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„Capture of visual attention by subliminally presented faces: Bottom-up versus top-down control"

verfasst von / submitted by

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Abstract

Visual attention can be oriented to a stimulus because of two major reasons. On the one hand a stimulus can capture attention because it is relevant for the current goal (top-down). On the other hand, attention can be oriented to a stimulus because of its salience or adaptive value (bottom-up). In this master thesis we investigated whether subliminally presented faces would capture attention in a bottom-up or top-down manner, when presented simultaneously in the opposing fields of vision. This was done using an adapted version of Posner's cueing paradigm. In the cueing display one goal-relevant (neutral) face and a second emotional (fearful or disgusted) face were shown. The neutral face was goal-relevant because participants were instructed to search for the neutral face in the target display and could therefore possibly capture visual attention. The emotional face could potentially capture attention because of its evolutionary relevance. Behavioural data did not reveal an orienting of attention to either type of stimulus. However, electrophysiological recordings showed a greater negativity at around 300 ms after cue onset, contralateral to the goal-relevant (neutral) face. This finding indicates that participants oriented their visual attention to the goal-relevant face in the cueing display. Therefore we argue that the top-down search set was able to override the bottom-up attentional bias for an emotional facial expression, when the stimuli were presented subliminally.

Keywords: Visual attention, subliminal, contingent capture, threat superiority effect, event-related potential, emotional faces

Zusammenfassung

Visuelle Aufmerksamkeit kann aus zwei wesentlichen Gründen auf einen Stimulus gerichtet werden. Einerseits kann ein Stimulus Aufmerksamkeit erregen, weil er für das aktuelle Ziel relevant ist (top-down). Andererseits kann ein Stimulus die Aufmerksamkeit auf sich ziehen, weil er besonders auffällig ist oder einen adaptiven Vorteil bietet (bottom-up). In dieser Masterarbeit untersuchten wir, ob subliminal präsentierte Gesichter die Aufmerksamkeit durch einen bottom-up oder top-down Mechanismus erfassen können, wenn sie gleichzeitig in den gegenüberliegenden Sehfeldern präsentiert werden. Dazu verwendeten wir eine angepasste Version von Posners Hinweisreizparadigma. In der Hinweisreiz-Anzeige wurden ein zielrelevantes (neutrales) Gesicht und ein zweites emotionales (ängstliches oder angewidertes) Gesicht gezeigt. Das neutrale Gesicht war zielrelevant, weil die Probanden instruiert wurden nach dem neutralen Gesicht in der Zielanzeige zu suchen und konnte daher potentiell die Aufmerksamkeit auf sich ziehen. Das emotionale Gesicht könnte die Aufmerksamkeit auf sich ziehen, weil es ein evolutionär wichtiger Stimulus ist. Die Verhaltensdaten zeigten keine Aufmerksamkeitsverlagerung zu einem der Stimuli. Allerdings zeigten elektrophysiologische Aufnahmen eine größere Negativität bei etwa 300 ms nach dem Hinweisreiz-Beginn, kontralateral zum zielrelevanten (neutralen) Gesicht. Dieses Ergebnis deutet darauf hin, dass die Teilnehmer ihre visuelle Aufmerksamkeit auf das zielrelevante Gesicht in der Hinweisreiz-Anzeige gerichtet haben. Daher argumentieren wir, dass das top-down Suchschema in der Lage war, eine bottom-up Erregung der Aufmerksamkeit für einen emotionalen Gesichtsausdruck zu überschreiben, wenn die Reize subliminal präsentiert wurden.

Schlüsselwörter: Visuelle Aufmerksamkeit, subliminal, Contingent Capture, Threat Superiority Effekt, Ereigniskorreliertes Potential, emotionale Gesichter

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1 Introduction

At any time point we are surrounded by thousands of stimuli which can reach our senses. Only some of these stimuli are selected for further processing, possibly because of the limited capacity of our cognitive system (Ansorge & Leder, 2011). The selection of certain items and suppression of others is called "attention". The opinions on how this process works are divers. They reach from the often quoted sentence from William James, that "Everyone knows what attention is." (James, 1890, p. 403) to statements like the one of Stuart Sutherland claiming that "[A]fter many thousands of experiments, we know only marginally more about attention than about the interior of a black hole." (Sutherland, 1998, p. 350). Even though the last statement seems discouraging, many promising findings have been made, to explain attentional processing. This master thesis will focus on visual attention and therefore several theories from this field will be discussed, in order to explain the results. The introduction will address covert and overt attention (1.1), the spotlight theory (1.1), Posners' exogenous cueing paradigm (1.1) and the event-related potential (ERP) N2pc. Furthermore the processing of emotional faces (1.2), the subliminal presentation of stimuli (1.3), the contingent capture theory (1.4.1) and the threat superiority effect (1.4.2) will be introduced.

1.1 Theories of visual attention

First experiments in the field of visual spatial attention date back to the 19th century, when Hermann von Helmholtz described that it is possible to keep a point under fixation, while shifting visual attention to another place in space (Von Helmholtz, 1867). This mental shift of attention is called "covert", as the eyes are not moving. It is not only an interesting phenomenon for researchers, but has implications in everyday life, for example in sports or social interactions, when someone wants to keep his focus of attention secret. A shift of attention in which the eyes, head or body are directed towards a stimulus is by contrast called "overt" (Posner, 1980). Many theories have put up ideas about the connection between covert and overt visual attention. For example, the premotor theory states that covert visual attention is a form of preparation for a saccadic eye movement (Rizzolatti, Riggio, Dascola, & Umilta, 1987). Rizzolatti and colleagues argue that covert attention is shifted to a certain point, when an oculomotor program for a saccade to this point is planned. In their experiment from 1987, participants were cued to shift their attention towards one of four locations and instructed to respond as fast as possible to a stimulus which could appear in one of the locations. It was shown that the incorrect orienting of attention caused a significant time delay in responding to the stimulus. The time delay increased with the distance between the attended location and the position of the stimulus and there was an additional cost when the two locations were on opposite sides of the horizontal or vertical meridian. The authors postulated that the time delay occurred, when attention was oriented incorrectly, because one ocular program had to be erased and the next one prepared.

Another prominent theory which illustrates how a shift of attention works, is the so called spotlight theory (Posner, Snyder, & Davidson, 1980). It compares visual attention to a spotlight which can wander around and enlighten certain objects, whereas others stay in the dark. If one wants to shift the attention from one point to another, one has to move the spotlight all the way between the two points in space, which takes a certain amount of time.

Posner's exogenous cueing paradigm has been invented to measure shifts of visual attention by the means of this time delay (Posner, 1980). During the task a target appears either on the left or right side of a fixation cross on a computer screen. Usually the goal in this experiment is to identify the location or a specific property of the target as fast and accurately as possible. The participants are instructed to fixate on the cross in the centre, while only shifting their visual (covert) attention towards the target to complete the task. Importantly, shortly before the target, a cue is presented at the same position as the target will appear (congruent trials) or at a different position (incongruent trials). The cue is usually the item which the researchers are interested in. If the cue captures visual attention, participants should be faster and more accurate in responding to the target in congruent in comparison to incongruent trials, because their attention is already shifted to the correct side of the display.

Another more precise possibility to locate visual attention focusing lies in measuring electrophysiological (EEG) recordings of the participants. An event-related potential (ERP) component called N2pc was described by Luck and Hillyard (1994) as a marker for visual attention. The N2pc component is defined as a relative negativity at occipito-temporo-parietal electrode sites at around 180-300 ms after stimulus onset contralateral to visual attention focusing. Meaning, if a person attends to a visual stimulus presented in the left hemifield, the N2pc can be recorded as a relative negativity on the right hemisphere of the scalp and vice versa.

1.2 Processing of emotional faces

Human faces capture visual attention more efficiently than non-face stimuli (Finkbeiner & Palermo, 2009). Perhaps, because faces are one of the most important stimuli for social interaction (Palermo & Rhodes, 2007). We are often able to identify the emotional state of our peers simply by reading his or her facial expression, which can be done within milliseconds (Smith, 2012). This makes it possible to act appropriately in everyday life and emotional situations. The evolutionary adaptive value of recognizing emotional faces is underpinned by the finding that the same emotional concepts are associated with the same facial expressions, across different cultures (Ekman & Friesen, 1971).

Furthermore, faces are thought to be processed partly along an evolutionary older subcortical route. The subcortical route involves the superior colliculus, the amygdala and pulvinar, which modulate cortical processes (Johnson, 2005). First evidence was provided by studies with brain injured patients. Adolphs and Tranel (2003) could show that adults with bilateral amygdala damage were more accurate in identifying a fearful scene when faces were erased from the picture as when they were visible, compared to control subjects. The authors concluded that the amygdala is more important for processing the emotional content of a facial expression than a scene. Similar results were found in an fMRI study with healthy participants, revealing stronger amygdala activation for emotional faces than scenes (Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002). Some researchers claim that the subcortical route of face processing is activated, even when attention is located at another position (Finkbeiner & Palermo, 2009).

