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EMOTIONAL ATTENTION
A cognitive neuroscience perspective

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Abstract

Attention is a cognitive mechanism that guides our perception in order to prioritize the limited resources to the most relevant information while ignoring distracting information. Attention can be voluntarily deployed to stimuli during tasks or goals, or the features of the stimulus can capture our attention either by being salient or being emotionally induced. Emotions affect multiple different cognitive processes such as attention because emotional stimuli can be relevant for defending or sustain life. This relationship between attention and emotion indicates that there should be interactive but distinct networks between these cognitive mechanisms as well as a modulative effect on perceptional and attentional systems. Emotions were in general demonstrating a facilitation affect on attentional and saccadic processes as well as broadening or narrowing the scope of attention. The reason behind emotions impact on attention was proposed to be for eliciting a change in the application of resources in order to solve the limited capacity problem and possibly to protect and sustain life. Inconsistent findings as well as limitations for emotional attention studies are discussed.

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Introduction

Visual attention is a mechanism that makes it possible to make sense out of all the information we encounter in our environment. Everywhere we look there is an overwhelming amount of information to process and by selecting the most relevant information while ignoring irrelevant noise we can understand our visual world in a seemingly effortless manner. Attention guides our eye movements and to focus on certain locations or objects in order to prioritize their processing (Chun, Golomb, & Turk-Browne, 2011). It is important to be selective about what information is going to be processed since there is a limited amount of resources and too much information to be processed effectively. Therefore, attention needs to distribute the resources to the most important events. The limitation lies in the available fixed amount in resources of energy in the brain that our neural activity consumes during cortical computation (Carrasco, 2011). The resources are distributed over cortical relevant regions for the brain to use effectively by using the sparse amount of neurons in accordance to the task demands (Lennie, 2003). In visual attention, the eyes show limitations as well such as having a decrease in resolution when the distance between the fovea and the target increases or by being unable to identify targets during interference of other irrelevant targets or when there are too much features and objects to process in a brief look (Zhao, Gersch, Schnitzer, Dosher, & Kowler, 2012).

The resources can be distributed in different ways depending on what and where attention focuses on, thus visual attention is usually divided into three main types: spatial attention, feature based attention and object based attention. Spatial attention refers to the attentional focus on a certain location where the stimulus of interest is located. Feature based and object based attention means that a certain feature that is usually salient, meaning that the feature or the object as a whole is unusual or extreme. Together, these three different types of attention optimize our visual system while focusing on different kinds of information (Chun et al., 2011)(Carrasco, 2011). In order to attend to the targets in our visual environment, different attentional networks guide the selective processes: vigilance, orienting and executive control (Posner & Rothbart, 2007). Alerting is responsible for maintaining high sensitivity towards incoming stimuli, orienting is the ability to select information from sensory input and finally executive control defined as the mechanism that resolves conflict among different types of responses. By doing an attention network test (ANT) demonstrated distinct neural networks for these attentional systems whereas alerting showed activation in thalamic regions,

orienting attention was associated with parietal activations and executive control with anterior cingulate cortex activation (Raz & Buhle, 2006).

In order to make vision more effective, saccadic eye movements and visual attention works together to select relevant information and prioritize the limited resources for an active goal or behaviour (Zhao et al., 2012). Since we cannot consciously attend to all input of sensory information at the same time, the limited capacity for paying attention is suggested to be a bottleneck. Bottleneck is restricting the rate of flow and when the information has been selected and is engaged in processing, it has to be carried out until it's finished. Thus it is not possible to carry out a second task at the same time but only serially (Schubert, Fischer, & Stelzel , 2008). One classic example of attending to one event prevent awareness to others is the attentional blink phenomenon. It has been demonstrated that participants presented with two stimuli rapidly after each other were only able to attend to the first target and were unaware of the second one (Nieuwenstein, Van der Burg, Theeuwes, Wyble, & Potter, 2009). The selection is dependent on top-down or bottom up biases for a particular stimulus competing to other targets for the available resources, a competitive bias known as the biased competition theory (Desimone & Duncan, 1995). The stimulus can either match the internal template and thus gains prioritized processing (top-down) or it can be visually salient and differ to its background that induces the bias (Beck & Kastner, 2009). After the selection of relevant information has been picked out from the competing options, attention decides how well that information will be processed and what the speed and accuracy of the execution for the task is going to be (Chun et al., 2011). Attention has the ability to ease sensory processing through the whole cortex like for an example changing the perceived qualia of the attended objects (Carrasco, Ling, & Read, 2004). This modulation effect in turn leads to a maintained sensitivity towards this stimulus, hence alerting (Chun et al., 2011). Although, it cannot be maintained forever due to the limitation of resources meaning that attention is shifting. Since perceptual and cognitive mechanisms are not always operating at peak levels, rather the activation levels and efficiency change in a regular and repeated way (Berridge & Waterhouse, 2003). The reason behind decrement of alertness is thought to be due to exhaustion of the limited resources available for the brain not being refilled (Davies & Parasuraman, 1982), reductions in general alertness (Frankmann & Adams, 1962) or as a result of boredom (Manly, Robertson, Galloway, & Hawkins, 1999).

What stimuli get selected for prioritized processing can depend on a certain task or goal (endogenous attention) or it can depend on the stimulus itself (exogenous attention)

involuntarily draw attention towards it automatically (Chun et al., 2011). Emotional stimuli might have evolved to ensure survival because the adaptive behaviour is dependent on the ability to prioritize relevant emotional information while down regulate irrelevant emotional information (Cohen, Henik, & Mor, 2011). The broaden and build theory proposes that negative emotions might have evolved to narrow our scope of attention as well as our thought of action like fighting or fleeing (Fredrickson, 2001). Positive emotions on the other hand might broaden the scope of attention and increase our thought of action repertoire for promoting exploration of the environment, learning new information and build resources (physical, intellectual, social) that can increasing the odds for survival (Fredrickson, 2001).

The aim for this essay is to examine the impact emotion has on visual orienting attention. Since emotional information is suggested to be important for survival it should gain prioritized processing for the limited resources in comparison to neutral information. Thus, orienting attention should get facilitated by increasing the amount and speed of saccadic shifts for emotional stimuli leading to an increase in detection compared to neutral targets. Additionally, the impact of emotions, either broadening or narrowing the scope of attention should be observable through an increase or decrease of targets due to a much wider or smaller attention span. However, in order to get a better understanding of emotional attention a taxonomy of attention with associated concepts will be described. The underlying network of orienting shift of attention will be examined as well as the usage of covert and overt eye movements. Secondly, the concept of emotion will be described as well as the neural process of the amygdala. Finally, the impact of emotions on attention will be elaborated along with the communications between the amygdala and attention network.

Orienting Shift of Attention

Because of the multiple visual options in our environment there is a need for dividing our attention to the relevant location of the target, this type of focus is referred to as spatial attention. The focus is usually compared to a spotlight (Posner, 1980) or a zooming lens (Eriksen & Yeh, 1985) which means that within the limited area of space there is an enhanced processing of the visual stimuli. However, attention is not just limited to just one location rather it can be split over several locations (Jans, Peters, & De Weerd, 2010) but when it is spread across space it reduces effectiveness (Eriksen & St James, 1986). Attention that is distributed over a larger region of the visual field is related to decrement in spatial resolution

as well as processing efficiency regarding any subregion of the attended area compared to focusing on one location only (Castiello & Umilta, 1992).

When we are observing a visual scene, we make a lot of eye movements referred to as saccades in order to capture the most relevant information on the high resolution fovea (White, Rolfs, & Carrasco, 2013). If the target needs to be localized and it is not present within the current region, attention guides and controls the eye movements to shift to another location to examine the targets whereabouts (White et al., 2013). Orienting attention to a location by moving the eyes is referred to as overt attention and this influence that attention has on eye movements suggests that these mechanisms are tightly interlinked. For instance, in a letter discrimination task, participants were presented with a central cue as a saccade target (ST) followed by a discrimination target (DT) presented well before the eye movement (Deubel & Schneider, 1996). The results showed that performance was at highest when the ST and DT referred to items at the same location compared to different locations. This result remained when the participants knew beforehand the location of the DT. The ability to direct visual attention to one location and in the same time preparing a saccade simultaneously to the next demonstrate two processes that are closely integrated spatially and temporary (Deubel & Schneider, 1996).

