detected. Although we did not replicate the effect of gender on emotion classification (Becker, Kenrick, Neuberg, Blackwell, & Smith 2007), we found an effect of cue gender on the Gabor classification that demonstrates the tuning of the visual system to certain spatial frequencies which is contingent on gender and a matching context. Considering that the second task was emotion classification, it seems plausible that the frequency tuning might be a top-down preparation mechanism for a faster emotion classification. This mechanism was only active when emotion was relevant in the corresponding context and relevant for fulfilling the task at hand.

In sum, the experiments in this dissertation suggest that natural emotional faces do not involuntarily capture bottom up attention regardless of task and context. Rather, given a certain relevance, early stimulus processing can be influenced top-down in order to preferentially select emotional facial stimuli.

Taking into account the present work and the studies of other researchers in the field (for recent reviews see Bar-Haim et al., 2017; Victeur et al., 2019), there is a considerable amount of evidence against a pure attentional capture of irrelevant emotional facial stimuli. Furthermore, the second aim of the present work was to identify conditions of attentional capture of emotional faces. A thorough understanding of the exact configuration that triggers attention to emotional faces is still a desiderate. Therefore, the following section is supposed to identify and concretize these conditions of attentional effects of emotional stimuli.

5.1 Relevance

In the present work, it was shown that distractors captured attention only when they contained a dimension that was either task-relevant or relevant for the decision on which stimulus was the target. Additionally, attention was drawn to gender information only when gender was relevant in the respective context (manuscript 3). Thus, the present studies offer evidence for a superior role of relevance of emotional stimuli in determining prioritized attention allocation.

According to the theory of priority maps relevance from different sources is incorporated in a calculation of conjoint relevance. This leads to attentional shifts towards the stimulus with the highest resulting priority (Bisley, 2011; Itti & Koch, 2001; Itty, Koch, Niebur, 1998; Koch & Ullman, 1985; Niebur & Koch, 1996; Theeuwes, 2010; Wolfe, 2007; Zelinsky & Bisley, 2015; for a discussion of the interplay of top-down and bottom-up factors see chapter 5.6.2). The following chapters present three main sources of top-down relevance, i.e. *tasks and goals* that have been addressed in manuscripts 1 and 2 of the present dissertation, *contextual factors* that have mainly been addressed in manuscript three, and chronic concerns. We only indirectly offer evidence for the latter in reporting the absence of attentional capture with a non-anxious sample (Puls and Rothermund, 2017), in a paradigm that has yielded emotion effects with anxious participants in the past. However, this third category of chronic concerns is strongly supported by the literature (e.g. Bar-Haim et al., 2007) and should also be mentioned here. Additionally, there may be other factors related to the domains of cognition, motivation, and emotion that will be partly discussed in Chapter 5.4.

5.1.1 Relevance due to Tasks and Goals

Task relevance is a very commonly investigated precondition of attentional effects and typically considered as evidence for top down control (Eriksen & Eriksen, 1974; Folk et al., 1992; Wolfe, 1994). Attentional biases that are contingent on current goals were previously found both in a spatial cueing task (Vogt, De Houwer, Moors, VanDamme & Crombez, 2010; Folk et al., 1992) and the flanker task (Eriksen & Eriksen, 1974). It was demonstrated in the context of priming (Feature Specific Attention Allocation Account; Spruyt et al., 2009¸ Spruyt, DeHouwer, Hermans, & Eelen, 2007) that processing one feature of a distractor does not mean that all features are processed. Rather, the relevance of the respective stimulus dimension is crucial for effects of this dimension on responses. Likewise, Barratt and Bundesen (2012) found flanker effects of emotional faces only when the task was the valence classification of the central target face, but not in a letter identification task. Accordingly, Zhou and Liu (2013) found compatibility effects in a flanker task for color, gender, and emotion with the strongest effects for the respective task-relevant dimension. Similarly, Victeur and colleagues (2019) obtained attentional capture for faces when faces were goal-relevant and additionally for emotion when facial expression was also goal-relevant. Interestingly, Vogt, Lozo, Koster, and De Houwer (2010) demonstrated, that relevance can also result from an internal emotional state that the person seeks to regulate. They found attention to stimuli related to cleanliness after inducing disgust. In this case, an internal goal might have been to remove the source of disgust.

In the present dot-probe-experiments (Puls & Rothermund, 2017) emotion was fully task-irrelevant. This was done because the intention of the first manuscript (Puls & Rothermund, 2017) was to test whether emotional faces capture attention purely bottom-up. Without task relevance the dot-probe experiments did not show any difference between emotional and neutral distractors. In the flanker experiments to the contrary, emotion was rendered relevant (experiments 1, 2, and 3, Tannert & Rothermund, 2018) through an emotion-related task. Although the results show that this manipulation alone was not sufficient to find emotion effects (experiments 1 and 2, Tannert & Rothermund, 2018), it led to emotion effects in conjunction with mandatory distractor processing. Without emotion being a relevant dimension, we found no significant differences between emotional and neutral faces (experiments 4a and 4b, Tannert & Rothermund, 2018). Thus, our experiments replicate the finding that goal relevance of emotional faces enhances attention to emotion. However, it is debatable, if what we consider as the current task is also the current task for the participants (Becker 2018). It is open, if due to certain contextual signals, beliefs, or motivational dispositions other goals become more relevant than the externally given task or are at least included in the net-effect of top-down relevance. This reasoning is in line with the extant literature on contextual effects in social information processing (e.g., Blair, 2002; Casper et al., 2010, Casper et al., 2011; De Gelder, Meeren, Righart, Van den Stock, van de Riet, & Tamietto, 2006; Lavie, Ro, & Russell, 2003; Müller & Rothermund, 2012; Van den Stock & de Gelder, 2014; Wittenbrink, Judd, & Park, 2001) and appraisal theories (Brosch et al., 2008; Brosch & van Bavel, 2012; Pool et al., 2016).