The capture of visual attention by faces is also dependent on which emotion is displayed. Khalid, Horstmann, Ditye, and Ansorge (2016) investigated differences in the shift of visual attention to fearful and disgusted faces. Both types of emotional expressions are negative and could indicate a nearby threat. A fearful face could indicate a more imminent danger whereas a disgusted face could denote a less impending threat like rotten food. Khalid and colleagues found differences in the capture of visual attention by the two emotional faces, which were in favor of a more prominent capture of attention by fearful than disgusted faces.

Additionally, by presenting faces as cues in our study we could make use of the “face inversion effect” (Yin, 1969). When a face is presented upside-down it has been shown that the identification of the emotional expression by the viewer is impaired (Khalid et al., 2016; McKelvie, 1995). Consequently, when faces are shown inverted they will have the same visual features as when shown upright, but the emotional content should not have an impact on the viewer. Thus, when investigating the capture of visual attention by emotional faces, trials with inverted faces can be used as a control. By showing that an attentional bias towards a specific emotional expression is present with upright faces, but not when the faces are shown upside down, one can claim that the effect derives from the emotional content rather than low-level features of the picture.

1.3 Subliminal presentation of stimuli

It has been shown repeatedly that even stimuli which are presented subliminally and are therefore not perceived consciously can capture our visual attention (Ansorge, Kunde, & Kiefer, 2014; Dehaene & Naccache, 2001; Mulckhuyse & Theeuwes, 2010; Tamietto & de Gelder, 2010). The first evidence for the impact of subliminally presented stimuli on behavioural responses was again gained by studies involving patients with brain lesions. Pöppel, Held, and Frost (1973) could show that four patients with a partial blindness (scotoma), due to lesions in occipital brain areas, could respond to a stimulus which was presented in their blind field. These patients were able to correctly carry out saccades towards the stimuli, above chance level, even though they claimed that they were not able to see the item. In similar studies these findings could be confirmed by showing that patients with “blindsight” could often accurately guess the location or even the shape and colour of an unseen item (Weiskrantz, 1997).

Lesion studies are not the only possibility to study the effects of non-conscious stimuli. Some techniques have been developed to present visual stimuli subliminally to healthy participants, therefore ruling out interpretational difficulties due to the brain damage of the patients. One approach, namely "masked priming", will be introduced in more detail (Ansorge et al., 2014; Marcel, 1983). In a masked priming experiment a prime (here called cue) is followed by a mask, which has the same shape as the cue (pattern masking) or surrounds the shape of the cue (metacontrast), at the same position as the stimulus has appeared. This approach is called "backward masking" as the cue precedes the mask. The time interval between cue onset and mask has to be short to provide a sufficient masking effect. Usually it does not exceed a few tens of milliseconds. In a similar approach, called "forward-masking", the mask is shown before the cue. Both procedures can lead to a reduction or the absence of conscious visibility of the cue, probably by an interference of the two stimuli (Kahneman, 1968). Still, the stimulus can capture visual attention, which can be measured by behavioural and electrophysiological experimental approaches.

1.4 Top-down versus bottom-up: Experimental strategies

A huge debate tackling the question which stimuli we orient to has brought forth two distinct mechanisms by which an item can capture attention (reviewed by: Ansorge et al., 2014; Ruz & Castillo, 2002; Theeuwes, 1993). First, selective attention can be deployed to successfully search for a certain object. For example, imagine being in a crowded place like a funfair and looking for your friend. If you know that he or she is wearing a green jacket, you can set up a "search set" for green jackets and ignore other colours in order to search efficiently. This strategy is called endogenous or top-down control as the search set is willingly created by a person to achieve a specific goal (Egeth & Yantis, 1997). An effect related to the top-down control of attention is the so called "contingent capture hypothesis". According to the contingent capture theory we will orient our attention involuntarily to stimuli which share features with the item we are searching for (Folk, Remington, & Johnston, 1992). In this example items like a green buggy might catch our attention for a moment even though we know we are only searching for green jackets.

Second, the properties of the stimulus itself can initiate an orienting of attention. For example while searching for our friend we might pass a ghost train and get distracted by a sudden, loud scream. As this behaviour is controlled by the environment it is called exogenous control or bottom-up orienting (Egeth & Yantis, 1997). Not only acoustic signals but also salient visual stimuli are able to capture our attention in a bottom-up manner. A stimulus can grab our attention because of its physical appearance like brightness, contrast or sudden onset. Additionally it has been claimed that humans are predisposed to orient towards evolutionary important signals like a threatening object or a fearful facial expression (Mathews & Mackintosh, 1998; Öhman, Flykt, & Esteves, 2001).

Especially when a stimulus is presented subliminally the opinions differ in whether it can capture attention in a bottom-up or a top-down manner (Ansorge et al., 2014; Mulckhuyse & Theeuwes, 2010). Intuitively one could think that subliminally presented items rather capture attention in a stimulus-driven way (bottom-up) as they are not even consciously perceived, whereas supraliminal presented stimuli attract attention when they are searched for (top-down). This is what early theories of visual attention have proposed (Posner & Snyder, 1975). More recent research has provided a different picture though and many researchers now hold the opposite opinion. Current studies have shown that subliminal stimuli do not capture attention automatically, as proposed before, but mainly when they match the present search set (Ansorge et al., 2014). Intermediate hypotheses exist as well. For example Finkbeiner and Palermo (2009) state that the processing of non-conscious stimuli varies with the type of stimulus presented. They argue that most subliminal stimuli need to be goal-relevant to capture attention but claim that there are exceptions from this rule.

In the following two subchapters studies in favour of an attentional capture by subliminal stimuli which fit to the current search set (contingent capture theory) are introduced (1.4.1) and research on stimuli which are nevertheless said to influence orienting exogenously (threat superiority effect) (1.4.2) are discussed.

1.4.1 Top-down: Contingent capture theory

Many studies have shown that our attention can be shifted to subliminal stimuli if they share features of the current search set (reviewed by: Ansorge, Horstmann, & Scharlau, 2011; Ansorge et al., 2014). This phenomenon is called "contingent capture of attention" and was first described by Folk et al. (1992). An example for an experiment showing contingent capture by subliminal cues is provided by Ansorge, Kiss, and Eimer (2009). In the study of Ansorge et al. (2009) a cueing display with four circles of different colours was shown. The cueing display was followed by a target display, containing four angular figures of different colours. As cues and targets appeared at the same location the targets served as masks and the cues were not perceived consciously. The participants were instructed to indicate the shape of one of the angular figures with a specific colour. For example: "is the red figure a diamond or a square?". It could be shown that participants responded faster to targets which were cued by a circle with the same colour they were searching for, even though a subsequent test showed that they were not aware of the cue. Besides the behavioural data, electrophysiological evidence of attentional capture by the goal-relevant cue (the N2pc component) was found. Similar experiments could repeat the results of an N2pc on masked colour primes which fitted the current search set and could not be observed if the same colour was task-irrelevant (Ansorge, Horstmann, & Worschech, 2010). Schmidt and Schmidt (2010) could show that a masked colour prime, which the participants were unaware of, triggered priming effects when the participants had to discriminate between target colours, but not if they had to differentiate between target shapes. If the task was to discriminate between target shapes the same pattern was observed for shape primes, but not for colour primes. Furthermore, Ansorge, Kiss, Worschech, and Eimer (2011) argue that even the initial stage of processing is affected by top-down control and not only later stages as another line of reasoning suggests (Theeuwes, 2010).

In sum, many researchers argue that subliminal presented stimuli will only evoke an attentional bias when the stimulus is goal-relevant because it is contingent on the current top-down search set.

1.4.2 Bottom-up: The threat superiority effect

Even though the top-down contingent capture of attention for subliminal stimuli has recurrently been demonstrated (Ansorge et al., 2014), some researchers claim that specific objects have the ability to capture attention exogenously (Mulckhuyse & Theeuwes, 2010). According to the threat superiority effect, a candidate group of objects are threatening stimuli, which humans are predisposed to rapidly orient their attention to (Mathews & Mackintosh, 1998; Öhman & Mineka, 2001). Öhman and Mineka (2001) proposed a neuronal "fear module" which has been preserved during evolution because of its adaptive value. The authors state that the fear module is automatically activated by threatening stimuli and relatively impenetrable to cognitive control. In other words, Öhman and Mineka suggest that fear relevant stimuli capture attention in a bottom-up manner, which cannot be interfered by top-down control.

Some visual search experiments have provided support for the threat superiority hypothesis. In the visual search task a single item among a number of distractors has to be detected as fast as possible (Wolfe, 1998). It could be shown that participants are able to detect an evolutionary threatening stimulus like a snake or a spider more rapidly among for example mushrooms or flowers than vice versa (detecting a mushroom among snakes) (Öhman, Flykt, et al., 2001). Many studies have found similar results showing emotional faces. Participants detected a face with a fearful or angry expression among neutral or positive face distractors more easily than vice versa (Fox et al., 2000; Hansen & Hansen, 1988; Horstmann, 2007; Horstmann & Bauland, 2006; Öhman, Lundqvist, & Esteves, 2001), (reviewed by: Frischen, Eastwood, & Smilek, 2008; Horstmann, 2009).