The processes of eye movements and spatial attention are notably working together in order to prioritize the limited resources to relevant target locations. Yet, these processes are dissociable meaning that it is possible to attend to a location without moving the eyes, a phenomena referred to as covert attention. For instance when looking forward, keeping the eyes fixating but attending to targets in the periphery (Corbetta et al., 1998). In a dual task paradigm, participants had to covertly attend to a location that was directed by a central pointer in order to identify a target (Belopolsky & Theeuwes, 2009). Depending on the target they had to direct their attention by moving the eyes (overt attention) to either the same location as the target (matched condition) or to another location (mismatched condition). The participants were much faster in initiating saccades in the matched conditions compared to the mismatched demonstrating that allocation of spatial attention facilitates oculomotor preparations. However, if the previous trial was a mismatch condition it suppressed saccade preparation in the next trial demonstrating that covert attention and eye movements are dissociable. This illustrates that although attention is shifted through the activation of a saccadic program they are still dissociable processes (Belopolsky & Theeuwes, 2009).

Furthermore, with covert attention it is possible to attend to more than one location simultaneously in parallel while with overt attention where eye movements are serial and only can attend to one location at the time (Carrasco, 2011). It is suggested that the interaction between overt and covert attention and in which order they are deployed is that covert attention precedes eye movements. Before the a saccade is deployed, pre-saccadic attentional shift automatically enhance the visual sensitivity of the next saccadic target thus making it more visible and outstanding compared to other targets when the eyes have fixated (White et al., 2013). This means that attentional selection of the saccadic target begins even before the eyes start moving to the new location. The notion of a pre-saccadic attentional shift have been observed in a visual discrimination task were the observers had an improved performance in identifying the stimuli if they appeared at the goal of a saccadic eye movement compared to other locations. Demonstrating that while saccadic eye movement planning is in motion attention is already shifting to the goal of the saccade (White et al., 2013).

Attention and eye movements are tightly interlinked (overt attention) influencing saccadic movements to relevant targets but still can be dissociable by attending to a different target in the periphery while keeping the eyes fixated (covert). Although, there is a controversy relationship between spatial visual attention and eye movements there are some areas that both mediate attention and oculomotor. An functional magnetic resonance imaging (fMRI) and surface based representation study were conducted on attentional and oculomotor brain activity (Corbetta et al.,1998). They compared two different tasks of covert shift of attention to targets in the periphery to attentional shifts to the same stimuli using eye movements. It was revealed that there were anatomically overlapping activity in frontal, parietal and temporal lobes, more specifically medial frontal gyrus (MeFG), precentral sulcus (PrCS), intraparietal sulcus (IPS), the junction between IPS and transverse occipital sulcus (TOS) and superior temporal sulcus (STS). These functional anatomical data imply that covert and overt attention are sharing a lot of the same functional anatomical brain areas suggesting that these processes are mediated by a common neural network (Corbetta et al., 1998).

Covert and overt attentions are seemingly working together but are in the same time dissociable and both are very important in our everyday life. While covert attention makes it possible to observe the environment while overt attention guides our eyes to the relevant location. Thus, covert and overt attentions have an important role in searching for objects, driving, crossing the street and in social situations like doing sports and dancing activities (Carrasco, 2011). When attending to a location and then reorienting to a new one leads to an

inhibition of processing of the original location. This phenomenon is known as inhibition of return and was first discovered by Posner and Cohen (1984) which encourages orienting to new locations which can be useful in foraging or other types of search behaviour These two processes explain how attention captures targets in the environment; either by keeping the eyes fixating or by moving them to another location. Attentional deployment is necessarily when there are multiple stimuli and events in the visual environment and there are mechanisms referred to as endogenous and exogenous attention that shift attention to novel locations and objects (Chun et al., 2011).

Attention can either be drawn to a location by a sudden stimulus such as a bright flash or a loud sound; hence this type of attention is referred to as a bottom-up exogenous attention since it is driven by the stimulus itself. Alternatively, attention can be driven by a symbolic cue that instructs the observer where to pay attention such as arrows or left/right words, referred to as a top down goal directed endogenous attention (Hommel, Pratt, Colzato, & Godijn, 2001). Our attention can be automatically captured by an event happening in a different and unattended location or it can be voluntarily shifted to a new location (Chun et al., 2011). Endogenous and exogenous attention is usually studied by using cues and targets that appears in a cued location makes the detection or discrimination of said target much faster and accurate if it appears in the cued location than in uncued locations for both endogenous and exogenous conditions (Carrasco, 2011). Shifting attention that is directed by central or sustained cues seems to be under conscious control which means that it is possible to allocate the resources to the valid cue accordingly however it is still very difficult to ignore cues that are transient or that appears in the periphery (Giordano, McElree, & Carrasco, 2009). This involuntary shift of attention happens even though the observer knows that the cues are uninformative and irrelevant (Montagna, Pestilli, & Carrasco, 2009). Furthermore, responding to the involuntary and irrelevant cue might lead to impaired performance (Hein, Rolke, & Ulrich, 2006). Endogenous attention takes about 300ms to deploy and is much slower than exogenous attention and rises and decays quickly with a peaking of 100-120ms (Hein et al., 2006). Thus, it has been suggested that slower saccades (>200ms) are under a top-down goal-directed control while faster saccades (<200ms) are thought to be bottom-up control (Mulckhuyse, 2018).

The Neural Network of Orienting Attention

Our attention is directed elsewhere to another location, either by an exogenous cue or an endogenous cue meaning that the stimulus can be voluntary selected based on an ongoing task

or goal or automatically by visual saliency but it can also be selected as recently proposed by its selected history (Awh, Belopolsky, & Theeuwes, 2012). Selected history refers to the phenomena where a stimulus has been selected due to gaining saliency from past experiences like appearing on a previous trial (Maljkovic & Nakayama, 1994) or being associated with a reward (Della Libera & Chelazzi, 2006), this selection happens irrespectively of goals and visual saliency. These types of stimuli are under a bottom-up control (Chica, Bartolomeo, & Lupiáñez, 2013). When attention is directed to another location due to a an exogenous or endogenous cue, medial regions of the prefrontal cortex including supplementary eye field (SEF) and the superior parietal lobe (SPL) generate a transient activity as attention disengages from fixation and instead shifts to another location (Kelley, Serences, Giesbrecht, & Yantis, 2008). Both top-down and goal directed relevant information and bottom-up visually relevant information are thought to be integrated in a priority map that guides or visual attention for selection (Fecteau & Munoz, 2006). The priority map is composed of topographic representations where representations of objects and locations in the environment are developed and necessary for saccadic programming in the superior colliculus (Chelazzi & Corbetta, 2000). Furthermore, the superior colliculus determines when and where in the environment to make a saccade due to its own retinotopic representation of the environment known as the common saccade map (Meeter, Van der Stigchel, & Theeuwes, 2010). Top-down, bottom-up relevant information or both can elicit an activation for a particular location (Fecteau & Munoz, 2006) and as the activation reaches a certain threshold within the saccadic map a saccade will be executed and directed to that location in question (Godijn & Theeuwes, 2002) The transition between locations are suggested to be facilitated by the FEF and IPS which are indexing the current position in the visual field while SPL is responsible for encoding any changes of spatial coordinates in order to track the position of spatial attention (Molenberghs, Mesulam, Peeters, & Vandenberghe, 2007). When a cue directs attention to a target at another location, both the anterior and ventral IPS of the parietal cortex have shown responses to the cue as well as detecting the target (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000) However, unlike these regions, the temporo-parietal junction (TPJ) in the right hemisphere located at the intersection between the parietal and temporal junction only show responses to target detection (Corbetta et al., 2000). Furthermore, the right TPJ has a stronger reaction to targets located at unattended compared to attended locations and when there is a need for reorienting the coupling between TPJ and visual occipital areas increases (Indovina & Macaluso, 2004).