5.1.2 **Relevance due to Context**

Contextual cues are able to trigger a broad range of different goals, tasks, risks, and opportunities. They vary in norms, rules, standards and expectations, elicit impressions of familiarity or closeness, and bring along different physical features like illumination, various sounds and different numbers of present stimuli. Especially relevant with regard to processing of emotional faces is the property of different contextual constellations to imply social norms and expectations concerning the display of emotions but also to activate different experiences with emotions that lead to certain expectations. Displaying emotions is the default in some situations while it can be seen as a sign of danger in others.

The relevance of a stimulus can be modulated by contextual factors, i.e. broken dishes may gain a negative valence in a kitchen scene, a neutral valence in the context of a waste dump and a positive valence in a wedding-eve party scene which in turn influences relevance values, i.e. the negatively connoted dishes get higher relevance values than the positively connoted ones and the neutrally connoted dishes are lowest in relevance. Similar contextual modulation of stimulus appraisal has been found by Judd & Park (2001) for the appraisal of black and white people in a church context or a family barbeque vs. a street context or gang incident. Additionally, context might moderate the interpretation of ambiguous emotional expressions. Thus, a slightly surprised face might be interpreted as happy in a wedding scene but as fearful in an underground station.

A related but different phenomenon is the modulation of perceived relevance through the interpretation of others facial expressions. When an observer encounters a person with an anxious facial expression, this expression serves as a relevance signal for other stimuli in the surrounding. Thus, the observer concludes from the anxious facial expression of a person, that somewhere in the surrounding is a dangerous item, person or incident, that needs to be attended. Other faces in the scene may then be interpreted as more dangerous as without this anxious face of the first person. Thus, in this case the anxious face serves as a relevance signal. Emotions can be divided into expresser-relevant and other-relevant emotions. While anger is an expresser-relevant emotion, which signals a high relevance of the expresser, fear is an other-relevant emotion signaling a high relevance of someone or something in the near surrounding of the expresser (Peeters, 1983; Wentura, Rothermund, & Bak, 2000).

Also the counter-regulation mechanism that was proposed by Rothermund and colleagues (2008) as well as Rothermund (2011) can be framed as a contextual relevance modulation. In a context suggesting a positive outcome, negative information is preferred, while in a context suggesting a negative outcome there is a bias to positive information. Thus, in a loss frame it is relevant to process positive information in order to stay sensitive to opportunities, while processing of negative information might avoid risky behavior in a gain frame.

Context-relevance has been investigated in the field of affective processing (Rothermund, 2011; Spruyt et al., 2009; Spruyt et al., 2007) and other social psychological phenomena (Blair, 2002; Casper, Rothermund, & Wentura, 2010, Casper, Rothermund, & Wentura, 2011; Müller & Rothermund, 2012; Wittenbrink, Judd, & Park, 2001). Some contexts might activate certain stereotypes or attentional sets, thereby facilitating attention to emotional distractors. Correspondingly, several studies revealed effects of stereotypes only in contexts that rendered these stereotypes relevant (Casper et al., 2010; Casper et al., 2011; Müller & Rothermund, 2012).

What is already known from social cognition, was illustrated by Schulte- Holthausen, Regenbogen, Turetsky, Schneider, and Habel (2016) in a flanker task. The experiment showed that flanker effects were contingent on the composition of emotion categories, i.e. they differed between experiments with a balanced composition of positive and negative emotions and experiments with an unbalanced composition in favor of negative emotions. When there were more negative than positive emotions, the latter produced more incompatibility effects as flankers. Several mechanisms can account for this pattern of results. One explanation is that the emotion composition anchors the expectable emotional range. This in turn leads to higher saliency of the less frequently shown and thus unexpected valence (Horstmann, 2005; Meyer, Niepel, Rudolph, & Schützwohl, 1991; Schützwohl, 1998). The present flanker experiments, however do not suggest this kind of anchoring effect. Rather in the third flanker experiment compatible happy trials, i.e. those trials where both stimuli were happy, appeared to be significantly slower than all other trials. In the study of Schulte-Holthausen and colleagues (2016), where effects were not calculated by controlling for target main effects explanations based on target effects are viable that might either refer to a general happy face advantage (Ekman et al., 1982; Kirouac and Dord, 1983; Ladavas et al., 1980) or to the fact that in the incongruent happy flanker condition all targets were negative and relatively similar to each other. This however, is no problem in our studies because we controlled for target main effects.

In manuscript three (Tannert & Rothermund, submitted), relevance was manipulated by the context. A gender-based tuning of the attentional system took place when contextual factors made gender relevant (romantic scene), but not when gender was less relevant within the respective context (street scene). Thus, gender information was attended only when people derived from contextual cues that it might be important to know, if the person within the visual focus was male or female. In this example context suggested attending the gender dimension through learned contingencies. This effect is similar to the effects, that have been found by Casper and colleagues (2010, 2011).

Macrae, Bodenhausen, and Milne (1995) as well as Fazio (2007) argued that only the relevant categories are activated in a certain situation, even when a given stimulus may belong to many categories. Context plays an important role in the decision on what category might be important, thereby influencing the evaluation of a person or item (Gawronski, Cunningham, LeBel, & Deutsch, 2010, Mitchell, Nosek, & Banaji, 2003; Olson & Fazio, 2003; Schwartz, 2007).

In a nutshell, context induces expectations and evaluations that modulate stimulus processing and, therefore, emotional faces capture attention in a context in which they are relevant.