More evidence for the threat superiority effect comes again from studies using Posner's cueing paradigm (Posner, 1980). For example Khalid et al. (2016) investigated whether a face with a fearful, disgusted or neutral expression could evoke a cueing effect. A single face was displayed on the left or right side of a fixation cross on a computer screen for 20 ms. It was followed by a cross which either appeared at the same position as the face had been (congruent) or on the opposite side (incongruent). Participants had to indicate the location of the cross (either left or right side) by performing a saccade to its position as fast and accurately as possible. The behavioural data demonstrated a threat superiority effect as more errors were made in incongruent trials with fearful compared to neutral faces (Khalid et al., 2016). This effect was shown for upright, but not for inverted faces, indicating that the emotional expression and not low level features of the pictures were responsible for the results. Interestingly, when using disgusted faces as cues a different pattern of results was found. The authors thus claim that the effect could be emotion specific for threatening stimuli and cannot be generalized to other negative emotions like disgust. It is important to note that the face cues in this experiment were not predictive of the target and there was no reason for the participants to pay attention to them. Therefore one can argue that the capture of attention happened in a stimulus driven, bottom-up manner.

The attentional bias for fearful faces could be shown repeatedly in many experiments using supraliminal and subliminal stimuli. For example Carlson and Mujica-Parodi (2015) found that task-irrelevant, masked fearful faces captured visual attention rather than a face with a neutral expression when they were displayed simultaneously. Besides behavioural data, electrophysiological (EEG) recordings have also shown that task-irrelevant fearful faces are processed differently from neutral faces. For example Pegna, Darque, Berrut, and Khateb (2011) found a modulation of the N170[1] component to subliminal fearful faces, even when attention was engaged in a different task.

Taken together, some indications have been made that threatening faces can capture attention without being task relevant and therefore constituting an exception from the contingent capture hypothesis.

1.5 Aim of the present study

On the one hand, numerous studies have shown that subliminal presented stimuli only attract our attention when they share features of our current top-down search set. On the other hand, research has repeatedly demonstrated that fearful faces can attract our attention in a bottom-up manner, without being goal-relevant. In this master thesis we wanted to investigate whether a fearful face can still evoke an attentional bias, to one side of the visual field, when an item which matches the top-down search set is presented in the opposing field of vision. To realize the experiment we chose to use an adapted version of Posner’s cueing paradigm showing threatening, disgusted and neutral faces. In the visible target display one neutral and one disgusted face were shown simultaneously in the left and right visual field. A symbol was displayed on both faces and participants were instructed to report the orientation of the symbol on the neutral face target. This instruction build up a search set for neutral faces. Shortly bevor the target display two masked faces were shown non-consciously. One face always had a neutral expression and the second face either a

[1] The N170 is an event-related component measured in electrophysiological recordings. It is defined as a negativity at around 170 milliseconds after stimulus onset at occipito-temporo-parietal electrode sites and is known to show a significant higher amplitude for faces compared to other objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996)

fearful or disgusted expression. Disgusted faces were also used as cues to investigate if the threat-superiority effect is limited to the emotion of fear in our experiment (as found in the study of Khalid et al. (2016)) or if it can be generalized to the emotion disgust. We were interested in whether the participants would orient their visual attention towards the goal-relevant neutral or salient emotional masked face. To answer this question we measured behavioural (response times and accuracy rates) and electrophysiological data (the N2pc component).

We hypothesized that the top-down search set for neutral faces would override a possible threat superiority effect, which would argue against an automatic, encapsulated fear module proposed by Öhman and Mineka (2001).

2 Method

2.1 Participants

Thirteen participants (eight female) with a mean age of 24.3 (range 19 to 27) took part in the experiment, which was carried out at the Faculty of Psychology at the University of Vienna. One participant had to be excluded from the EEG analysis because of insufficient data quality. All participants had normal or corrected to normal vision, reported to have no history of psychiatric or neurological disorders, and were naïve to the hypothesis of the experiment. Written informed consent was obtained prior to the experiment and the study was carried out in accordance with the declaration of Helsinki (World Medical Association, 2013)

2.2 Stimuli

For this study we used the same stimuli as Khalid and colleagues (Khalid et al., 2016). The stimuli were selected from the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist, Flykt, & Öhman, 1998) and show grey-scale images of five female and five male faces. All images are equated for luminance/contrast and spectral power and were cropped behind a white over layer, to ensure that only the face features were visible. The images subtended a visual angle of 11.2° vertically and 7.5° horizontally and were presented with an eccentricity of 9.2° on the left and right side of the display. The three facial expressions shown were “fearful”, “disgusted” and “neutral”. Faces in the target display had a white “T” in the centre of the picture, which was oriented in one of four possible directions (upright, inverted, flipped to the left or to the right) (Figure 1 and Figure 2).

Figure 1: Face stimuli. Faces with neutral (top row), fearful (middle row) and disgusted (bottom row) expressions. Female faces are presented on the left and male faces on the right hand side. The pictures are reprinted from Khalid et al. (2016).

2.3 Procedure

Participants were welcomed to the laboratory at the Psychological Department of the University of Vienna and informed about the general procedure of the experiment. The information provided included only the steps of the EEG application and the type of response they were asked to give e.g. seeing pictures on a computer screen and pressing buttons on a keyboard. After written informed consent was obtained we applied 64 active electrodes via a cap onto the participants head. While performing the task, participants sat in a quiet, dimly lit room in front of a 19-inch colour CRT monitor. Their heads were leaning on a chinrest to ensure a constant viewing distance of 60 cm from the screen. The study was comprised of a practice, a single and a dual task, which participants completed in approximately 40 minutes. Afterwards, participants were shown where they could wash out the electrode gel from their hair and were informed about the purpose and hypothesis of the study, if interested. From arrival to leaving the building participants spent around 2.5 - 3 hours in the laboratory and gained 6 LABS (Laboratory Administration for Behavioural Science) university credits as reimbursement. The study was controlled by MATLAB (2013b, The MathWorks, Natick, MA) using Psychophysics Toolbox extensions (Brainard, 1997). The statistical analysis was performed using SPSS 22 (IBM

Corporation, Armonk, USA), whereby a significant effect was defined by an α-level of $\alpha < 5\%$ ($p < .05$) and a statistical trend was reported at $\alpha < 10\ \%$ ($p < .10$).

2.3.1 Single task

Each experimental trial consisted of five displays. At first, a fixation cross was shown (1000 ms), followed by a forward mask showing a checkerboard (500 ms), the cueing display (50 ms), a backward mask created as a scrambled version of the previous faces (300 ms), and finally the target display (200 ms) (Figure 2). The cueing display included a neutral and an emotional face presented to the left and to the right of the fixation cross, randomized over trials. Consequently, there was always one face with a neutral expression and another face with either a fearful or a disgusted expression. In half of the trials the face cues were shown in upright and in the other half in inverted orientation, balanced across blocks.

In the target display, a neutral and a disgusted face were presented, one on each side of the fixation cross. Twenty ms after target onset a white "T" was presented in the centre of each face, which was oriented either upwards, downwards, to the left, or to the right. Therefore the faces were shown without any visual distraction for 20 ms and with a "T" for the following 180 ms. Participants were asked to indicate the orientation of the "T" which was superimposed on the neutral face by pressing one of four buttons (2, 4, 6, 8) with their forefinger on the keyboard. The next trial started after a button press was registered.

The experiment was divided into eight blocks, consisting of 60 trials each, resulting in 480 trials in total. In addition, 10 practice trials were performed to accustom the participants with the experimental procedure. A dual task (see 2.3.2) of two blocks (120 trials) was conducted at the end of the experiment (Figure 3).

Half of the trials were congruent trials, so that a neutral face cue was followed by a neutral face target (for example a neutral face cue on the left side preceded a neutral face target on the left side). During the incongruent trials the neutral face cue was followed by a disgusted face in the target display (for example a neutral face cue on the left side preceded a disgusted face target on the left side).

The combination of conditions resulted in a 2 x 2 x 2 design with the following factors: Emotion in the cueing display (fearful vs. disgusted), congruency (congruent vs.

incongruent) randomized over trials, and the face orientation (inverted vs. upright) presented in blocks. All conditions were realized equally often, randomized for each block, no identical face cue was repeated in succeeding trials, and no condition (emotion, congruency) or face feature (gender) was repeated more than five times in a row.

2.3.2 Dual task

The dual task followed the same procedure as the main experiment, but additionally to the main task, participants had to report the location of the neutral face in the cueing display (left or right). The response was given by pressing the buttons 4 or 6 on the keyboard.