Corbetta and Shulman (2002) proposed a model of two integrative anatomically and functionally attentional networks for orienting attention containing dorsal and ventral fronto-parietal regions composed of earlier models (Posner & Petersen, 1990; Mesulam, 1999). It is a combination of the Mesulam's model of the attentional network of parietal and frontal regions including IP to FEF system that generates attentional sets (goal-directed stimulus, response selection and stimulus processing) (Mesulam, 1999) with the Ponser's posterior attention system of FEF orienting function (Posner & Petersen, 1990). The dorsal fronto-parietal network consists of the dorsal parietal cortex and more precisely the IPS and SPL, the dorsal frontal cortex along the precentral sulcus and the FEF (Chica et al., 2013). The neural network plays an important role in goal-driven and endogenous attention as we select sensory stimuli according to our goals and expectations. It enables this selection as well as connects them to its appropriate motor responses as people change their motor plan for a target (Rushworth, Krams, & Passingham, 2001). During target detection search, if the stimulus is expected to be hard to distinguish from the background FEF together with the inferior frontal sulcus (IFS) send top-down signals to the visual cortex. The visual cortex then mark the location for the subsequent stimulus by suppressing activity for unattended locations thus selectively modulates information from the attended area for the brain to process (Sylvester, Jack, Corbetta, & Shulman, 2008). Hence, the dorsal system is involved with both generating and maintaining endogenous signals that arises from a particular goal and pre-existing information about possible events leading to a bias towards relevant stimuli. The network then sends top-down signals to sensory cortex for a biased processing (Corbetta, Patel, & Shulman, 2008).

The second network behind attention is the ventral fronto-parietal network is not responding to any expectations or preperations of a task but it does respond along the dorsal network when there is a target detected relevant to the behaviour (Corbetta et al., 2000). During reorienting attention to another location, both of the networks are engaged and have an enhanced response for stimuli appearing at unattended locations (Chica et al., 2013). For instance, enhanced responses have been observed in Posner spatial cueing paradigm when the participants expect a target appearing at one location but instead appear at an unexpected location (Vossel, Thiel, & Fink, 2006) or if the target appears sporadically such as in oddball paradigm (Stevens, Calhoun, & Kiehl, 2005). The ventral fronto-parietal network core region is the TPJ but it also includes ventral frontal cortex (VFC) and parts of the middle frontal gyrus (MFG), the inferior frontal gyrus (IFG), the frontal operculum and the anterior insula. TPJ always activates when there is a requirement for reorientation either expectedly or

unexpectedly, compared with the right IFG that exclusively responds to unexpected conditions of reorientation (Doricchi, Macci, Silvetti, & Macaluso, 2010). As the ventral fronto-parietal network detects targets that are relevant for a particular behaviour it needs to filter out any other stimuli that is not significant. TPJ redirects attention to novel and relevant targets and when the observer encounters distracting stimuli, the right TPJ deactivates until the right target is detected (Shulman, Avtafiev, McAvoy, d'Avossa, & Corbetta, 2007). Additionally, when there are changes to sensory stimuli, TPJ show stronger activations to targets that are salient because of its relevance to the task which are suggesting a role of identifying salient information within the sensory environment (Downar, Crawley, Mikulis, & Davis, 2001). Hence, the ventral network does not usually get activated for irrelevant and distinctive stimuli (exogenous orienting) but only for stimuli that are task relevant (Corbetta et al., 2008). Thus exogenous attention for stimuli that are irrelevant and potentially dangerous does not activate this reorienting network (Chica et al., 2013). Exogenous cues have instead shown activations in the occipito-temporal junction (Natale et al., 2009). In a study using endogenous and exogenous and neutral cues to colour singletons showed that exogenous orienting involved a partially overlapping circuit in the extrastriate visual cortex (Kincade, Abrams, Astafiev, Shulman, & Corbetta, 2005). Thus, possibly mark a location for the FEF in the dorsal frontoparietal regions to direct attention to. The absence of brain activity of exogenous effect might be explained by the temporal resolution in the fMRI design thus since exogenous cues peaks around 100ms after stimulus onset it might have been too fast and brief to be captured (Chica et al., 2013). However, other studies have observed activation in the dorsal network regarding exogenous irrelevant stimuli indicating that exogenous orienting might recruit the same network for directing attention (Corbetta et al., 2008). Corbetta, and collegues (2008) thus conclude that the distinction between exogenous and endogenous might not be possible to separate into distinct neural systems but rather the distinction seems to lie between the systems in orienting such as exogenous and goal driven (dorsal attention system) and the stimulus driven reorienting (the ventral and dorsal attention systems).

In order for the attentional system to act in a coherent way, there is a need of interaction between these two distinct anatomically and functionally networks. Thus, there should be a site of convergence between the dorsal and ventral fronto-parietal networks and it is the regions within the lateral prefrontal from the ventral network that are suggested to be responsible for this. Asplund, Todd, Snyder and Marois (2010) conducted an fMRI study on participants that were searching for a target in a rapid serial visual presentation (RSVP)

stream among sudden distracting irrelevant stimuli. By examining if the surprising distracting stimuli impairs the goal-driven attentions search for the target, meaning that the stimulus-driven attention is disrupting goal-driven behaviour, there some interaction by an underlying neural mechanism. The results revealed that the inferior frontal junction (IFJ) located posterior to the inferior frontal sulcus and part of the ventral fronto-parietal network did not only support stimulus-driven attention but also goal-driven attention as it integrated with the dorsal fronto-parietal network. IFJ activity had a positive correlation to activity with FEF as well as IPS while having a negative correlation with TPJ during the goal-directed attention task. Contrarily, during reorientation the integrated activity between IFJ and FEF and IFJ and IPS decreased while there was an increased activity between IFJ and TPJ instead (Asplund et al., 2010). This finding has been further supported by a more recent study using fMRI demonstrating that IFJ activity were related to detecting relevant stimuli and were integrated with both dorsal and ventral fronto-parietal networks (Sebastian et al., 2016). Furthermore, when applying meta-analytic connectivity modeling (MACM) it contributed with a specific functional role for IFJ and it were suggested to be converging stimulus-driven ventral and goal-directed dorsal attention processes (Sebastian et al., 2016). Both these studies results highlight the importance of the function that the IFJ has on the dorsal and ventral attentional networks.

The interaction between these attentional systems during reorienting are thought to start with the ventral fronto-parietal network function as an alerting system that enables detection of salient behavioural stimuli in the environment but lack the high resolution spatial sensors (Corbetta & Shulman, 2002). As the relevant target has been detected, the dorsal IPs-FEF system localizes the targets precise position. When the stimulus is detected, the TPJ-VFC system from the ventral network works as a circuit breaker for ongoing cognitive activity. Thus, ones a low-frequency or unexpected event is detected the current attentional set has to break in order to attend to the new one and process the novel stimulus (Shulman et al., 2002). It is the IPS from the dorsal fronto-parietal network that provides the TPJ with information about the targets behavioural relevance either directly or indirectly in a top-down manner by modulating the visual cortex (Corbetta & Shulman, 2002). Hence, the dorsal network directs attention and the eyes towards at the stimulus located at the unexpected location with spatially selective responses (Corbetta et al., 2008).

To summarize, in this section of orienting shift of attention it has been covered the different ways of how attention is allocated to targets in the environment by using eye

movements (overt) or by not using eye movements (covert). That attention can be drawn automatically and involuntarily to a stimulus because of its features in a bottom-up manner (exogenous attention) or being voluntarily allocated because of a goal or a task in a top-down manner (endogenous attention). The interplay of orienting attention and eyes are enabled by the attention orienting system that involves two separate but integrative networks that have constant communication between each other and sends top-down signals to the visual areas. This leads to detection and shift of attention towards the stimulus. By knowing how orienting attention shift towards targets by using the eyes, the question remains if emotional stimuli would have an impact on attention for being relevant for survival and if so how. In order to answer that question, an explanation of what emotions are and what underlying neural processes of the amygdala enable these emotions will be covered for a greater understanding.