5.1.3 Relevance due to Chronic Concerns

Although the current studies indicate no automatic capture of emotional faces unless they are relevant (task- or context-relevant), it needs to be discussed why some studies demonstrate the capture of emotional stimuli without establishing corresponding contextual conditions or increasing goal relevance. The majority of supporting results comes from clinical or subclinical studies with participants who were relatively anxious or have affective disorders (Bradley, Mogg, Falla, & Hamilton, 1998; Fox, 2002; Liu, Qian, Zhou, & Wang, 2006; Mathews, Mackintosh, and Fulcher, 1997; Rapee & Heimberg, 1997; Staugaard, 2010; Yiend, 2010, for an overview see: Bar-Haim et. al., 2007). Additionally, the effects are usually more pronounced when the emotional stimuli are associated with the respective emotionally meaningful topic (Riemann & McNally, 1995): Socially anxious people are more vigilant about faces than people that are normal in social anxiety (Bar-Haim et al., 2007; Staugaard, 2010). Furthermore, people with illness anxiety respond more strongly to stimuli associated with a disease than people without illness anxiety (Owens, Asmundson, Hadjistavropoulos, & Owens, 2004). Bar-Haim et al. (2007)

showed in their meta-analysis that anxious people have a significant bias towards threat-related stimuli in different attentional paradigms (emotional Stroop, dot-probe paradigm, emotional spatial cueing). Particularly in the dot-probe paradigm, significant emotional capture occurs only with participants who show high anxiety scores (Bar- Haim et. al, 2007; Bradley & Mogg, 1999; Mogg and Bradley, 1994). Correspondingly, high anxiety as well as attention to emotion preferentially occur in female participants (Tran, Lamplmayr, Pinzinger, & Pfabigan, 2013; Wrase et al., 2003) and participants that are low in testosterone (Tran et al. 2013; Wrase et al., 2003; van Honk et al., 1999; Wirth & Schultheiss, 2007). Additionally, women can usually classify facial expressions better than men (Ladavas, Umilità, & Ricci-Bitti, 1980, Kirouac and Dore, 1984, Erwin et al., 1992, Hall et al., 1999, Hall and Matsumoto, 2004). It is assumed that anxious people have a more sensitive valence evaluation system, which makes them attribute a high threat potential to even minimally threatening stimuli and thus renders those stimuli more relevant (Mogg & Bradley, 1998). In other words, emotional stimuli constitute a chronic concern for these people, which might explain why they respond to emotional faces preferentially, even when the task is unrelated to emotions and the context does not imply emotional relevance.

Taken together, these findings show that typical psychology student samples, which consist of around 70% female students (German Federal Ministry of Education and Research, 2020), who tend to have higher social anxiety and lower testosterone than male students, can bias the results regarding attention to emotional faces in a way that promotes emotional capture effects (Bekker, 1996; Fredrikson, Annas, Fischer, & Wik,1996; Hale, 1996; Turk et al., 1998; Xu et al., 2012). This might enhance the impression that emotional stimuli are per se bottom-up salient. The present experiments, however, were conducted with a mixed sample from the University of Jena that was recruited at the main campus instead of the psychology department. Thus, an absence of emotional capture effects in our experiments can be explained by a balanced gender distribution, an average anxiety level, and thus no heightened relevance of emotional faces.

5.2 Attentional Capture Despite Absence of Emotion Effects

Following the classical distinction of bottom-up vs. top-down attentional effects, we did not find evidence for early bottom-up attentional capture of facial expressions of emotion. One major argument for this conclusion is that effects occurred only when emotion was task-relevant. However, two accounts have been frequently applied to explain the absence of attentional capture effects in response time measures without negotiating the presence of early attentional capture per se.

1. The rapid recovery account (Theeuwes, 2010; Theeuwes, Atchley, & Kramer, 2000) states that an initial salience-based attentional shift towards non-relevant stimuli can be corrected quickly by top-down sets via rapid disengagement (175ms). This leads to fast processing of top down relevant stimuli despite initial capture of irrelevant stimuli. Thus, this explanation is supporting the pure capture account.
2. According to the contingent capture account, goals and tasks can top-down influence the initial capture. This results in the fact that stimuli that match the current target set are prone to capture attention at an early information processing stage (Folk, Remington, & Johnston, 1992).

Both accounts assume attentional capture as well as top-down control. Nonetheless, the latter one supposes an initial purely bottom-up capture, which is unbiased by top-down attentional sets. Consequently, both explanations lead to different predictions concerning the time course.

5.2.1 Arguments for Rapid Recovery in Attention Allocation to Facial Expressions of Emotion

The absence of salience based capture effects in cueing experiments is mostly explained by supporters of the pure capture hypothesis with the notion that although capture was not observed it was still present initially but recovered rapidly (Belopolsky et al., 2010; Theeuwes, 2010a, Theeuwes, 2010b). In additional singleton tasks capture effects of irrelevant distractors manifested at short cue-target-intervals (CTIs) and vanished at CTIs of 150ms-200ms (Theeuwes et al., 2000). This is seen as evidence for an initial capture which is interfered by other mechanisms later in time. Because in our dot-probe studies stimuli were not only presented sequentially but additionally target-distractor similarity in our dot-probe studies was nearly absent (circle/square as target vs. face as distractor), attention can be disengaged within 175ms (Theeuwes, 2010). Thus, in most of our studies it might have switched to target position in due time before target presentation, regardless of whether the distractors were emotional or neutral. However, within a time window of 24ms as in experiment five (Puls & Rothermund, 2017) disengagement is not plausible, even when there is no similarity between distractors and task-relevant target stimuli. Consequently, experiment five (Puls & Rothermund, 2017) should have shown initial pure capture even if there was a rapid disengagement process that helps to follow task instructions. Experiment five showed no attentional capture of emotional faces. This argues against a rapid recovery explanation. However, this is no evidence against the notion that salient emotional faces capture bottom-up attention. It is still possible that the saliency of two faces with a sudden onset is so high that there is only minimal added saliency due to the emotional expression (Theeuwes, 1994; Yantis, 1996).

A related, commonly used argument for initial pure capture is that irrelevant distractors produced inhibition of return (IOR) (i.e. Theeuwes & Godijn, 2002), which is considered as evidence that attention has been moved to this spot, which is then inhibited for a certain time (Posner & Cohen, 1984). This notion leads to nearly the same predictions for timing as the previous. The only difference occurs when CTIs are very long because then IOR would predict reversed effects due to the inhibition of the target-position in congruent trials. In the present dot-probe tasks, CTI ranged from 24ms to 1000ms. Thus, if emotional faces had captured attention in the present dot-probe tasks (Puls & Rothermund, 2017), the typical timing of IOR should have shown across the different CTI-variations, with emotion effects of irrelevant distractors being apparent in those experiments with a short CTI, absent with a middle CTI and reversed with a longer CTI. Although there might be a tendency to the described pattern in studies which included fearful faces, the absence of any significant emotion effect shows that there is no reliable evidence for inhibition of return.