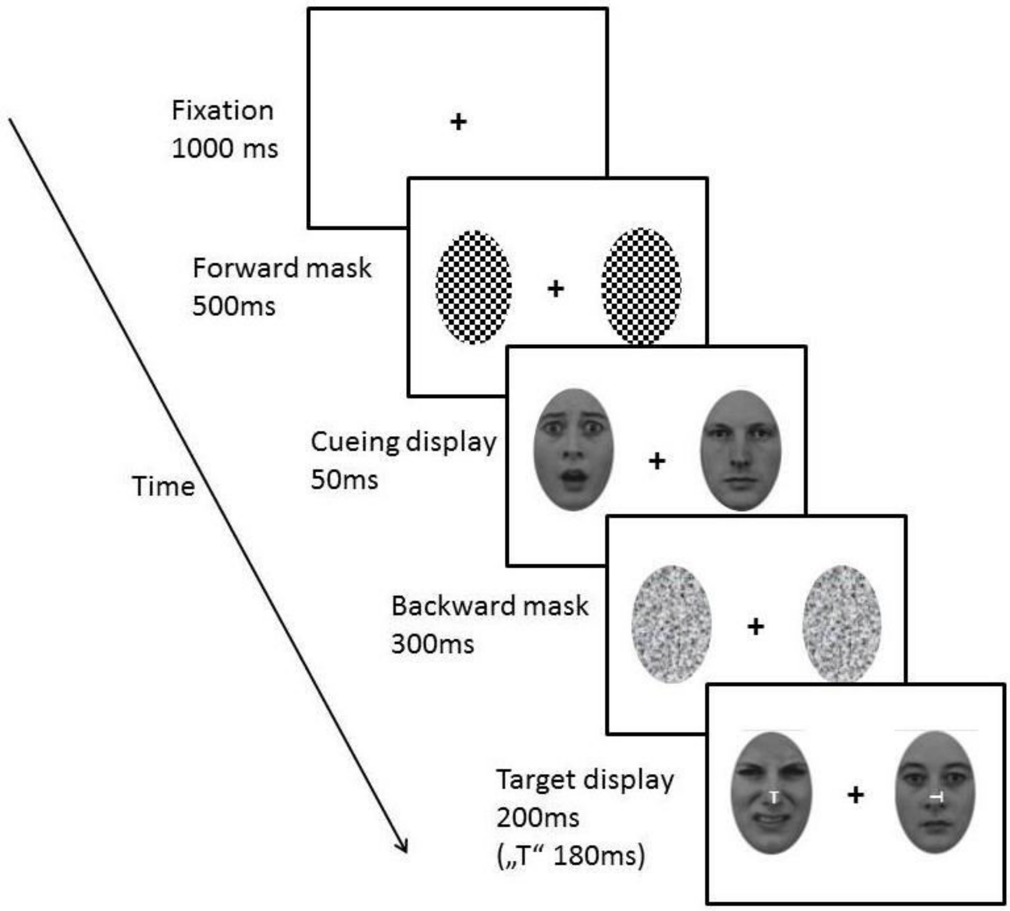

Figure 2: Stimuli sequence. Example sequence for a congruent trial (neutral faces were displayed on the same sides of the fixation cross in the cueing and target displays).

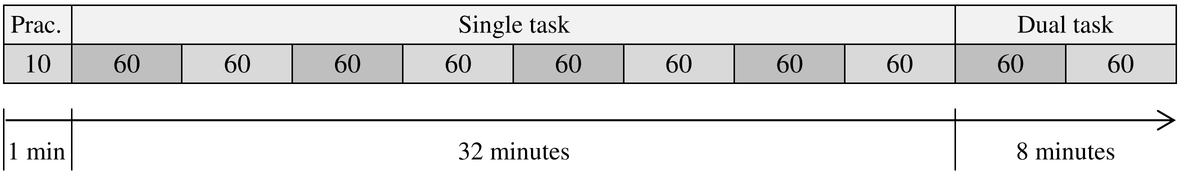

Figure 3: Experimental procedure. The study started with 10 practice trials followed by the single and dual task. The single and the dual task were divided into blocks of 60 trials showing either upright or inverted faces in the cueing displays. For example, dark grey blocks indicate trials with upright and light grey blocks indicate trials with inverted faces. Whether the first block showed upright or inverted faces was counterbalanced over participants.

2.4 EEG data acquisition

During the whole experiment EEG data were recorded at 1000 Hz by a full-band DC-EEG system (neuroConn GmbH, Ilmenau, Germany) with active electrodes at 64 positions of the 10/20 system (Jasper, 1958). Electrode impedance was kept below 5 kΩ (kilo-ohm) (Kappenman & Luck, 2010). The ground electrode at FCZ served as an online reference and the signal was re-referenced offline to the average of the signal from both mastoids electrodes (TP9 and TP10). Offline processing of the EEG signal was conducted using EEGLab (Delorme & Makeig, 2004), implemented in MATLAB (2013b, The MathWorks, Natick, MA). The EEG data were analysed for the electrodes PO7/8 for two different time windows, namely 180-280 ms and 270-320 ms after cue onset. Mean amplitudes of the grand averages over all participants were calculated for both time windows.

3 Results

3.1 Behavioural data

To investigate whether visual attention had been attracted by the emotional or neutral face in the cueing display, error rates and response times were recorded. Mean error rates and mean response times for correct trials were analysed by a 2 (emotion: fearful vs. disgusted) x 2 (orientation: upright vs. inverted) x 2 (congruency: congruent vs. incongruent) repeated measures analysis of variance (ANOVA).

3.1.1 Response time

The response time was calculated as the time from target onset till a button press was registered. Responses were given at M = 841 ms, SD = 187. Only trials with correct responses and with a variance of less than 3 standard deviations (SD) from the individual mean were included in the following analysis. The ANOVA revealed no main effects of any factor on response times (Figure 4). The expected effect of congruency did not reach significance $F(1, 12) = 8.99$, $p = .362$, nor was an interaction of congruency and orientation present in our data $F(1, 12) = .022$, $p = .883$.

For further analyses we calculated the same ANOVA for fast responses. Thus, the response times for each participant were sorted from fast to slow responses and the first quartile (25 %) was analysed. Again, congruent and incongruent trials did not differ significantly from each other $F(1, 12) = 1.322$, $p = .273$ nor did we detect an interaction of congruency and orientation $F(1, 12) = .722$, $p = .412$. In contrast to the analyses over all responses, the ANOVA for fast responses revealed a trend for the factor orientation $F(1, 12) = 4.462$, $p = 0.065$ which indicated that responses were given faster for upright faces. Furthermore, there was a significant interaction of emotion and orientation $F(1\ 12) = 5.352$, $p = ,039$. The Post-Hoc test revealed that responses were given significantly faster when upright fearful, compared to inverted fearful faces were shown $F(1, 12) = 12{,}248$, $p = .004$. This difference was not found for disgusted faces $F(1, 12) = .127$, $p = .727$.

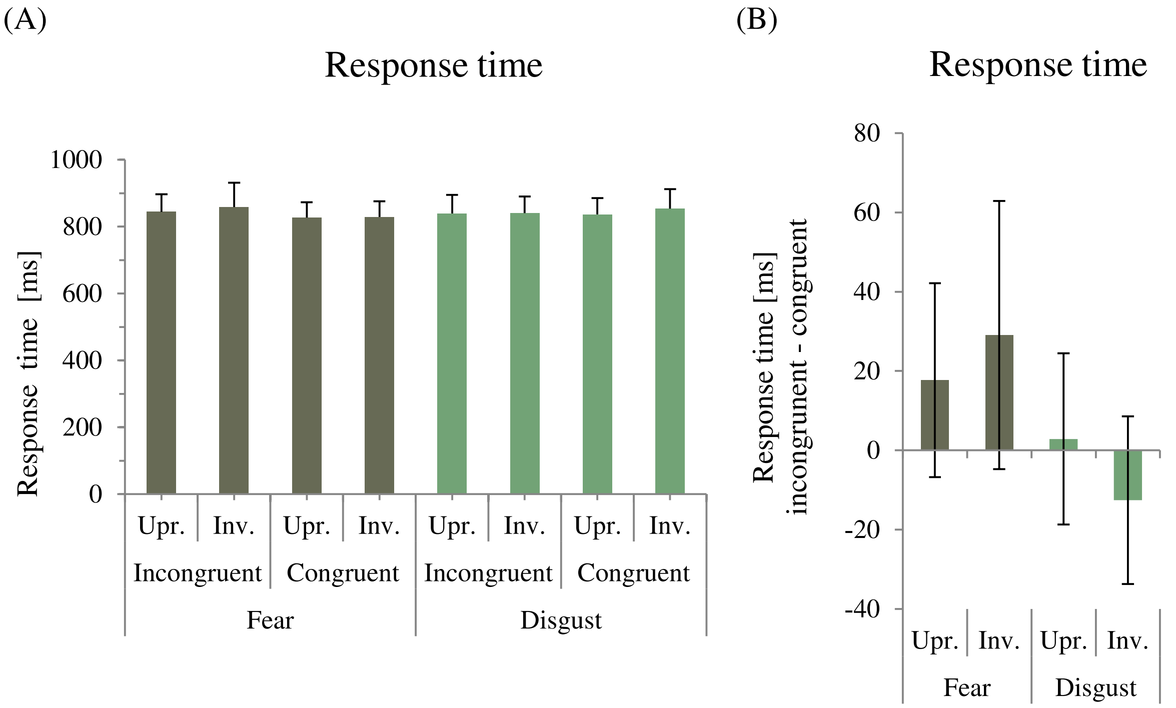

Figure 4: Response time. (A) Mean response times for all eight conditions (emotion = fear vs. disgust, congruency = congruent vs. incongruent, orientation = upright (Upr.) vs. inverted (Inv.)). (B) Mean response time difference between congruent and incongruent trials. Error bars represent one standard error of the mean.