Emotions

Emotion, mood and feelings have distinct differences between them even though they can be used interchangeably in everyday language (Gazzaniga, Ivry, & Mangun, 2014). Emotions are an experience that is brief and intense and are usually a response to an inner thought or something happening in the environment. Hence, it can be specifically positive or negative depending on the situation and can interrupt what is going on in the moment or affect a change in behaviour or thought. (Positive emotions can promote flourishing, encouraging engagement in behaviours leading up to success in relevant goals and plans while negative emotions on the other hand motivate identification and avoidance of misfortune by either escaping or attacking (Nesse & Ellsworth, 2009). Thus, the emotional processes are thought to have evolved for increasing the chance of survival and reproduction by guiding our behaviour (Gazzaniga, et al., 2014). Feelings are rather a subjective experience derived from the emotion like for an example feeling scared but it is not the same thing as the emotion. Moods on the other hand are referred to as being a diffuse and long lasting emotional state that does not derive from any specific trigger. Instead of interrupting an event it influences the thought or behaviour (Gazzaniga et al., 2014). Furthermore, there are two different ways of distinguishing emotions; they can be primary or secondary emotions. Primary emotions are thought to be innate, evolutionary, adaptive and shared across cultures including; anger, fear, sadness, disgust, happiness, surprise and contempt. Secondary emotions are a mix of primary emotions like remorse, guilt, submission, shame, love, bitterness and jealousy (Gazzaniga et al., 2014). Furthermore, emotion can be categorized after valence like how unpleasant/pleasant or good/bad an emotion is or after arousal describing the intensity of

emotion such as high or low (Russell & Fernández Dols, 1979). According to Ochsner and James Gross (2005), they define emotions as valenced responses to an external stimulus and/or an internal mental representation that must follow a certain criteria. Emotions affect changes across several response systems (e.g. experiential, behavioural, peripheral and physiological), have identifiable triggers, be either an unlearned or learned response (automatic withdrawal from danger or like a fearful conditioned stimulus), that can also appraise different types of processes to access the significance of a stimulus to a current goal and lastly depend upon various neural systems (Kevin, Ochsner, & Gross, 2005). There is an agreement between scientists that emotions are consisting of three components involving a physiological reaction to a stimulus, a behavioural response and a feeling (Gazzaniga et al., 2014). Finally, there are six different kinds of emotions considered to be basic (anger, fear, disgust, happiness, sadness, and surprise) and all of them have distinct neural and physiological substrates as well as corresponding feelings and expression (Tracy & Randles, 2011) which will be presented in much further detail.

Even though most scientists have found ways of separating emotions from feelings and moods there is still no coherent answer to what an emotion is. The problem lies in that there is no coherent idea about how emotions arises and there are many different theories that have tried to explain that phenomenon such as physical theories like James Lange, Cannon-Bard and Schachter-Singer two factor theory. These theories share a common assumption that emotion contains a series of several steps after the stimulus that has triggered an emotion has been perceived by the senses. The following steps are concerning a physiological, behavioural response to the stimulus as well as the subjective experience or feeling that results from the emotion (Gazzaniga et al., 2014). Hence, emotions can be regarded as a set of component processes with an emotion triggering stimulus resulting in a specific emotion. The stimulus can either be external or internal. External is referring to a natural event or other people's behaviour while an internal stimulus can be memories, imagination or hormonal changes. Additionally, the stimulus that affects our emotions can also derive from us through behaviour of shame or guilt (Scherer, 2005). According to the James Lange theory proposed by William James and James Lange, physiological reactions such as acceleration of heart rate or breathing and sweating begins after the stimulus has been perceived causing an automatic and possibly unconscious interpretation of these physiological reactions. Hence, the physiological reactions occur before the emotion (Dalgleish, 2004). In contradiction, the scientists Canon and Bard thought that since many emotions (e.g. anger, excitement and sexual interest) share the same

physiological responses it is too hard to differentiate which emotion is experienced. Thus, the Canon-Bard theory proposes that after an emotional stimulus has been perceived the information travels to the thalamus which is then redirected to both the neocortex and the hypothalamus independently and simultaneously. The neocortex enable the generation of the emotion while hypothalamus is generating the physiological changes in the body (LeDoux, 2003). Hence, the physiological reactions and the emotion are operating in parallel (Dalgleish, 2004). These both theories contained factors that were seen as plausible according to the scientists Stanley Schachter and Jerome Singer. They agreed with the James Lange theory in equating the perception of the body's reaction with an emotion but they also thought that the Cannon-Bard theory was right about that it is not that there are a unique automatic pattern for every each emotion there is. This made them develop their own theory referred as the Schachter-Singer two factor theory (1962). They propose that all emotional stimuli results in basically the same physiological response referred to as the undifferentiated physiological arousal and that it could be interpreted differently depending on the situation and label. When the emotional stimuli have been perceived, physiological changes occurs and a search begins for what caused the arousal. The search for a cognitive explanation or label is usually straightforward and quick because the event is often easily recognisable. The prior knowledge about the stimulus results in an attribution of the arousal to the stimulus and label the emotion accordingly. Thus, whatever one believes caused the emotion determines how the emotion is labelled (Gazzaniga et al., 2014; Schachter & Singer, 1962).

Emotions are usually studied in an approach-withdrawal manner (pleasant/unpleasant) which has revealed two very important brain regions that are tightly correlated with the emotional experience (Davidson, 2003). The brain regions considered are the prefrontal cortex (PFC) and the amygdala and are generally thought to be involved in these kinds of emotional processes (Anders, Eippert, Weiskopf, & Veit, 2008). However, the focus will be on the amygdala and its neural processing of emotions. Following will be an examination of the underlying neural system of emotions, and more specifically the amygdala. Examining the neural systems for both attention and emotion are relevant for understanding how emotions impact attention and how that elicits a communication between these neural processes.

The Neural Mechanisms of Emotion

Scientific investigations of emotion have revealed a complex and interconnected neural network of brain structures associated with various kinds of emotions which is called the limbic system. The limbic system contains a network between multiple brain regions such as

the hypothalamus, anterior thalamus, cingulate gyrus, hippocampus, amygdala, orbitofrontal cortex and basal ganglia. According to the limbic system theory (MacLean, 1949), these brain networks was first thought to be the mediator of emotions. This theory have in recent years been questioned but several brain areas of the limbic system have been established to be important regarding emotional processing (Gazzaniga et al., 2014) which will be presented in much more greater detail.

The amygdala serves a crucial part in emotional processing and especially regarding fear however not exclusively (LeDoux, 2003). The amygdala consists of 13 nuclei in primates divided into three main groups that work as a gatekeeper for input or output to other brain regions (Gazzaniga et al., 2014). Basolateral nuclear complex received inputs from the sensory systems, the centromedial complex function as an output for innate emotional responses and cortical nucleus receives input from the olfactory bulb and cortex (Pitkänen, Savander, & LeDoux, 1997). When looking into molecular and cellular levels of the amygdala nuclei however it should be emphasized that these studies are conducted on animals due to technical limits (LeDoux, 2015).

The most studied emotions in the amygdala are negative emotions and fear especially since the underlying mechanisms can rapidly detect and respond to dangerous stimuli. In a PET neuroimaginal study the male participants had to watch a three second long presentation containing gray scale face expressions in different degrees of sadness and anger (Blair et al., 1999). The contrast analysis between the neural and the different degrees of emotion demonstrated that there was a correlation between the intensity of the perceived emotional stimuli to the degree of activation in the amygdala. Additionally, other brain areas like the right, inferior and middle temporal gyri, and anterior cingulate cortex (ACC) also got activated. However there was no amygdala activation for the angry face stimuli, instead brain areas like the right orbitofrontal cortex (OFC) and bilateral anterior cingulate cortex were highly activated in correlation to the level of angriness (Blair, Morris, Frith, Perrett, & Dolan, 1999). These results have been further supported by an fMRI study on both female and male participants (Yang et al., 2002). The amygdala has not only been shown to activate in response to negative emotions but to positive as well demonstrated by several fMRI studies (Anders et al., 2008; Yang et al., 2002). For an example, in a gender discrimination task conducted by Yang and colleagues (2002) different pictures presenting different emotional facial expressions of happiness, fear, anger, sadness and neutral showed a significant activation in the amygdala for all these emotions in question. Furthermore there were no

significant differences in activation between the four different emotional expressions and there was also no significant difference in activation level between left and right amygdala (Yang et al., 2002). In the same study it was showed that there was a less accuracy in gender discrimination when a facial expression of fear was presented in comparison to the other emotional expressions. Thus, it was discussed that there might be a higher level of involvement of attention, processing a fearful stimulus than processing the other emotions involved in the study. Furthermore, an fMRI study investigating two different features of an emotional stimulus; the valence (how negative and positive a stimulus is) and arousal of a stimulus in relation to the amygdala's activity (Anders et al., 2008). It was conducted by an investigation of both visual and auditory stimuli's affect on amygdala activation and the stimuli could be either positive or negative. The results demonstrated that activation in the amygdala was more strongly correlated with valence than arousal. The activation was greater in the left amygdala for negatively valenced images while the right amygdala responded more to positively valenced images. Furthermore, both negative and positive stimuli led to activation in the right caudolateral orbitofrontal cortex when analysing the whole brain however the left region of the orbitofrontal cortex was only activated in response to the negative stimuli. Finally, arousal of the visuo-auditory emotional stimuli was associated with activation in the right inferior orbitofrontal gyrus and the supplementary motor area from the dorsomedial prefrontal cortex (Anders et al., 2008). In another study, arousal was shown to be related to activation in the amygdala for positive emotion stimuli like happiness and humour demonstrating that arousal can be a component that affects amygdala activity (Costafreda, Brammer, David, & Fu, 2008).