Finally, supporters of the rapid recovery account (Theeuwes, 2018) argue that a faster detection of targets can be attributed to bottom-up intertrial priming instead of top-down modulation of attentional capture in many cases where target features are known in advance (Müller, Heller, & Ziegler, 1995; Treisman, 1988; Wolfe et al., 2003). Indeed, we varied target selection criteria blockwise, which is assumed to facilitate intertrial priming (Tannert & Rothermund, 2018). However, target selection criteria and emotion were orthogonally varied, i.e. receiving positive feedback for correctly classifying the emotion of a female face in trial n offers no emotion specific advantage in trial n+1. Additionally, we are not able to directly investigate the effect of knowing selection criteria in advance without a condition where target features are not known in advance.

Importantly, our results suggest that attention is not captured by emotional facial stimuli with extremely short CTIs (24ms). Thus, our studies do not significantly support the arguments that are stated in favor of the rapid recovery account. However, this conclusion needs to be handled with care, because our studies were not explicitly designed to test the assumptions of the rapid recovery account.

5.2.2 Arguments for Contingent Capture for Facial Expressions of Emotion

In contrast to the proponents of the rapid recovery account, advocates of the contingent capture account (Folk & Annett, 1994; Folk & Remington, 1998; Folk et al., 1992; Folk, et al., 1994; Lamy, 2010) argue that top-down sets can modulate attentional capture itself, i.e. they propose that capture does take place very early if and only if the stimulus matches the top-down attentional set. Thus, the contingent capture account predicts attentional capture whenever emotion is task-relevant. However, the present work contains three experiments where emotion is task-relevant (Tannert & Rothermund 2018, E1, E2, E3) with only one of the experiments showing attentional effects of emotion. The respective experiment deviates from the other two in that the flanker processing is forced by an additional target selection attribute and spatial uncertainty. This, however, indicates that the effect is a disengagement effect rather than a capture effect. Since emotion was fully irrelevant in the dot-probe studies, we cannot draw on the first manuscript (Puls & Rothermund, 2017) to support the contingent capture account. For this reasoning we would have needed to find evidence for attentional capture of emotional stimuli in a condition where emotion was explicitly task-relevant like e.g. in Everaert, Spruyt, and DeHouwer (2013, E2) or Wirth and Wentura (2018). Thus, the present data offer no clear-cut evidence for the contingent capture account, which again suggests, that attentional capture by emotional faces did not take place.

In sum, our findings support neither the rapid recovery account nor the contingent capture hypothesis but rather suggest that irrelevant emotional faces impair target responses when attention has already been allocated to the respective stimulus. The present work offers no evidence for attentional capture of emotional faces. However, the third experiment in Tannert & Rothermund (2018) shows a slowdown of responses in presence of an emotional flanker, which impairs task fulfillment. Thus we found an involuntary effect of emotional compared to neutral distractor stimuli that is most probably caused by an impaired disengagement.

5.3 Main Findings

In sum the present thesis leads to three main findings:

1. Emotional faces do not capture attention in an automatic, goal-independent, fast, resource-free bottom-up fashion.
2. Under certain circumstances, emotional stimuli are attended involuntarily and also when attending is disadvantageous for the current task.
3. Attentional capture is the result of an interaction of bottom-up saliency and different variables that constitute top-down saliency, including contextual variables, task-constraints and chronic concerns.

The above notions are inconstistent with the fear module theory (Öhman & Lundvist, & Esteves, 2001; Öhman & Mineka, 2001) and cast doubt on a pure bottom-up-capture of emotional faces. Although the present findings suggest that top-down influences play an important role in attentional selection of emotional faces and give first hints on relevant top-down variables it still needs to be discussed, how exactly top-down influences interact in the selection of emotional stimuli.

5.4 Theoretical Perspectives

A thorough understanding of any process in human beings should include the ability to predict its progression and the progression of related processes as well as to mimic the process i.e. to deliberately trigger it. Within the framework of attentional capture of emotional faces, this means to correctly foresee attentional effects of emotional faces given certain defining parameters (goals, stimulus features, context conditions). Additionally, it means to purposefully elicit attentional effects under controlled experimental conditions.

Therefore, the present chapter aims at embedding the results of our experiments into broader theories of attention. The goal is to understand the underlying selection mechanism more deeply by identifying universal selection principles.

5.4.1 Selective Explanatory Capacity of the Different Experimental Paradigms

An understanding of the process of attentional selection needs reliable findings from experimental paradigms and a principle understanding of what these paradigms do. However, the present chapter illustrates, that the mechanism of the different attentional paradigms is not fully understood and why this is problematic for the reasoning concerning attentional capture of emotional faces.

Bottom-up capture is characterized as fast and effortless. It is typically found in the very beginning of the selection process. In contrast, top-down (Posner et al., 1980) attention is effortful and slow. However, both accounts are challenged by findings like those in the present work: task-irrelevant information has a fast and involuntary influence on target responses which is not driven by the stimulus itself but contingent on goals and other contextual variables (E3, Tannert & Rothermund, 2018, Tannert & Rothermund, submitted). Thus, while the effects are involuntary like typical bottom-up effects, they are goal directed and context-dependent like typical top-down effects.