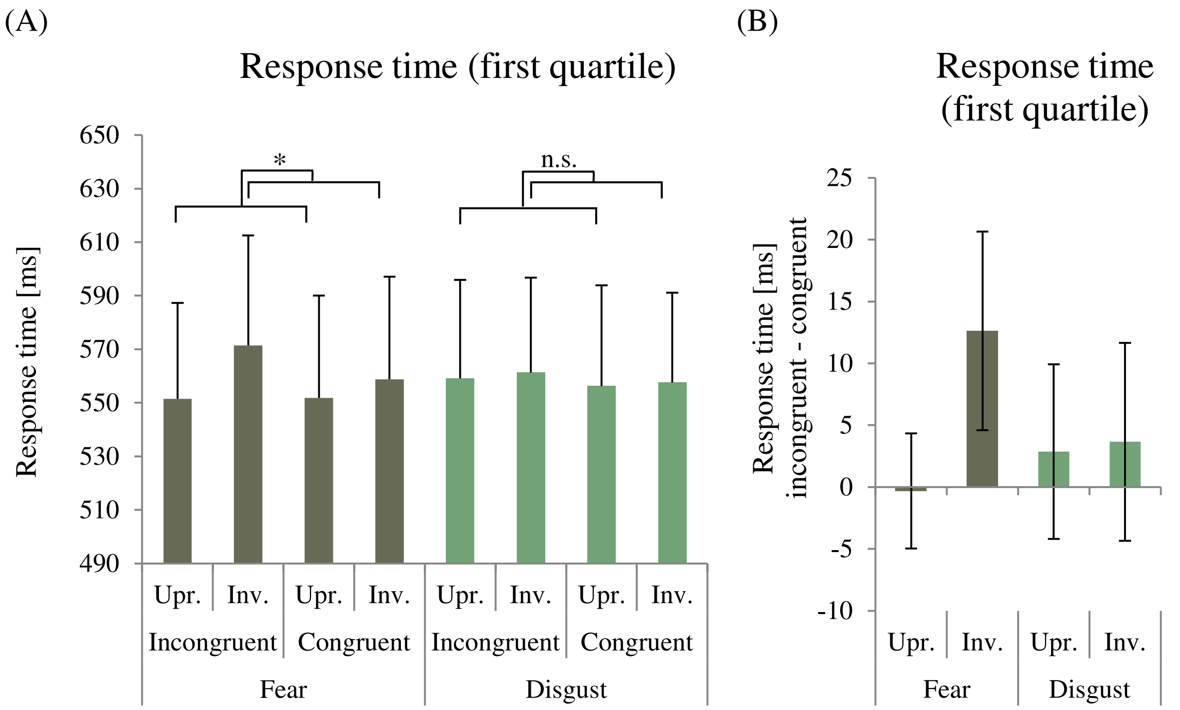

Figure 5: Response time (first quartile). (A) Mean response times for the 25 % fastest responses for all eight conditions (emotion = fear vs. disgust, congruency = congruent vs. incongruent, orientation = upright (Upr.) vs. inverted (Inv.)). Responses were significantly faster when fearful upright faces were shown in the cueing display, compared to fearful inverted faces. (B) Mean response time difference between congruent and incongruent trials. Error bars represent one standard error of the mean.

3.1.2 Accuracy

The ANOVA revealed a significant effect for the factor “emotion”, showing that participants made less correct responses when fearful instead of disgusted faces were presented in the cueing display $F(1, 12) = 6.93$, $p = .022$. Contrary to our expectations there was no main effects of congruency $F(1, 12) = .103$, $p = .754$ or significant interaction between orientation and congruency $F(1, 12) = 1.895$, $p = .194$ (Figure 6).

In total, correct responses were given in 81 % (SD = 10) of the trials in the single task (“report the orientation of the T”). In the dual task (“report the location of the neutral face in the cueing display”) correct responses were given in 49 % (SD = 4) of the trials, indicating that participants performed at chance level and did not perceive the cues consciously.

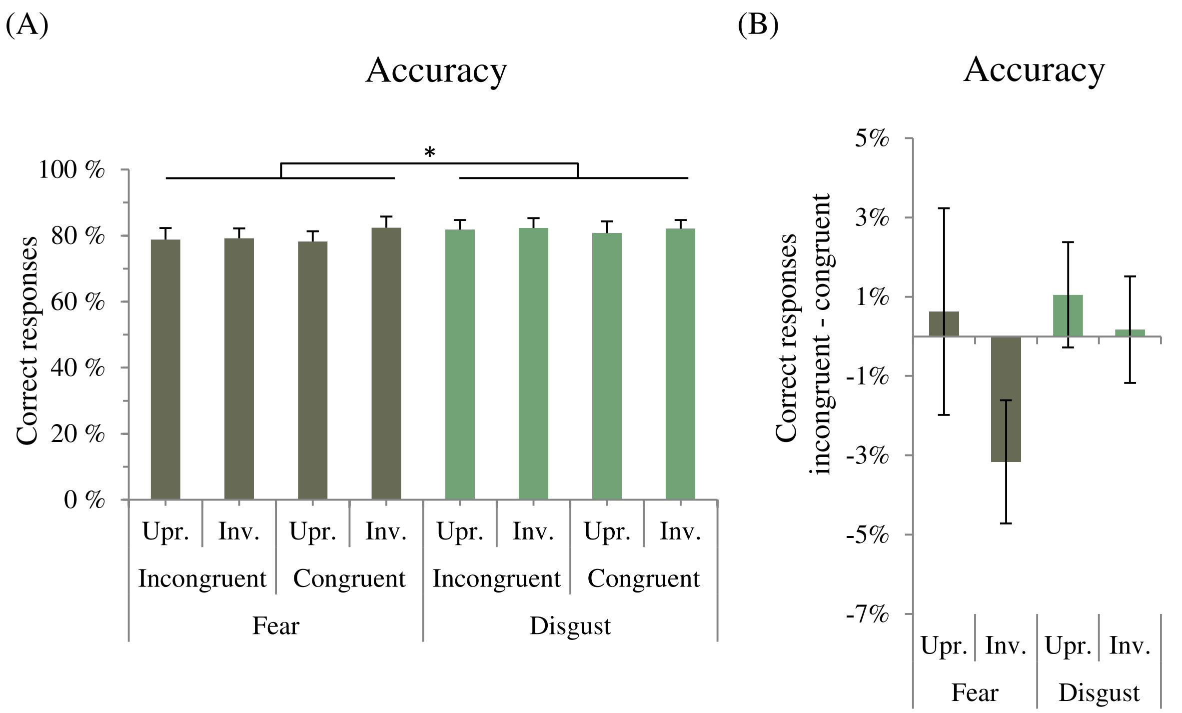

Figure 6: Accuracy. (A) Mean accuracy for all eight conditions (emotion = fear vs. disgust, congruency = congruent vs. incongruent, orientation = upright (Upr.) vs. inverted (Inv.)). More errors were made when fearful faces were presented as cues, compared to disgusted faces. (B) Mean accuracy difference between congruent and incongruent trials. Error bars represent one standard error of the mean.

3.2 EEG data

EEG data analysis was performed for the electrodes PO7/8 at which the N2pc component can be measured (Luck & Hillyard, 1994). The mean amplitude after cue onset was calculated and the difference between the ipsi- and the contralateral sides, on which the neutral face cue had been presented, was compared. First, the time window of 180-280 ms after cue onset was analysed. A (2x2x2) ANOVA with the factors (emotion: fearful vs. disgusted), (orientation: upright vs. inverted), and (lateralization: ipsi- vs. contralateral) did not detect any significant effect. Second, the same (2x2x2) ANOVA was calculated for the time window 270-320 ms after cue onset, because the EEG plots indicated that the typical waveform of the N2pc can be found at this later time point in our data (Figure 7). For this time window a significant interaction between orientation and lateralization was present $F(1, 11) = 6.601$, $p = 0.026$. The Post-Hoc test revealed that the interaction was significant for upright faces $F(1, 11) = 8.433$, $p = 0.014$, but not for inverted faces $F(1, 11) = 0.882$, $p = 0.368$ (Figure 8).