It is important to acknowledge that there is a difference in emotional value between stimuli; some can be intrinsically relevant depending on the individual whereas other stimuli can be biologically relevant for all thus affecting selective attention differently (Mulckhuyse, 2018). For instance, amygdala activation differ depending on the type of the emotional stimuli like an emotionally expressed face to more complex pictures even though they are both classified as emotional stimuli (Vuilleumier, 2002). This was demonstrated by an fMRI study examining the amygdala responses for fearful and threatening facial expressions in comparison with negative IAPS pictures. The amygdala responded more to the emotional expressions than for the emotional induced pictures suggesting a difference in biological value for the two stimuli. This might be due to facial expressions being more intrinsically relevant for all whereas the IAPS pictures can be differently relevant for different individuals

(Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002). However, even though the amygdala responds differently to different types of stimuli there seems to be no biological difference found for exogenous covert attention between faces and emotional scenes (Carretié, 2014).

There are two different but simultaneous pathways within the brain that brings the emotional stimulus into awareness referred to as the low road (unconscious) and the high road (conscious). The information about the aversive stimulus travels through these pathways upon reaching the amygdala. The information travels through the low road much quicker (about 15ms in rats) as it is sent directly from the thalamus to the amygdala which is especially important in preparing the flight and fright response for avoiding dangerous situations (Gazzaniga et al., 2014; LeDoux, 2015). The high road on the other hand is longer (about 300ms in rats) where the information travels from the sensory cortex to the thalamus and back again for a more detailed analysis which is then finally sent to the amygdala. This slow process is also important since it enables a more accurate analysis of the information to confirm whether the stimulus was actually dangerous or not (Gazzaniga et al., 2014; LeDoux, 2015). LeDoux (2012, 2015) emphasizes that the mechanisms for detecting dangerous stimuli is part of an evolutionary inherited survival system which gives rise to a motivational state and emotional behaviour.

The amygdala have been demonstrated to be very important in a variety of different emotions and emotional tasks however there are several more brain areas that have been shown to be necessary for emotions. An fMRI study was conducted trying to classify the neural networks underlying the basic 6 emotions of disgust, fear, happiness, sadness, anger, and surprise (Saarimäki et al., 2015). The participants watched emotional induced movies or mental imagery and found specific neural signatures in brain regions for each emotion in a multimodal manner. Further, the subjective experience of the emotion was correlated with activation in the same neural network as well suggesting a link between the activities of the brain regions with the subjective emotional experience. Several brain regions where found to be involved for emotional activation (medial prefrontal cortex, posterior cingulate cortex, precuneus, anterior prefrontal cortex, lateral occipital cortex, postcentral gyrus, precentral gyrus and middle temporal gyrus), among them were the amygdala that was related to activations for happiness, fear and disgust. Except from the amygdala and also the insula, there was no region that was more important for a specific single emotion (Saarimäki et al., 2015).

In sum there seem to be a big interactive network of brain regions that accounts for our subjective emotional experience including the amygdala which mediate multiple different emotions on both their valence and arousal (happiness, fear, anger and sadness). The attentional and emotional concepts have been explained and the neural processes of these systems have been examined but what still remains are if emotional stimuli have an impact on attention for being relevant for survival. The next section will cover the final objective of how emotional stimuli impact attention by looking into how the neural processes of emotion and attention are communicating and if that would lead to facilitation in the orienting attentional and saccadic processing of emotional compared to neutral stimuli.

The Impact of Emotion on Attention

Emotions affect multiple different cognitive processes which can be observed in everyday life when for instance experiencing anger makes it harder in concentrating on a task or when we are really enjoying something makes us unaware of our internal physiological states such as hunger or tiredness (Gazzaniga et al., 2014). Attention and emotion are distinct and complex brain systems (Raymond, Fenske, Nader, & Tavassoli, 2003) and while attention allows people to select relevant information for prioritized processing emotions play an important role in facilitating these processes as well as capturing our attention (Phelps, Ling, & Carrasco, 2006). Attention is a cognitive process that has been demonstrated to be affected by emotions because it is the emotional arousing stimulus that reaches awareness when the attentional resources are limited (Gazzaniga et al., 2014). Thus, attention being more prone to respond to emotional salient stimuli as well as down-regulate the influence of irrelevant emotional stimuli is thought to have evolved for our survival since adaptive behaviour is dependent upon it (Cohen et al., 2011). For a stimulus to be considered as emotional it needs to elicit an emotional response like action tendencies, behavioural responses and change in ones subjective feeling (Brosch, Pourtois, & Sander, 2010).

Neural mechanism of emotional attention

Emotions are thought to involve two motivational circuits in the brain which are implemented by the limbic system and are phylogenetically old and responsible for protecting (defensive) and sustain (appetitive) life (Bradley, 2009). This circuit is involved in activation for cortical and subcortical structures and affect other cognitive processes such as attention, perception and action (Bradley, Keil, & Lang, 2012). These circuits mediate changes in the environment which can either be threatening or promoting survival and the neural firing of

this circuit follows a two way activation in engaging sensory systems which increase attention and facilitate the processing of perception and also engaging motor action (Lang & Bradley, 2010). Depending on the context of the situation it leads to a certain appropriate motor behaviour. If the context is threatening the system activates a behavioural response like withdrawal, escape or attack. However, if the context is appetitive for life like sustenance, procreation, and nurturance and the system will activate and promote ingestion, copulation and care giving (Bradley et al., 2012). The feeling of pleasure work as a parameter for which motivational system is engaged, if the pleasure goes down it activates the defensive system while for increasing pleasure, it activates the appetitive system. Furthermore, the intensity of the activation is dependent on the judgement of level of arousal (Lang, Greenwald, Bradley, & Hamm, 1993).

As for all processing of visual stimuli it begins with the eyes which are responsible for gathering information from the environment and most likely information that is either salient or relevant (Lang & Bradley, 2010). The photoreceptors and the optical system fixate on the emotional stimulus and is then passed on to get processed in a hierarchy manner through the ventral temporal stream from the primary striate cortex (V1) to more higher processing areas in the visual cortex. Finally, it is sent to the inferotemporal (TE) area to the lateral nucleus of the amygdala. As the stimulus has gone through this subcortical phylogenetically old pathway, the amygdala processes the emotional stimulus by its arousal as well as valence (Anders et al., 2008) and it does so even though the stimulus is not task relevant (Luo et al., 2010) or in focus of attention (Pourtois et al., 2010). This retinotopic pathway is primarily involved in the processing of rough visual features, low frequencies, motion as well as transients (Schiller, Malpeli, & Schein, 1979). For an example, the amygdala responds more strongly for emotional stimuli like facial expressions that have a low compared to a high spatial frequency (Vuilleumier, Armony, Driver, & Dolan, 2003). When the emotional stimulus has been processed, the amygdala then sends feedback to the visual areas through the amygdala's basal nucleus (Lang & Bradley, 2010). This feedback can modulate the gain of neural responses along with other attentional signals and thus perceptually enhancing the relevant emotionally stimulus (Peelen, Atkinson, Andersson, & Vuilleumier, 2007). As illustrated in an fMRI study, the increase of responses for emotional faces in the visual cortex had disappeared when the amygdala was damaged (Vuilleumier, Richardson, & Armony, 2004). This bidirectional connections with visually processing areas have mostly been demonstrated in studies on monkeys (Amaral, Behniea, & Kelly, 2003) but also in a DTI