Our studies were not specifically designed to answer the question if top-down attentional control is executed pre-attentively, like it was assumed by the contingent capture account, or counter-regulates initial bottom-up capture by regulating the disengagement process. However, our dot-probe results clearly argue against the pure capture account and due to the broad variation of SOA also against the rapid recovery account. Thus, if at all the dot-probe results could be regarded as compatible to the contingent capture account. This reasoning is interesting, when one considers the findings from clinical psychology, that show attentional capture of task-irrelevant emotional faces for anxious participants (Bradley, Mogg, Falla, & Hamilton, 1998; Fox, 2002; Liu, Qian, Zhou, & Wang, 2006; for an overview see: Bar-Haim et. al., 2007). This is, given our proposition regarding chronic concerns as a factor of top-down saliency, in line with the contingent capture account. The flanker studies however, revealed the necessity of distractor processing, which suggests a disengagement-based explanation. Thus, the flanker studies clearly argue against contingent capture.

Interestingly, evidence in the literature for contingent capture (Folk et al., 1992; Yantis & Egeth, 1999) comes primarily from spatial cueing experiments (Folk et al., 1992; Folk et al., 1994; Folk & Remington, 2006; Gibson & Amelio, 2000; Remington, Folk, & McLean, 2001; Pratt, Sekuler, McAuliffe 2001). On the contrary, visual search experiments, namely the additional singleton paradigm, mostly support the rapid recovery account and the pure-capture hypothesis (Theeuwes et al., 2000; Kim & Cave, 1999). Lamy (2010) criticizes this asymmetry because the additional singleton paradigm focuses on the salience of the distractor vs. salience of the target, while cueing studies focus on the match between distractors and top-down attentional set. The reason is, that although in both paradigms two stimuli are presented simultaneously, i.e. in direct competition, the nature and function of the stimuli in the task is very different. In Cueing studies, both competing stimuli need to be ignored, while in the additional singleton paradigm one of the presented stimuli is the target and thus needs to be attended. In cueing studies, the typical finding is that differences in attention between distractors occur on the respectively task-relevant dimension. Thus, the cueing paradigm illustrates the congruency of a top-down attentional set with distractor characteristics. The saliency of the distractors is ignored. In additional singleton studies to the contrary, task-irrelevant singletons capture attention, when they are salient on a task-irrelevant dimension. Thereby it is manipulated if the saliency of the target matches the saliency of the additional singleton but it is kept constant if the attentional set matches the irrelevant singleton. Thus, the additional singleton paradigm shows the presence of bottom-up-mechanisms, but not the absence of top-down effects.

Roque, White, & Boot, 2016 conducted a study, where they assessed attentional capture in several attentional paradigms in a single session with a single participant sample. They replicated the classic top-down effects in the cueing paradigm (Folk et al., 1992) and the contingent blink paradigm (Folk, Leber, & Egeth, 2002) and bottom-up-capture in the additional singleton paradigm (Theeuwes, 1992) as well as the irrelevant singleton paradigm (Yantis and Jonides, 1984). However, correlation analyses revealed only low correlations of attentional effects within the group of top-down-capture paradigms or within the group of bottom-up-capture paradigms. Furthermore, there occurred correlations of bottom-up-capture effects with top-down-capture effects. Additionally, reliability of bottom-up measures was rather low. Although we missed to introduce control conditions (top-down component and stimuli that are known to be bottom-up salient) into our cueing studies (Puls & Rothermund, 2017) to validate the design and exclude procedural deficits of the paradigm, it is plausible that we did not find any attentional capture of emotional faces because the top-down attentional set advised participants to ignore the absolutely task-irrelevant distractors. Thus, our results are in accordance with the results of Roque et al. (2016).

A similar result was obtained by Mogg, Bradley, Dixon, Fisher, Twelftree, and McWilliams (2000) in the comparison of attentional effects of threatening faces in a dot-probe task and in a modified Stroop color naming task.

This illustrates, that different paradigms did not by chance yield different results concerning bottom-up and top-down mechanisms but are conceptually differing in a way that fosters either the detection of top-down effects or the detection of bottom-up effects. The mentioned discrepancies and the very unreliable and diverse findings of attentional processes in general are a problem for answering our research question, because we cannot know, if the absence of differences between emotional and neutral distractors is due to problems of the experimental paradigm or due to the (bottom-up or top-down) saliency of natural emotional faces. Thus, an understanding of the discrepancies between the paradigms would offer highly relevant information for the main aim of this thesis.

5.4.2 **Experience-Based Selection**

While dot-probe studies uncover top-down processes in early target selection, the additional singleton and irrelevant singleton paradigm revealed early bottom-up effects of salient stimuli on stimulus selection. In our flanker studies to the contrary, we found clear evidence for top-down regulation of attentional selection of natural emotional faces. In recent articles, Theeuwes (2018) as well as Failing and Theeuwes (2018) suggested to consider a third category of attentional processes besides bottom-up and top-down attention, that might also account for the differences between effects in paradigms with direct competition between target and distractor and those where only distractors compete: The concept of experience based selection.

Essentially the experience-based selection account predicts a preferred processing of stimuli that are or have previously been associated with reward or punishment via contingency learning. This idea is interesting in the scope of this dissertation because emotional faces are a stimulus category that is frequently encountered in daily life and often paired with relevant outcomes that might pose reward or punishment for the respective subject. Thus, preferred processing of emotional faces can also be interpreted as a result of experience based selection. Consequently, this account might summarize several effects of top-down saliency mentioned above thereby integrating and explaining their contribution in the selection process.