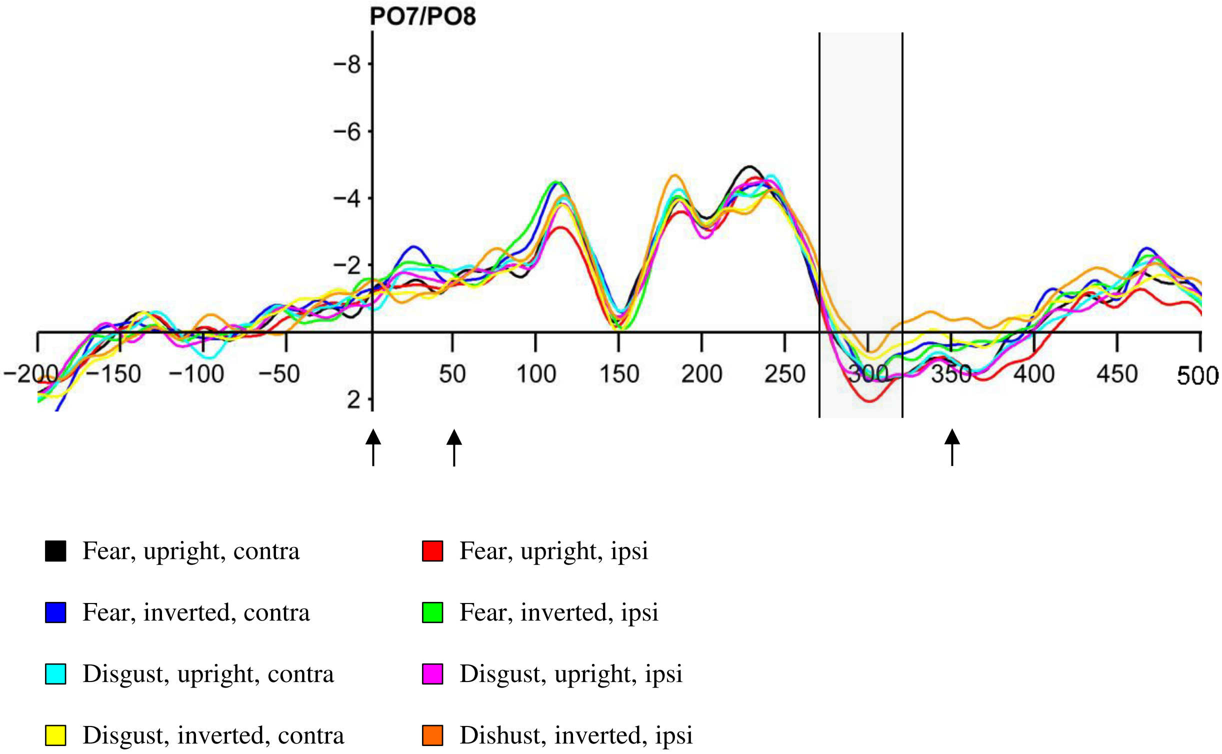

Figure 7**:** EEG plotting. EEG plots from electrodes PO7 and PO8 for all eight conditions. Each condition is represented by one colour, with the emotion (fear or disgust) and orientation (upright or inverted) of the emotional cueing face indicated in the key. Ipsi and contra refers to the position of the neutral face cue. On the x-axis the time in milliseconds and on the y-axis the amplitude in microvolt is plotted. The grey area indicates the time window 270-320 ms after cue onset. The black arrows show the time point of cue onset (first arrow), the backward mask (second arrow) and the target display (third arrow).

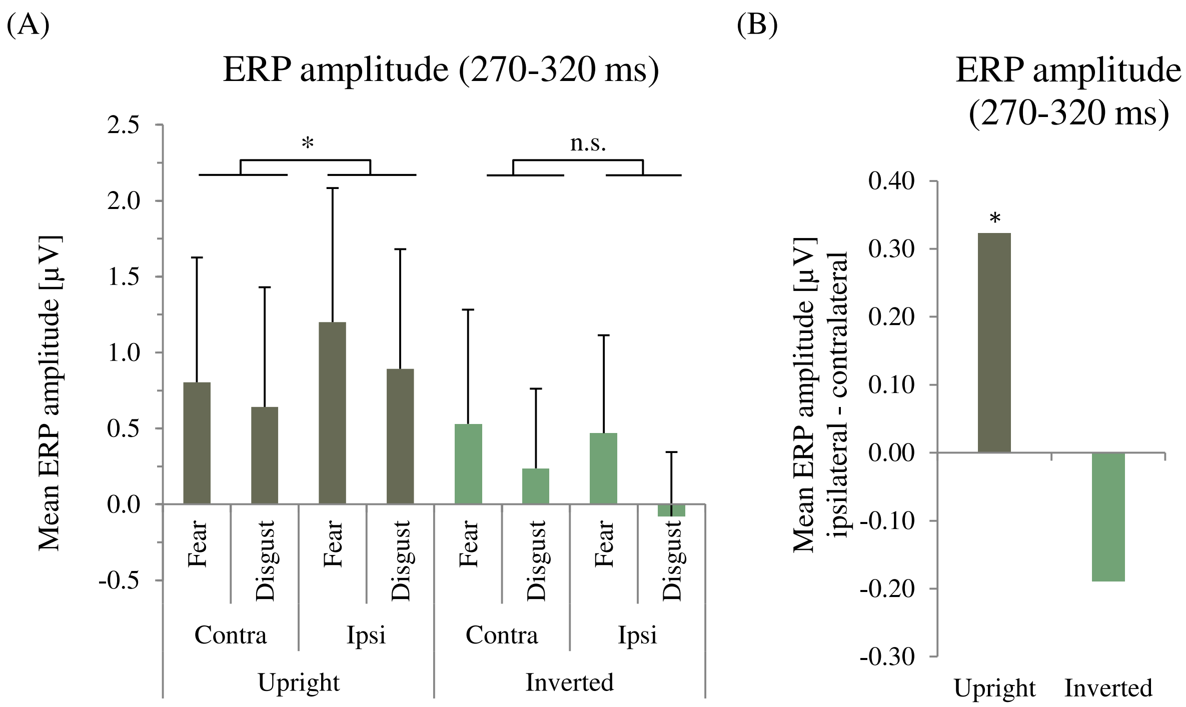

Figure 8: ERP amplitude. (A) Mean ERP amplitudes for the time window 270-320 ms after cue onset for all eight conditions (emotion: fear vs. disgust; lateralization: contra- vs. ipsilateral; orientation: upright vs. inverted). For upright faces, a greater negativity contralateral compared to ipsilateral to the neutral face cue was measured. (B) Mean ERP amplitude differences between contralateral and ipsilateral electrode sites for the same time window for all upright and inverted conditions. Significant contra- ipsilateral differences were only detected for upright faces. Analyses were performed for the electrodes PO7/8. Ipsi- and contralateral were defined as the positions towards the neutral face in the cueing display. Error bars represent one standard error of the mean.

4 Discussion

In this experiment we investigated whether subliminal presented faces would capture visual attention in a goal-driven (top-down) or stimulus-driven (bottom-up) way. In each trial two pictures were shown in the cueing display. One, which matched the top-down search set (neutral face) and one, which could capture attention because of its emotional expression (disgusted or fearful face). Therefore, the two mechanisms acted as opponents in this study, possibly inducing a shift of attention to the opposite sides of the display. Results of the behavioural measurements did not show a capture of attention for either type of stimulus, whereas the EEG data indicated that attention was captured by the stimulus which fitted to the current search set. Additionally, accuracy rates indicated that participants made more mistakes, when fearful compared to disgusted faces were presented.

4.1 Orientation of visual attention to the goal-relevant face

To ascertain to which side of the display the participants oriented their attention, we collected behavioural and EEG data. In the behavioural measurement we expected to find shorter response times or less errors for congruent compared to incongruent trials, indicating that the goal-relevant picture captured attention in the cueing display. This typical cueing effect was not present in our data.

A possible explanation for the outcome is that the response mode used was not able to detect the effect. Bannerman, Milders, and Sahraie (2010) performed an experiment in which the sensitivity of two different response modes was tested. They conducted an exogenous cueing paradigm with fearful and neutral faces as cues. A single face appeared either on the left or right side of a fixation cross, followed by a cross on the same (congruent) or opposite (incongruent) side. Participants had to indicate the location of the cross. Both, the presentation time of the cues (20 ms or 100 ms) and the response mode (button press or saccade) were varied. Bannerman and colleagues found a cueing effect for fearful faces only with short presentation times, when participants had to saccade to the target, or with long presentation times when participants gave the response manually by a button press (see appendix 1 for a figure of the results).

In our experiment the cues were displayed for 50 ms and followed by a 300 ms mask. Thus, the presentation time was rather short, but the SOA (stimulus onset asynchrony)[2] was long, due to the backward mask. Solely changing the response mode, to executing saccades instead of giving a button press, would therefore not be sufficient in our task. The SOA has to be born in mind as well. According to (Posner & Cohen, 1984) different SOAs can have a great impact on the behavioural data in a cueing paradigm. In their experiments cueing effects were only present for SOAs shorter than 200 ms. The ideal SOA varies with the experimental setup and sometimes the duration is dependent on other aspects of the paradigm. Like in our case, we needed a long backward mask to present the cues subliminally. Nevertheless, the long SOA might have inhibited a potential cueing benefit for congruent in comparison to incongruent trials.