study on humans (Catani, Jones, Donato, & ffytche, 2003). The tractography results in a DTI study showed direct connections from the extrastriate occipital cortex, more specifically V2 and V4 areas to anterior temporal structures such as lateral temporal cortex, parahippocampal gyrus and amygdala. Thus, these bundles of fibres allow a direct and fast access to visual information for the amygdala to process (Catani et al., 2003). Emotional relevant stimuli affect attention by the amygdala sending output signals of the processed emotional stimuli from the central nucleus (Ce), following activation of cholinergic projections from nucleus basalis (NB) in the forebrain (Pourtois, Schettino, & Vuilleumier, 2013; Corbetta & Shulman, 2002). Subsequently it releases acetylcholine to modulate parietal and frontal sensory cortical areas. This system may lead to alerting reactions and therefore shift attention. Finally, the orbitofrontal (OF), rostral regions in the anterior cingulate (ACC) and dorsolateral prefrontal cortex (DLPFC) are thought to modulate the strength of the output signals and this feedback loop. For instance, in a study on the interaction between emotion and attention regulation for voluntary and involuntary attention allocation, measurements of event-related potential and reaction time were used on patients with OF damage and healthy subjects (Hartikainen, Ogawa, & Knight, 2012). The patients went through a lateralized visual discrimination task with novel task irrelevant pictures that could be pleasant, unpleasant or neutral with a subsequent presented neutral target. This arrangement created a comparison of the effects between automatic attention regarding emotional and neutral stimuli and the effects that followed on the allocation of voluntary attention to the subsequent neutral stimulus. Patients with OF lesions demonstrated less attention drawn to the emotional distracters and resulted in an enhancement in target detection in comparison with the healthy subjects demonstrating the opposite effect. These results support OF being responsible for modulating attention allocation on emotional stimuli (Hartikainen et al., 2012). During top-down allocation of attention, frontal, parietal and sensory areas distribute the resources to task relevant locations or targets while mediating voluntary control (Pourtois et al., 2013).

Additionally, amygdala might be contributing to orienting attention to relevant stimuli since single-cell recordings in monkeys have demonstrated that the amygdala combines information about value and spatial position in the environment. The amygdala neurons showed a faster and stronger response for a visual cue that predicted a rewarding stimulus located in the contralateral compared to the ipsilateral hemifield (Peck, Lau, & Salzman, 2013). Yet, these bilateral connections between the amygdala and extrastriate visual cortex are probably operating globally at a hemifield level since there is no strict retinotopic

organization between those two (Gomez et al., 2011; Ferneyhough, Kim, Phelps, & Carrasco, 2013). Although, this suggests that the amygdala sends emotional feedback to the high level visual areas (e.g. fusiform cortex) and increase the sensitivity of visual inputs of relevant stimuli from other locations.

In sum, these distinct regulatory systems enable several ways of modulating sensory pathways and also decide what comes to our conscious experience and memory (Pourtois et al., 2013). Following, several studies of orienting attention being modulated by emotional stimuli compared to neutral ones will be presented. Hence, if orienting attention can be modulated by a stimulus being significant as in inducing pleasure or arousal, the magnitude should be increased by either pleasant or unpleasant stimuli compared to when the stimulus is neutral (Bradley, 2009).

Emotion modulation on attention

As covered earlier, attention has been demonstrated to be more prone respond to relevant and salient stimuli and since emotional stimuli is thought to have evolved for our survival (Cohen et al., 2011) makes emotional stimuli not an exception. Attention enables a selection for prioritized informational processing of relevant stimuli and the following studies will demonstrate how emotions facilitate this process and capturing attention.

In a longitudinal study using skin conductance response for measuring the significance of the stimulus affect on orienting for participants viewing novel pleasant, unpleasant and neutral pictures found results that were in accordance with this notion (Bradley, Lang, & Cuthbert, 1993). All novel pictures showed measurable skin conductance changes for orienting responses. However, the electrodermal responses were greater for pleasant and unpleasant stimuli in contrast with neutral pictures. In the second session which took place a week later, the participants were shown the same pictures again. The results showed the same pattern of affective modulation where pleasant and unpleasant pictures elicited greater orienting responses in contrast of the neutral stimuli. However, the repetition of neural pictures resulted in decrement in significant changes of electrodermal activity, although the skin conductance changes also diminished eventually but in a slower rate. These results demonstrate that the magnitude of modulation in orientation is affected by if the stimulus is pleasant or unpleasant and that novelty is the primary reason why orientation is drawn to neutral stimulus (Bradley et al., 1993).

The impact of emotions on overt attention. The effect of emotional salient stimuli on attentional overt orientation has been further demonstrated in a study using fear-conditioning by using neutral stimuli and associating it with electrical shocks (Schmidt, Belopolsky, & Theeuwes, 2015). When presenting the fear conditioned stimulus simultaneously with a neutral stimulus showed that voluntary saccades were initiated faster for the threatening stimulus compared to the neutral. When the stimulus was briefly presented a subsequent endogenous cue followed, instructing at what location to pay attention. The saccades were mistakenly drawn to the location with the threat instead of the other location that was supposed to be attended to. This implies that attention is automatically shifted towards a threatening stimulus and which also interfere with saccadic execution (Schmidt et al., 2015). In a follow up study to the previous mentioned. The study followed the same principles but, a stimulus was conditioned with safety were used meaning that when the stimulus appears on the screen it was certain that there was no electric shock to be delivered (Schmidt, Belopolsky, & Theeuwes, 2017). When the safety stimulus appeared it interfered with the voluntary saccades as well however, only with a relative long time interval between the cue and the stimulus. Since the threat conditioned stimulus was the only one that affected voluntary eye movements early in time implies that the selection is driven exogenously (Schmidt et al., 2017). Orienting attention gaze has been demonstrated to be modulated by emotion in gaze cueing studies with usage of dynamic gaze sequence (Lassalle & Itier, 2015). In these studies, different emotional facial expressions like fear, anger or surprise were investigated by at what time they were presented and how it affected the magnitude of the emotional affect on orienting attention. When the emotional stimuli were presented either before or during gaze shift there were no modulation on gaze orientation observed. In contradiction, when the emotional expression were presented after the gaze had shifted when the observer reacted like the stimulus had just been seen showed an increased effect on gaze orientation for emotional expressed faces compared to neutral. This implies that the particular order, of which the emotional stimuli are presented in regards to gaze, modulates orienting attention, in particular when the stimulus followed gaze shift (Lassalle & Itier, 2015). These studies clearly demonstrate that overt shift of attention is affected by emotional stimuli that are either defensive or sustaining life. Following, the capture of covert attention and oculomotor control by emotional stimuli will be examined.

The impact of emotions on covert attention. Endogenously driven saccades have been shown to be facilitated by emotional stimuli compared to neutral (Bannerman, Milders, de

Gelder, & Sahraie, 2009). In a force choice task, the participants were instructed to make a fast saccade to either an emotional or neutral stimulus which were presented left or right of fixation. The stimuli were photos of fearful faces and body postures and they were presented in pairs with the neutral stimulus. The time it took for the execution of a saccade (saccadic latency) to be made after the target has been presented was measured and the pairs of stimuli were presented either for quickly (20ms) or longer (500ms) periods. When the pairs were presented for a shorter duration it resulted in shorter saccadic latency for the emotional stimulus. However, the results were inconsistent when the pairs were presented for a longer time (Bannerman et al., 2009). In an exogenous emotional spatial cueing there was an investigation whether fearful facial expressions and body postures presented in different lengths of time have any effect on saccades (Bannerman, Milders, & Sahraie, 2010a; Bannerman, Milders, & Sahraie, 2010b). The emotional or irrelevant neutral stimuli appeared suddenly either left or right of the fixation point followed by another neutral stimulus at which the participant had to make a saccade to, either to the cued or opposite location. The cue varied in duration while the time between the offset of the cue and the neutral target onset were always zero. There were decreased saccadic latency in the trials with a briefly presented cue (<40ms) when the saccade and the previously cued location matched and if the cue was emotionally induced. However, the opposite occurred in a briefly presented cue trial when the saccade and cued location were invalid. The saccade latency was longer as attention was directed to the opposite location for emotional than neutral cues. In sum, emotional stimuli can facilitate saccades when it is directed to the same location or it can interfere as it is directed to the opposite location (Bannerman et al., 2010a; Bannerman et al., 2010b). The emotional significance of a spatial cue does not only facilitate saccade execution but also enhancing our ability to discriminate small details and fast temporal flicker in our environment. An emotional cue that directs our attention can improve spatial resolution of a stimulus (Bocanegra & Zeelenberg, 2011).