The concept of experience-based selection processes is grounded on assumptions previously published by Awh, Belopolsky, and Theeuwes (2012) as well as several other authors in the context of value-driven attentional capture (VDAC) or value modulated attentional capture (VMAC, Anderson, 2016; Chelazzi, Perlato, Santandrea, Della Libera, 2013, Le Pelley, Mitchell, Beesley, George, & Wills, 2016; Vuilleumier, 2015). Therefore, Theeuwes (2018) as well as Failing and Theeuwes (2018) suggest a stimulus selection process that is caused by implicitly learned contingencies between certain stimuli or stimulus selections and rewards or punishments (Anderson, Laurent, & Yantis, 2011a, 2011b; Chelazzi et al., 2013; Gottlieb, Hayhoe, Hikosaka, & Rangel, 2014). These contingencies are believed to have been built up in previous learning occasions, with strength of the attentional effects being a function of the value of the respective reward. Rewarded attentional selections are more probable than non-rewarded selections. Stimuli associated with high rewards are more prone to attract attention than those associated with low rewards (Anderson & Yantis, 2012; Della Libera & Chelazzi, 2006). However, some findings also indicate equally strong preferences for gain-related or loss-related stimuli, that are not relevant in the current task anymore (Müller, Rothermund, & Wentura, 2016; Wentura, Müller, & Rothermund, 2014).Effects have been found for instrumental reward contingencies (Della Libera & Chelazzi, 2006, 2009; Failing & Theeuwes, 2014 ; Hickey, Chelazzi, & Theeuwes, 2010) as well as for classical reward contingencies (Bucker & Theeuwes, 2017; Notebaert, L., Crombez, G., Van Damme, S., De Houwer, J., & Theeuwes, J., 2011) and for stimuli that signalled the possibility of gaining a reward through a certain behavior in the past that are now completely response-independent and no longer signal reward in the current task (Anderson, 2013 ; Chelazzi et al., 2013; Failing & Theeuwes, 2017; Le Pelley et al., 2016). Preferred selection of stimuli associated with high rewards was also shown on a neuronal basis (Kiss, Driver, & Eimer, 2009; Serences, 2008; Shuler & Bear, 2006).

On the one hand, the experience-based selection is assumed to be much like bottom-up capture, i.e. fast, efficient and effortless (e.g., Bucker et al., 2015; Failing, Nissens, Pearson, Pelley, Theeuwes, 2015) and it overrides top-down task instructions just as bottom-up capture (Anderson et al., 2011a; Failing & Theeuwes, 2018). On the other hand goals and tasks pose the contextual framework around reward contingencies. Reward expectations are tightly connected to the task, i.e. a certain behavior can be expected to lead to rewards when the task is calling for it. Consequently the experience based selection account predicts effects of those distractors that have something in common with stimuli that are part of a reward contingency, may it be a formerly experienced and established one or an instructed contingency. Thus effects that are predicted by experience based selection have much in common with the effects found in the present experiments.

Relation of Experience-Based Selection to Classical Concepts

A logical consequence of the propositions of the experience-based selection account is that effects considered as bottom-up may not always and exclusively be a result of the stimulus inherent capacity to evoke attention (i.e. sudden onset). It may instead be the result of numerous exposures with the respective stimulus (a wall appearing in front of a person, a ball coming near fast). These exposures either established a classical contingency between stimulus and the typical reward that can be expected in its presence or lead to consolidation of an operant reward contingency. In the latter case the action (attentional shift towards suddenly appearing stimuli) that was most frequently rewarded (having caught the ball, arriving at the intended location) or less frequently punished (ball in the face, head bangs wall) in presence of the respective stimulus (instrumental learning) is integrated into the operant contingency. Consequently, attentional effects may result from an expectation of reward/punishment in presence of the stimulus or the learned contingency between a certain behavior in presence of the stimulus and a reward or punishment. The high saliency of sudden onset stimuli, however, facilitated contingency learning.

Saliency and Experience-Based Selection

Experience based selection does not directly depend on saliency and is also able to override and modify saliency (Bucker & Theeuwes, 2017; Failing et al., 2015; Failing & Theeuwes, 2017, Yantis and Jonides, 1990). However, several researchers identified an interdependence of saliency and experience-based learning (e.g. Wang, Yuan, Yan, & Li., 2013). On the one hand, contingencies can lead to increased saliency (e.g. Failing & Theeuwes, 2014; Hickey, Chelazzi, & Theeuwes, 2010; Kiss et al., 2009) or at least to changes in stimulus representation on the saliency map (Chelazzi et al., 2014; Theeuwes, 2018) that are equal to the "sharpening" concept by Desimone (1996). On the other hand, however, physical saliency makes certain stimuli more prone to be integrated in contingencies than non-salient stimuli because of their physical advantages (Failing and Theeuwes, 2018) in rivalry with other present stimuli. Thus, salient stimuli have a better figure to ground ratio and may be processed more easily. This leads to faster formation and higher strength of contingencies related to salient vs. nonsalient stimuli (e.g. Failing & Theeuwes, 2018; Hickey, Chelazzi, & Theuwes, 2010; Le Pelley, Pearson, Griffiths, & Beesley, 2015). However, saliency alone might not be sufficient to initiate an attentional capture. Likewise, top-down tasks may boost the probability of contingency formation by increasing the probability for processing the respective stimulus, which is a precondition for the stimulus to become part of a reward contingency (e.g., Anderson et al., 2011b; Theeuwes & Belopolsky, 2012). This might explain, why saliency, that has been believed to be a purely bottom-up property is not always leading to attentional capture irrespective of the task. And more heretically this might even suggest, that experiences with stimulus characteristics such as sudden onset or bright color are at least a necessary condition for their bottom-up saliency. This in turn would mean, that bottom-up saliency results from the interplay of reward learning and physical discriminability and becomes automatized due to repeated exposure. Thus, what is called bottom up saliency, might just pose the most automatized end of the top down relevance continuum.

Experience-Based Selection in the Context of the Present Findings

All in all, the concept of experience-based selection nicely fits the main message of the present paper, i.e. 'relevance matters', and might either be an additional mechanism that shapes relevance or the underlying structure that determines how all other mentioned aspects shape relevance. Certainly, emotional faces are a category that is related to many experiences and resulting reward contingencies in every human subject. The importance of contextual cues for the attention to emotions as well as the preference for anxiety related stimuli in anxious people (Bar-Haim et al., 2007) can be explained by reward contingency episodes. A preferred attention to gender stimuli in the context of romantic scenes with the intention to classify emotions (Tannert & Rothermund, submitted) might go back to strongly rewarded experiences as well as reward expectations, such as Liefooge et al. (2012, 2013) demonstrated. However, many findings concerning experience-based selection do not focus the question, if the attentional prioritization can be considered attentional capture. In a search-paradigm, Notebaert and colleagues (2011) found attentional prioritization of conditioned color stimuli. However, the search slopes indicated that search was not parallel, which suggests that the attentional prioritization was no capture.