Furthermore, mean responses were given rather late (~ 800 ms). Participants were instructed to answer as quickly and accurately as possible. However, the task might have been too complicated to be answered as fast as in other cueing experiments. For example, in the prior mentioned study of Bannerman et al. (2010), responses were given twice as fast as in our experiment (~ 400 ms). In the experiment of Bannerman and colleagues the location (left or right) of a single target had to be reported, whereas in our study the participants had to differentiate between two emotional expressions and report one of four possible orientations of a symbol.

In sum, we did not find a cueing effect for emotional or goal-relevant faces in the behavioural data. As the EEG data indicate a capture of attention by the goal relevant face (discussed in detail in the next paragraph), we assume that the behavioural measure was not able to detect an attentional shift because of the long time delay between the cue onset and the response of the participants. The response mode, the long backward mask and slow response times might have made it possible for the participants to respond to the target without being influenced from attentional capture by the cue.

To identify in which direction the participants shifted their attention, we recorded EEG data and analysed a well know marker of visual attention, namely the N2pc component (Luck & Hillyard, 1994). The N2pc is defined a relative negativity at occipito-temporo-parietal cortices, contralateral to the stimulus to which a participant orients his attention.

[2] The SOA is defined as the time between two stimuli, like the cue and the target picture in our experiment

Usually the component can be measured at around 180-300 ms after stimulus onset. Contrary to the view that visual attention focusing can only be measured in this time window, some authors have found evidence for attentional capture at different time points, depending on the stimuli and task set. For example Verleger, vel Grajewska, and Jaśkowski (2012) measured contralateral-ipsilateral (C-I) differences for different types of stimuli (diamonds and squares) and stated that the C-I differences have several peaks. They distinguish between P1pc (60-100 ms), N1pc (120-160 ms), N2pc (220-280 ms), and N3pc (360-400 ms).

To the best of our knowledge, there is no previous study that used the same stimuli as we did, showing two faces subliminally and simultaneously and measuring EEG recordings. Thus it was uncertain to which time point the C-I differences would be present in our data. The ANOVA for the typical time window of the N2pc (180-300 ms) did not reveal any main effect or interaction. Experiments analysing this time window often use stimuli which are more simple and easier to distinguish than the face stimuli we used. For example, Ansorge and colleagues, in whose lab this study was performed, often used the N2pc to demonstrate the capture of visual attention by a searched for colour using basic shapes (Ansorge et al., 2009; Ansorge, Kiss, et al., 2011). Different colours are much easier to discriminate from one another than two faces showing different expressions. This could be the reason why C-I differences were present at a later time point in our data (270-320 ms).

According to Verleger et al. (2012) later C-I differences, like the N3pc, might be evoked by stimuli which are hard to differentiate. Even though the N3pc in the study of Verleger and colleagues was found at an even later time point (360-400 ms), the line of reasoning is the same. Additionally, an N2pc in the time window around 300 ms after stimulus onset, indicating visual orienting, is not completely uncommon and has been reported in other studies as well. For example, at 270-320 ms in a study on the effects of task instructions on visual attention by Burra and Kerzel (2014) or at 240-320 ms in a experiment by McDonald, Green, Jannati, and Di Lollo (2013) on the "salience-driven selection hypothesis".

It should be mentioned that there are findings that speak against the hypothesis of a delayed N2pc because of the difficult discrimination of the face stimuli. In their review

Palermo and Rhodes (2007) state that ERP and MEG data have shown that the emotional content of a face can be registered and discriminated as fast as 80 ms after stimulus onset, in some cases. There are many differences between our study and most of the studies cited by Palermo and Rhodes paper. Often only one face at a time was shown (Liu, Ioannides, & Streit, 1999) and even when two faces were shown simultaneously, they were not actively compared by the participants (Pourtois, Grandjean, Sander, & Vuilleumier, 2004) nor were they shown subliminally. Furthermore, in comparison to our study, different electrode sides or brain regions were analysed. For example, a positivity for fearful faces was found at frontal cortices at 100 ms (Holmes, Vuilleumier, & Eimer, 2003) and 120 ms (Eimer & Holmes, 2002) after stimulus onset. Thus, even though it has been argued that the emotional contend of facial expressions can be distinguished rapidly, we suggest that a direct comparison is still more difficult than for example for different colours and can delay the time point of the N2pc.

We propose that the relative negativity contralateral to the goal-relevant neutral face cue indicates an orienting of visual attention to this stimulus. There are two possibilities how the data can be interpreted.

On the one hand, the negativity could reflect a delayed N2pc, indicating that the neutral face captured attention because it fitted to the top-down search set. On the other hand, the C-I difference could be driven by an active suppression of the emotional face. An ERP which is thought to reflect the suppression of a visual stimulus is called P_D (distractor positivity) (Hickey, Di Lollo, & McDonald, 2009). It is defined as a relative positivity contralateral to the distractor. Hickey et al. (2009) do not describe the P_D as independent from the N2pc, but propose that the N2pc is subdivided into the P_D reflecting distractor suppression and an N_T (target negativity) for target processing. The properties of the two components, as a negativity contralateral to the target (N_T) and a positivity contralateral to the distractor (N_T), does not make it possible to distinguish between the two in a display with a lateralized target and a distractor shown at the same time, as used in our experiment (see Figure 9 for an illustration). Therefore, we cannot disentangle if the orientation towards the goal-relevant face was mainly driven by a capture of visual attention by the neutral face, or by a suppression of the emotional face. This question can be answered in further experiments (see 4.3 Outlook).

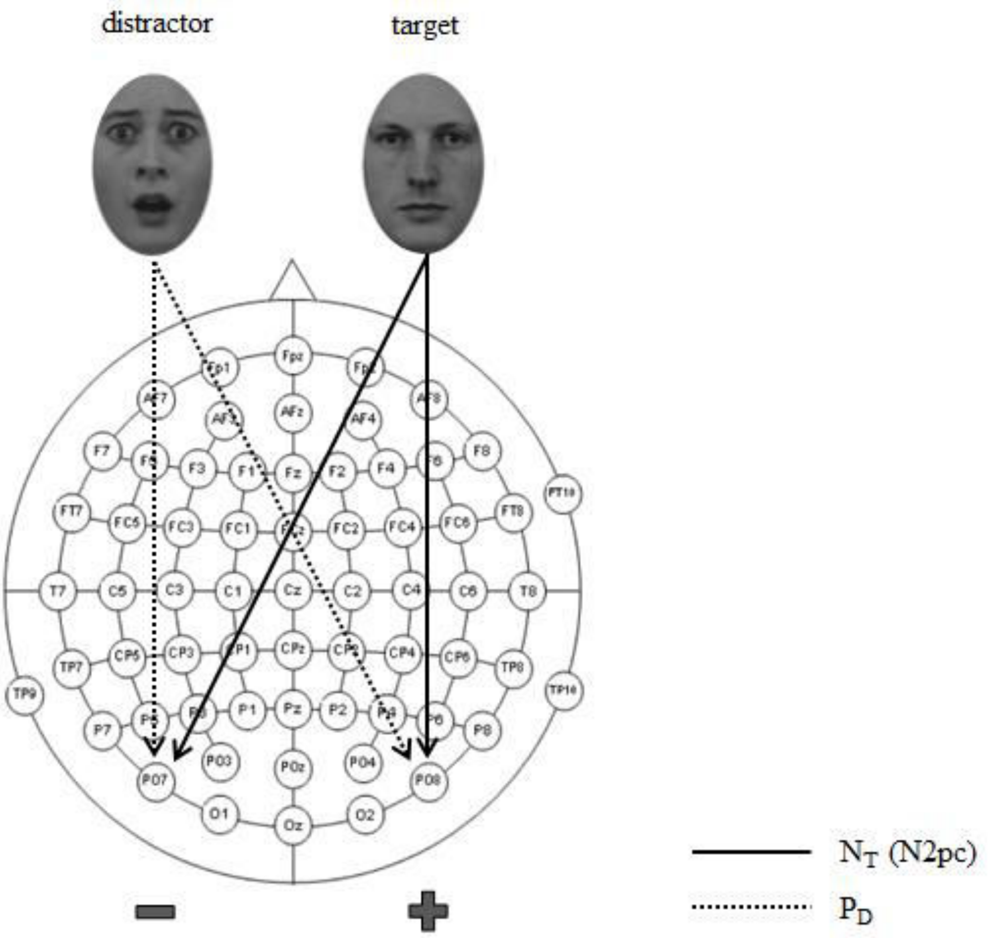

Figure 9: Schematic illustration of the EEG measurement of the N_T and P_D. The N_T (and the N2pc in its original definition) are measured as a relative negativity contralateral to the target. The P_D is defined as a relative positivity contralateral to the distractor. Both ERPs evoke a greater negativity at PO7 compared to PO8 in the depicted example trial.

Importantly, the effect was present for upright, but not for inverted faces. Trials with inverted faces served as a control, because inverted faces share the same visual features as the upright faces, but the identification of the emotion is said to be impaired (McKelvie, 1995). As the C-I difference was only found for upright faces, we can state that the effect is not driven by the differences in low level features of the stimuli.