The affect of positive and negative emotional stimuli on orienting attention have been supported in studies both regarding overt and covert attention which have resulted in improved spatial resolution of a stimulus, facilitation or interference of saccade latency. However, there have been studies on emotion and saccadic latency in visual search where there was no significant results regarding such modulation. For instance, in a visual search task of colour singleton was used to investigate if emotional stimuli get automatically prioritized in the competition of attention (Devue & Grimshaw, 2017). The coloured target

appeared in an array along with distracting photos of angry and neutral facial expressions that were completely task irrelevant. The distracting stimuli of facial expressions drove oculomotor behaviour in a bottom-up manner but neither emotional nor neutral facial expressions captured attention more than the other eye-tracking measures indicated (Devue & Grimshaw, 2017). This has been further demonstrated in a much earlier study conducted by Hunt, cooper, Hungr and Kingstone (2007) but by using task relevant emotional stimuli instead. Participants were instructed to execute speeded saccades towards a predefined target while ignoring distracters of happy or angry faces. When emotions were the target of search, the task irrelevant happy and sad faces captured attention but there was no difference between these different emotional expressions regarding the amount of executed saccades. Additionally, the speed of the saccades did not differ between angry face targets and other targets. They concluded that emotional information can be used for voluntary goal directed tasks to capture attention but does not capture attention in a bottom-up manner and thus not affecting early visual selection processes (Hunt et al., 2007).

Emotions broadening the scope of attention. Emotions have been demonstrated to change the scope of attention were positive emotions broaden our attention span while negative emotions on the other hand are narrow it (Fredrickson & Branigan, 2005; Rowe, Hirsh, & Anderson, 2007) suggested by the Broaden and build theory by Barbara Fredrickson (2001). Positive emotions are thought to have evolved in order for learning of the environment and encourage exploration while negative emotions are evolved in order to see only the most relevant options in order to survive (Fredrickson, 2001). The relationship between positive affect and attention were examined in two separate cognitive domains: semantic search through a remote association task and visual selective attention through an Eriksen flanker task (Rowe et al., 2007). Positive affect showed correlated effects on both tasks. There was an enhancement of access to remote associations in the semantic domain as well as an increase in processing of spatially adjacent flanking distracters. These results supports the notion of positive emotions broaden the attention span since there were both an increase of semantic access and the participants attended to more targets through the expanded scope of visuospatial attention (Rowe et al., 2007). A similar task was conducted and revealed that participants with negative or neutral mood were less interfered by the incompatible flanker distracters when the eccentricity of the flankers was increased (Moriya & Nittono, 2011). However, there are contradicting results from an exact replication of the flanker task regarding positive affect's influence on compatibility effect of flankers (Bruyneel

et al., 2013). One possible explanation to these disagreeing results is that positive affect might not elicit a broadened attentional processing but rather enhancing the dominant attentional focus at that moment. Hence, when the dominant attentional focus is broad it gets even more broadened by positive affect and when the focus is narrow it gets even more narrow (Huntsinger, 2013). Although there is some mixed support regarding broadened scope of attention in participants experiencing positive mood in interference tasks, there are some behavioural evidence for this effect. In two EEG studies, participants had to perform oddball detection tasks at fixation while being induced of either positive or neutral mood from mental imagery of autobiographic memories combined with music (Vanlessen, Rossi, De Raedt, & Pourtois, 2013; Vanlessen, Rossi, De Raedt, & Pourtois, 2014). The results showed an advantage in reaction time in localizing stimuli in the periphery for positive mood compared to neutral (Vanlessen et al., 2014). However, when the participants were asked to discriminate more fine-grained details of the peripheral textures the accuracy dropped (Vanlessen et al., 2013). These findings demonstrate an influence on the trade-off between coarse and detailed stimuli analyses by positive induced mood. Detrimental effects of detailed processing are a logical outcome by a broadened attentional scope thus, a broadened scope means spreading of available resources to a larger area which decrease the processing strength in that given location (Carrasco, 2011). Electrophysiological studies have also reported supporting findings for this effect which have contributed to an insight into its neurobiological foundation. For instance, an ERP study discovered an alteration between positive mood and the earliest stage of stimulus processing at the C1 level (Vanlessen et al., 2013). C1 is the first visual evoked potential that comes after the appearing of the stimulus and is thought to be generated in V1. The positive mood group showed an enhanced C1 activation for the peripheral task relevant stimuli independently of position. This result suggests a stronger V1 processing for the stimuli selected by attention (Vanlessen et al., 2013). Similar results have been found in a study were the stimuli were task irrelevant (Rauss, Schwartz, & Pourtois, 2011). To summarize, positive affect showed an enhanced effect in specific gain control mechanisms operating in the early visual cortex and since the stimuli used in these studies were not biological or motivationally significant it indicates that the effects were due to alterations within the internal states. Positive affect seem to enhance these processes and at the same time without impairing other processes as a consequence (Vanlessen, De Raedt, Koster, & Pourtois, 2016). This might imply that positive affect can generate an increase of resources however that is not the case. Rather, positive affect elicit a change in the application of resources in order to resolve the task more efficiently (Vanlessen et al., 2016).

Additionally, in a study on negative emotions and its impact on narrowing attention revealed that by listening to negative emotional music led to a narrowing of attention by 36% as well as decreasing performance in a reading task (Huttermann & Memmert, 2015). It should be noted however that while positive mood such as joy and happiness are both considered to be low in approach tendencies and are never related to avoidance behaviour, negative mood differ (Vanlessen et al., 2016). Anger is more associated with approaching tendencies; anxiety is related to withdrawal behaviour while sadness is much less characterized with a strong tendency towards any behaviour. Thus, these emotions differ in physiological reactions, action-tendencies and mental processes making studies on negative mood more dependent on what type of negative affect to use (Vanlessen et al., 2016). For an example, fear and disgust had different effects on perception in attention during a target localization task (Susskind et al., 2008). A fearful induced mood was demonstrated to be associated with a subjectively larger visual field, faster eye movements when localizing targets and an increased perception whereas for disgust had opposite results and dampened perception (Susskind et al., 2008). As for anxiety it was demonstrated to broaden attention both in phobic participants (Weymar, Keil, & Hamm, 2013) as well as for nonphobic participants, however depending on the type of anxiety (Rossi & Pourtois, 2014). Results from electrical neuroimaging demonstrated that when the anxiety was anticipated and were due to psychosocial threat there was an enhanced state of sensory sensitivity for threatening information shown in early visual processing within the striate cortex. This means that attention was broadened and thus maintained an efficient goal-directed processing as well as ignoring irrelevant stimuli. However, bodily threat was associated with impairment in goal-directed processing and a decrease in filtering out irrelevant information (Rossi & Pourtois, 2014). To conclude, negative mood seem to have different effects on attention by either broadening or narrowing the scope depending on the characteristics of the emotion while positive mood is mostly related to only a broadened attention (Vanlessen et al., 2016).