The differentiation of classical and instrumental learning might be relevant when interpreting effects of different attentional paradigms. The dot-probe-paradigm is more prone to activate classical contingencies because distractor processing does not require behavior. Flanker experiments to the contrary may trigger instrumental contingencies in addition to the classical ones, since an action is requested while attentional competition continues. Consequently, there might be settings where contingencies are build up in a classical manner in a setting, where no actions were available to modify the outcome. These contingencies might lead to attentional capture of the respective conditioned stimuli in a dot-probe task, but not in a flanker task. Conversely contingencies, that have been built up as instrumental contingencies, might lead to effects in flanker-studies but not dot-probe studies.

In a nutshell, the present work shows an absence of bottom-up attentional capture of emotional faces and, under certain circumstances, attentional effects of emotional stimuli that are involuntary, i.e. cannot be considered as top-down. Thus, the concept of experience-based selection seems promising to explain these seemingly contradictory effects.

5.5 Methodological Challenges

The present dissertation offers some clear-cut conclusions that are based on a systematic investigation of the effects of emotional faces on attention. However, the present studies have some shortcomings that might qualify the interpretation of the present data. These limitations will be addressed in the current chapter.

5.5.1 **Overlap of Features**

In the flanker experiments we did not find attentional effects until we made emotion task-relevant and flanker processing mandatory. However, we tried to boost flanker processing by including a target definition task that required participants to find the male (female) face and classify its emotion. However, gender and emotion have been found to highly overlap in visual features (Becker et al., 2007; Hess, Adams, Grammer, & Kleck, 2009), i.e. female faces overlap with features of sad and anxious faces while male faces show characteristic features of angry faces. This might account in some way for emotional effects as well. For example, an emotional distractor could be more distracting than a neutral one, because in half of the trials the gender-typical features do not correspond to the displayed emotion. This deviation elicits a certain saliency. Apart from feature-related explanations, also a deviation of displayed and stereotypically expected emotion of the distractor face could account for a delayed target processing (Plant, Hyde, Keltner, & Devine, 2000). In both cases neutral facial expression does not interfere with either male or female gender information. Thus, a different target identification task should be applied in order to rule out alternative explanations concerning featural overlap.

5.5.2 **Singleton-Target Prevented Processing of Distractors**

Another methodological issue that challenges the claim, that mandatory distractor processing is part of the attentional effects found in flanker experiment 3 (Tannert and Rothermund, 2018) is the singleton status of the targets in the flaker experiments 1 and 2 (Tannert & Rothermund, 2018). The difference between the two studies in manuscript two (Tannert & Rothermund, 2018) which show no effect despite task relevance of emotion (E1 and E2, Tannert & Rothermund, 2018) and the one that shows an effect (E3, Tannert & Rothermund, 2018) was, that in the latter one flanker processing was mandatory due to spatial uncertainty of the target. Although task relevance was given in all three of them, in only one of these experiments emotional distractors lead to a stronger delay than neutral. Thus, we argued that while top-down goal relevance was not sufficient to modulate the initial shift towards the emotional of both distractor faces, it was sufficient to render distractor processing mandatory. However, in flanker experiments 1 and 2 participants could not only easily identify the target because of its singleton status and its fixed position, but also inhibit the fixed distractor positions. To rule out these alternative explanations, additional studies should be conducted where presentation mode (fixed position vs. variable), singleton status, and the number of distractors (as a related factor) are manipulated independently from mandatory distractor processing.

5.6 Future Directions

In the previous chapters we elaborated attentional effects of emotional faces based on two series of systematic investigations in two different attentional paradigms and one additional experiment using a dual-task paradigm. The presented evidence integrates previous single findings and corroborates the assumption that emotional faces do not automatically capture spatial attention. However, our results raise further questions that our experiments were not designed to answer. Therefore, this chapter will illustrate some important future directions.

5.6.1 Perceptual Load

In manuscript two (Tannert & Rothermund, 2018) we shortly mentioned the problem of perceptual load especially when natural faces are used. Although this problem is no argument against natural faces, because they still offer important ecological validity, it needs to be discussed to what extent the conclusions of this thesis are affected by the problem of perceptual load. Lavie and Tsal (1994, see also Lavie, 1995, 2000) propose, that participants scan the whole visual field for relevant information as long as enough capacity is available. Thus, attentional capture by irrelevant distractors is more likely when attentional resources are not fully exhausted. However, Lavie and colleagues (2003) showed that, non-facial distractors' but not facial distractors' capacity to distract was reduced by perceptual load. Thus, facial distractors were processed irrespective of the set size and could not be eliminated by increasing the perceptual load. However, in our flanker experiments (Tannert & Rothermund, 2018) targets *and* distractors were *natural* faces and thus competed for attention directly. Additionally, the task was rather demanding. Bindemann, Burton, & Jenkins (2005) found flanker effects of emotional natural faces only when the target was no face. This suggests a capacity limit that prevents processing of natural flanker faces, when a second, more relevant complex face is present. Accordingly, Mohamed, Neumann, & Schweinberger (2009) found tremendous reduction of the face-sensitive N170 under high perceptual load, suggesting an impaired face processing under high load. Additionally, Martens, Leuthold, & Schweinberger (2010) as well as Schweinberger, Burton, & Kelly (1999) found that processing of emotional expression (happy vs. angry) was not independent of identity processing. In the Garner interference paradigm (Garner, 1974; Garner 1976) facial expression could be ignored when identity or gender was processed but not the other way round (Atkinson, Tipples, Burt, & Young, 2005; Baudouin, Martin, Tiberghien, Verlut, & Franck, 2002; Schweinberger & Soukup, 1998, Schweinberger et al., 1999). The findings suggest that in contrast to the assumption of independent processing (Bruce and Young, 1986) emotion classification requires identity and gender information. This is consistent with our findings in manuscript 3 (Tannert & Rothermund, 2020), where gender-dependent stereotypical information was consulted in order to prepare for emotional processing.