Our EEG data indicate that visual attention was oriented towards the subliminally presented goal-relevant (top-down) face, even though an emotional (bottom-up) face was shown simultaneously. It has often been reported that participants rapidly orient their attention towards threatening stimuli like snakes and spiders (Öhman, Flykt, et al., 2001) or angry (Fox et al., 2000) and fearful (Khalid et al., 2016) facial expressions. Öhman and Mineka (2001) even proposed a “fear module” which evolved as an adaptive mechanism to detect a potential threat early. According to this hypothesis, attention is automatically captured by a threatening stimulus and a top-down search set cannot interfere in this mechanism.

Our data support a different view, namely that visual attention is oriented to stimuli which fit to the current search set, especially when they are presented subliminally (Ansorge et al., 2014). Nevertheless, this finding does not rule out the possibility that threatening stimuli are able to capture attention. In our experiment emotional and goal-relevant faces were shown simultaneously. Therefore we cannot state that the emotional faces did not demand attention, but we could show that a possible bottom-up capture of attention has been overridden by the top-down search set.

Similar results have been found by Vogt, De Houwer, Crombez, and Van Damme (2013). In their experiment participants performed a dot-probe task with threatening and neutral pictures and a second task which set up a search set for one of the used pictures. It was shown that attention was oriented towards the goal-relevant picture, even when a threatening picture was shown simultaneously. This effect was still present when Vogt and colleagues tested highly trait-anxious participants or when a stimulus indicated a genuine threat, namely an aversive noise. These results show that the orienting of attention towards goal-relevant stimuli is a robust phenomenon.

In comparison to the study of Vogt et al. the stimuli in our study were shown subliminally, therefore providing further support for the theory of an automatic capture of attention by goal-relevant stimuli, which are not perceived consciously. The idea that subliminally presented stimuli could automatically capture attention when they are searched for has been seen as unlikely for a long time (Mulckhuyse & Theeuwes, 2010). On the contrary, our results support the hypothesis that the orienting of attention towards subliminal stimuli is contingent on the top-down search set, also known as the contingent capture theory (Folk et al., 1992) . Additionally, the strength of this mechanism could be shown as it was still present when “competing” for attention with a second, more salient stimulus.

4.2 Effects of different emotional faces

Besides the expected influence of the pictures on visual attention (see 4.1) we found significant effects of emotion in the behavioural data. Accuracy rates indicated that the participants made more errors when fearful compared to disgusted faces were shown in the cueing display. Furthermore, an analysis of the fastest, correct responses showed that the response time was shorter when upright fearful, compared to inverted fearful faces served as cues. This effect was not found for disgusted cues. Two different lines of reasoning can be made to explain these results.

First, the fearful face could have had a different effect on the participants than the disgusted expression because of its emotional content. Fearful and disgusted facial expressions are thought to be processed partially along different routes, involving the amygdala for fearful and the insula for disgusted expressions (Fusar-Poli, Placentino, Carletti, Landi, & Abbamonte, 2009). Furthermore, it could also be shown that subliminally presented fearful and disgusted faces affect the judgment of the emotion of a subsequently shown face, differentially. For example in an experiment by Lee, Kang, Lee, Namkoong, and An (2011) fearful and disgusted faces were shown as primes and preceded a morphed "50 % happy" face. Participants judged the 50 % happy face as significantly more unpleasant, when primed with a fearful face, than with a control 50 % happy face. This effect was not found for disgusted faces. In our experiment the different emotions could have functioned as primes. Following the reasoning of Lee et al. (2011) the neutral target face could have been perceived as more negative when primed with a fearful compared to a disgusted face. This could have made it more difficult to discriminate between the neutral and disgusted target face and caused the error rates to increase.

However, in our experiment a more straight forward priming effect is possible. As the disgusted face was presented in the cueing and target display, the repetition could have facilitated the processing of the disgusted face in the target display and therefore fewer errors were made, compared to trials with fearful cues (Kristjánsson & Campana, 2010). Furthermore, participants were slower in responding to the target when cues were inverted fearful faces than upright fearful faces, because, again the processing of upright faces was facilitated. These assumptions are speculative and would have to be tested for example by letting the participants judge the emotional content of the target faces.

Speaking against this hypothesis, one would expect a priming effect to be most prominent for disgusted upright faces, as these are shown in the target display. Contrary to this expectation there was no interaction in the accuracy rates with orientation. For the fastest response times, an interaction with orientation was present, but only for fearful and not for disgusted faces.

Second, differences in the behaviour, for disgusted and fearful cues, could be explained by different exposure rates to the stimuli. In the target display disgusted and neutral faces were shown. Fearful faces were never displayed, because we wanted to ensure that a potential capture by the fearful face is solely driven by a bottom-up effect. Since Zajonc (1968) proposed the "mere exposure effect", it has been shown recurrently that repeated presentation of a stimulus can alter the attitude and processing of these stimuli. Stimuli which have been presented more often are thought to be processed easier than stimuli which have not been shown as often. This effect is called "perceptual fluency" (Bornstein & D'Agostino, 1994). In our experiment, a potential hypothesis is, that errors have been made more often in trials with fearful compared to disgusted faces, because these were novel and therefore more difficult to process. The finding that responses were slower for fearful inverted faces, compared to fearful upright faces is in line with this hypothesis: Fearful inverted faces might have been most difficult to process, as they were never shown in the target display and inverted faces are, compared to upright faces, not known from everyday situations.

Further studies could use a fourth type of emotional face to enable that every emotion is presented equally often. For example, neutral and happy expressions could be shown in the target display and fearful, disgusted, and neutral expressions in the cueing display. Therefore, disgusted and fearful faces are only used as subliminal cues and presented with the same rate. Hence, a potential difference in the data can be attributed to the emotional content.

In sum the significant effects of emotion could indicate a difference in the processing of the emotional content, a priming effect or a difference in the exposure rates.

4.3 Outlook

A follow-up experiment on this master thesis is planned to answer some of the open questions. The setup and instructions of the experiment will be changed slightly, so that participants will be instructed to search for the fearful face instead of the neutral face in the target display. As discussed in chapter 4.1, there are two possibilities how the C-I difference in our data can be interpreted. On the one hand, it can reflect a suppression of the distractor face. In this case it is possible that the C-I difference becomes smaller, as a neutral face (which is the distractor in the follow-up experiment) possibly needs less suppression than a salient emotional face (which has been the distractor is the present experiment). On the other hand, it is likely that the C-I difference indicates a capture of visual attention by the goal-relevant stimulus. In this case we would expect a greater difference in the EEG signal, as both mechanisms (bottom-up and top-down) would orient attention towards one side of the display.

Both assumptions mentioned above imply that the threat-superiority-effect has an impact on visual attention, which has been overridden by the search set in our study. If this assumption is wrong and the emotional faces do not demand attention, there should be no difference between the data of the present and follow-up experiment.

5 Conclusion

In the present study we investigated whether a subliminally presented neutral face which fitted to the current search set, or a face with an emotional expression would capture visual attention, when both are presented simultaneously.

We did not find evidence for an orienting of visual attention in the behavioural measurements. However, the EEG data indicated that participants oriented their attention towards the goal-relevant neutral face more often. This finding is in congruence with the contingent-capture hypothesis and additionally shows the strength of the effect: Visual attention was deployed to the goal-relevant stimulus, even though a more salient, evolutionary important stimulus was presented on the opposite side.

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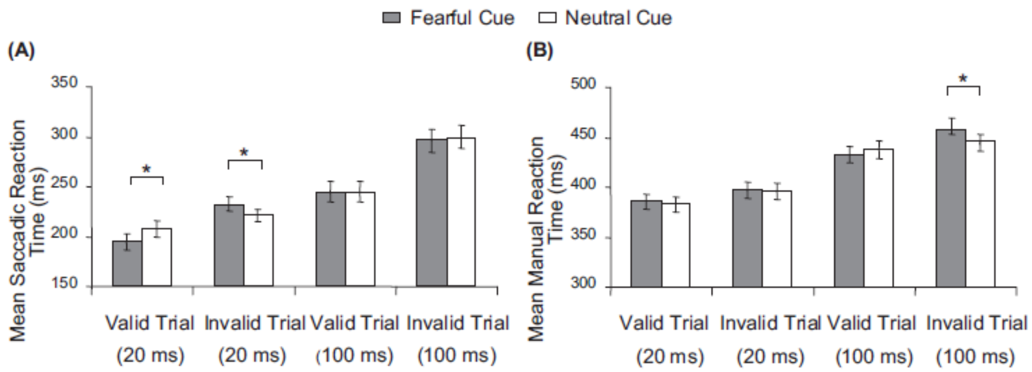
List of figures

List of abbreviations

C-I	contralateral – ipsilateral
EEG	electroencephalography
ERP	event-related potential
kΩ	kilo-ohm
M	mean
Ms	millisecond
N_t	target negativity
P_d	distractor positivity
SD	standard deviation
SOA	stimulus onset asynchrony

Appendix



A1: Results from Bannerman et al. (2010)