Discussion

Since our brain has a restricted amount of energy to consume for neural activity we are limited in the capacity in processing all the competing options that our visual world has to offer (Carrasco, 2011). Attention is a core mechanism that tries to distribute these resources to visual information by selecting information considered to be important while ignoring information considered being irrelevant (Chun et al., 2011). Emotional stimuli seem to be thought as prioritized since attention does not only draws and have shorter saccadic latency

towards emotional stimuli appearing at the same location as the task goal but also when it is appearing at the opposite location as the location that was supposed to be attended to causing longer saccadic latency. These results suggest that emotional stimuli, both conditioned as fearful (Schmidt et al., 2015; Bannerman et al., 2010a; Bannerman et al., 2010b) and safe (Schmidt et al., 2017), can draw attention automatically and involuntarily and interfere with saccadic execution. This supports that emotional stimuli facilitates orienting saccadic shifts when the stimuli appears at the same direction which may indicate that the protecting and sustaining motivational circuit of emotion affect the exogenous orienting attention system. However, it could be argued that these results might be due to an interaction between the emotional stimuli and the capture of exogenous attention since sudden appearing stimuli are visually salient and thus can capture attention in a bottom up manner (Yantis & Jonides, 1984) However similar results have been demonstrated in a study with a different setup using both exogenous and endogenous cues for the emotional stimuli (Nummenmaa, Hyona, & Calvo, 2009). Additionally, when presenting the same emotional and neutral stimuli with one week in between showed that the emotional stimuli still elicited effect while neutral stimuli did not in the second session (Bradley et al., 1993). These results add support that the effect on orienting attention might not be due to the stimuli's physical saliency but instead because of the emotional feature of the stimuli. The emotional feature of a stimulus seem to capture attention in a bottom-up manner but not exclusively since it also facilitates endogenously drive saccadic speed for emotional stimuli compared to neutral (Bannerman et al., 2009). Hence, emotional stimuli seem to get prioritized processing when attention is automatically drawn towards the stimulus and when the participant voluntarily selects where to deploy attention. Additionally, attention selecting emotional stimuli for prioritized processing can explain why emotional significant cues have been correlated with an enhanced ability for discriminating small details of a stimulus as well as improving the spatial resolution of a stimulus (Bocanegra & Zeelenberg, 2011). Hence, if the stimulus is of importance then it gains more resources for processing.

The studies have mostly been on negative emotions and especially with fear but also on positive emotions were both do seem to have an impact on orienting visual attention for overt and covert as well as endogenous and exogenous attention. The reason why emotions seem to have a stronger impact on saccadic shifts of attention might be explained with evolution. There is far more risk to not respond to negative emotional stimuli because the formal can be important for survival and need proper motor behaviour in order to survive like attacking or

fleeing. Positive emotions however, merely promote exploration, learning new information and building resources but yet important for sustaining life (Fredrickson, 2001). Thus, it could be speculated that although both are considered important for survival negative emotional stimuli would elicit a greater impact on visual orienting attention compared to positive emotional stimuli since it has the potential to be dangerous (Vaish, Grossmann, & Woodward., 2013). Since negative emotional stimuli, and especially fearful would need a fast reaction for survival it could be suggested that it activates the exogenous attention system capturing attention in a bottom up manner. Additionally, positive emotions was observed to broaden attention through an increase of the C1 level in V1 leading to an increase of detection of stimuli in the periphery as well as irrelevant stimuli (Vanlessen et al., 2013). Negative emotions on the other hand have been demonstrated to narrow the scope of attention resulting in a decrease of performance (Huttermann & Memmert, 2015). This further support the broaden and build theory and can provide a better understanding of the evolutionary importance of emotions. Positive affect might change the appliance of the resources in order to resolve the task more efficiently (Vanlessen et al., 2016). Thus positive emotions being important for sustaining life and by eliciting positive affect being profitable for efficient task resolving might explain why positive emotional stimuli are in favour compared to neutral stimuli regarding to capturing of attention.

However while emotional cues have been related with an enhancement of discrimination of small details and spatial resolution of stimuli (Bocanegra & Zeelenberg, 2011) it seems that when the scope of attention is broadened the accuracy for discriminating fine-grained details of peripheral textures dropped (Vanlessen et al., 2013). It makes sense that detail discrimination drops when attention is broadened since it means that there is a wider area to distribute resources to and thus also decrease in performance (Carrasco, 2011). So why can positive emotional stimuli also enhance the discrimination of small details? A possible explanation is that positive emotions might create ways in order to encounter information that might be interesting by either broadening the scope of attention when it is narrow or by enhancing the processing of the attended stimuli even more when the focus of attention is already covering a larger visual field (Vanlessen et al., 2016). Even though there is much support for emotions having an impact on attention there are several studies where opposite findings or no findings at all could be seen. In visual search tasks there was no significant difference found between emotional and neutral stimuli having an impact on saccadic latency (Devue & Grimshaw, 2017) or between positive and negative emotional

stimuli (Hunt et al., 2007). To conclude from those studies it would seem that emotions does not capture attention more than neutral emotions in a bottom-up manner and by that also not affect early visual processes (Hunt et al., 2007). If emotional stimuli have a priority in allocating attention which leads to an attentional shift towards these stimuli that should imply that searching behaviour for these kinds of stimuli would increase performance. Hence, there is some mixed support for this notion. However, it could be argued that these results could be due to the novelty of the neutral and emotional stimuli both capturing attention in a bottom-up manner and thus also affecting saccadic latency in the same way. It would have been interesting if the study would have been repeated after certain amount of time using the same stimuli and see if the results would have been different, then the extraneous variable of novelty could have been controlled and change the results. It could also be speculated that emotion does not always have an impact on attention but rather endogenous attention can choose to ignore irrelevant emotional stimuli during high cognitive demanding tasks such as driving a car and seeing a wasp (Cohen et al., 2011). In such situations it can be needed for our survival to decrease the disruptive effect of emotional stimuli and attention should prioritize the task of driving to avoid any accidents (Cohen et al., 2011).

There has also been some inconsistent results for the broaden and build theory were negative emotions that should narrow the scope of attention have instead broaden it (Susskind, Lee, Cusi, Feiman, Grabski, & Anderson, 2008; Weymar et al., 2013). Negative emotions differ in approach and avoidance tendencies, physiological reactions, and mental processes and should be taken into consideration when conducting studies using negative emotions. Inconsistency has also been observed for positive emotions and their influence on compatibility effect of flankers, the researcher concluded that there might not be broadened effects on attentional processing due to positive affect but instead an enhancement of the dominant attentional focus at that moment (Huntsinger, 2013). This inconsistency for both negative and positive emotional impact on attention calls for further studying in order to get a better understanding of this mechanism. Inconsistent results might be due to several variables that can affect the results and need to be taken into account. For an example, emotions having an impact on orienting attention seem to be dependent on what order (Lassalle & Itier, 2015) the emotional stimuli are presented and for how long (Schmidt et al., 2017). Hence, these conditions can influence the outcome weather there will be a modulation on gaze orientation or not and for how long the stimuli can be processed which affect saccadic latencies. Furthermore, studies on emotions can be difficult to conduct since it is hard to know how

much of a feeling is being felt by the individual because different emotional stimuli differ in value such as being intrinsically relevant for the individual while some are behaviourally relevant for all (Mulckhuyse, 2018). Depending on if the emotional stimuli being used are emotionally expressed faces or complex pictures can therefore affect selective orienting attention differently (Vuilleumier, 2002). Since conducting studies on emotional stimuli and its impact on orienting attention is dependent on so many different variables it can be hard to draw any general conclusions. However, most studies seem to support that emotions do have an impact on visual orienting attention and saccadic shifts as a result of the amygdala sending top down signals to the orienting attentional network that target the stimulus for enhanced processing.

For future research it would be interesting to examine from the opposite point of view, how attention impact emotions. Even though emotions are thought to be important for our survival we cannot attend to all emotional stimuli that appear in the visual field especially during high cognitive tasks that includes risk for not paying attention. Most studies used in this essay are also conducted on negative emotions, fear especially and to get a better understanding of how emotions impact attention it would be useful to conduct more studies on various emotions. Moreover, future research could benefit of trying to separate emotions from endogenous and exogenous attention to be able to understand the mechanisms underlying emotions impact on visual and selective attention. Finally, conducting studies on individual differences to see if some individuals are more prone or unsusceptible to respond to different types of emotions (negative or positive) would have different impacts on the orienting attentional system. Thus, it could be also interesting to take emotional intelligence into consideration to see if people with a higher level or lower level of emotional intelligence are correlated with a higher or lower activation in orienting attention.

Conclusions

Combining these results from various studies support that emotional stimuli, either positive or negative can modulate orienting attention for both overt and covert attention. However, this modulation effect of saccadic latency seem to be absent in visual search. Negative emotions usually have a stronger impact than positive emotions on attention and perception thus, there seem to be a bias towards negative stimuli because it has more informational value than positive emotional stimuli. However, it is clear that emotion plays an important role in enhancing attention and perceptual processing. Emotion and attention are

constantly communicating, bringing unattended emotional stimuli into awareness. Finally, emotions being important for our survival mean that by affecting attention and perception processes it elicit a change in the application of resources in order to solve the limited capacity problem. Thus, sustain high level performance for an appropriately behavioural response, possibly to protect and sustain life.

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