This could be another relevant factor, that partly causes the differences in attentional capture between schematic and natural faces. While natural faces are prone to offer a clue on emotional expression via identity and gender information, schematic faces are completely uninformative in this respect. This should clearly reduce complexity and lead to more capacities for distractor processing. Thus, an absence of attentional effects of emotional faces might be caused at least in part by the use of natural instead of schematic faces.

Additionally, the dependent parallel processing of identity/gender and emotional expressions corroborates the idea that perceptual load has impaired distractor processing in our studies, where always at least two faces with different identity appeared. Consequently, the absence of emotion effects in E1 and E2 (Tannert & Rothermund, 2018) might be attributed to perceptual load. We could argue that E3 (Tannert & Rothermund, 2018), which yielded emotion distraction effects, was comparable to these experiments in complexity and stimulus composition, indicating no major influence of perceptual load on expected emotion effects. However, in E3 (Tannert & Rothermund, 2018) the target defining characteristic was gender, i.e. the participants knew (block-wise) that the upcoming target (distractor) will be male (female). This might have led to a reduction of complexity and thereby might have released processing capacities. Based on this, some researchers might argue that stimulus complexity and resulting capacity limitations might not only have counteracted attentional effects in the *flanker experiments* (Tannert & Rothermund) but might also have caused the absence of capture in the *dot-probe studies* (Puls & Rothermund, 2017). Although studies 4a and 4b suggest at least some distractor processing by revealing compatibility effects of the respective task relevant dimension, future studies should keep in mind the perceptual load hypothesis and try to rule out this alternative explanation by careful planning. Investigations might contain a natural face condition and a schematic face condition.

5.6.2 **Relevance Maps and the Context-Dependency of Top-Down Task-Relevance**

We showed that attention to emotional faces is not determined by the stimuli alone via bottom-up saliency but depends on certain top-down influences. This suggests, that the processes that are active in attentional selection of emotional faces are structurally comparable to those in attentional selection of other stimuli. We identified contextual information and task as relevant factors. However, it is still unclear, how exactly these factors contribute to the process. Many models have been proposed to account for bottom-up saliency (for a review see Itty & Borji, 2015). However, only few scientists described how exactly top-down saliency contributes to the conjoint relevance (Cave & Wolfe, 1990; Navalpakkam & Itti, 2015; Oliva et al., 2006). But even in these models top-down factors are mostly reduced to information on target defining features and probable target locations. Influences from complex background pictures like those in Puls and Rothermund (2017) or learning history that has been proposed in the context of experience based-selection however, might interact with other saliency factors in a rather complex fashion which is not further explored yet. There might be variables that add up linearly to form a summed top-down saliency value (Brosch et al., 2011; Zoest and Donk, 2004). However, most probably certain characteristics of the context rather act like moderators that can modulate the influence of others in an interactive multiplicative way. This is supported by empirical findings. Bacon & Egeth (1994) tested for the selection of the search mode in response to certain task demands and its consequences for the influence of target distractor similarity and distractor saliency. They found, that bottom-up influences were contingent on a feature search mode was only adopted when a bottom-up singleton detection mode was ineffective. Thus, as long as singleton search is effective enough, feature search is avoided even when the target features are known. TBacon and Egeth (1994) argue, that participants voluntarily decided to adopt a more convenient search mode instead incapable of ignoring the salient singleton. This argues against a purely additive calculation of relevance on the salience map. Rather it suggests an interactive account.

Future research attempts should aim at explicitly designing studies that reveal more on the interplay of the different factors mentioned here. The idea of experience based selection has been introduced in chapter 5.4.2 and might be a viable account to integrate several factors, that have been identified to moderate attention to emotional faces apart from stimulus inherent characteristics.

6 Conclusion

Considering our own results and those reviewed in the current dissertation, I conclude that emotional faces are not unconditionally salient in the sense of a preferred bottom-up selection. Instead, as it is the case for most other stimuli, the preferred processing of emotional faces is contingent on individually varying and changeable relevance in the present situation. When people must choose to attend to emotional or non-emotional stimuli they will preferentially attend to those which are most relevant to them in the current situation. In this respect, relevance is dependent on the person's goals, tasks, reinforcement history, contextual factors, and perhaps other not yet investigated variables. This does not necessarily mean that a person can solve his or her current task or problem without any distraction. Rather, people seem to attend to stimuli that match the current set of goal-relevant properties preferentially, i.e. the more similar the distractors are to the momentarily relevant stimuli, the more difficult it is to ignore the distractors. Our data is not sufficient to finally decide whether the top-down influence on early stimulus selection meets the principles of contingent capture theory (Folk & Annett, 1994; Folk & Remington, 1998; Folket al., 1992; Folk, et al., 1994; Lamy, 2010) or whether it follows the rapid recovery account (Theeuwes, 2010a, 2010b; Kim and Cave, 1999). The predictions of the different accounts should be tested in additional experiments, like e.g. a cueing paradigm that includes a condition where emotion is task relevant. However, it might be that neither of the two theories can account for the effects but rather the newly proposed experience-based selection approach, which has yet to be tested. Therefore, future studies should focus on the different attentional patterns in different experimental paradigms, applying the principle of experience-based selection. This could scrutinize possible hypotheses that can be derived from this relatively new concept. The concept of experience-based selection sets a promising framework to explain the partly inconclusive results, which neither fit the characteristics of bottom-up capture nor are volitional like a top-down process.

Jan Theeuwes closes his considerations on experience-based selection with the notion that visual selection may not be a 'deliberate choice' (Theeuwes, 2018, p. 9). Rather experiences create 'a universe that is automatically forced upon us' (Theeuwes, 2018 p. 9). I agree. However, since the value of all rewards depends on our personal preferences and needs, every person acts automatically in accordance with what they would aspire, if they were voluntarily choosing their behavior. Thus even though stimulus selection seems to proceed involuntarily in this certain moment, the result will be on average the most desired.

7 References

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