Deviant Contrast Sensitivity May Explain Enhanced Angry Superiority Effect in Anxious People

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Abstract

The ability to recognize facial expressions is very important, but not all emotions are recognized as fast as others. Research investigating the detection of facial expressions in healthy participants shows inconsistencies in theories about emotion superiorify effects, since both happy- and angry superiority effects have been found. These inconsistencies can be solved by studies which state that the stimulus properties affect the detection of stimuli, and not the emotional content of the face. However, research investigating the detection of facial expressions in anxious participants does not have these inconsistencies and only report angry superiority effects. Based on the healthy research, it is possible that the detection of stimuli in anxious people is also affected by the stimulus properties, however, these studies found only one superiority effect. Based on the fact that there are no inconsistencies found in the anxiety research, this thesis will research the question if the threat bias seen in anxious people is a visual instead of an emotional problem, as this may explain why anxious people detect the threatening stimuli more efficiently. A literature review was done, researching the direct and indirect effect of stimulus properties on the detection of stimuli in anxious participants. Even though there was not enough evidence to proof a direct effect of stimulus properties, literature shows that the indirect effect of stimulus properties is very likely. Based on these conclusions, it is suggested that the stimulus properties affect the detection of stimuli in anxious patients in a way that specific stimulus properties are detected more efficiently than others. This may explain why there are no inconsistencies in the anxiety research, because threatening stimuli have stimulus properties that are being detected more efficiently than happy stimuli in people suffering from anxiety.

Keywords: Angry superiority effect, anxiety disorder, attentional bias, emotion recognition, facial emotional expressions, happy superiority effect, low-level image features, stimulus properties, threat bias

Section I: Introduction

The ability to recognize and perceive emotional facial expressions is crucial for everyday social interaction and interpersonal communication (Kessels et al., 2014). Facial expressions allow us to recognize the emotional state of someone and are used in the process of non-verbal communication (Ratliff & Patterson, 2008; Tian et al., 2001). Because people can immediately recognize the emotional state of a person, information of the facial expressions are often used in automatic systems of emotion recognition (Mao et al., 2015). The most generally recognized emotions are happiness, surprise, sadness, anger, fear and disgust and it is shown that faces with emotional expressions attract and hold more visual attention compared to neutral expressions (Ekman & Keltner, 1997; Vuilleumier & Schwartz, 2001).

Because the recognition of facial emotions is so extremely important, a lot of research has been done investigating this topic and shows that not all emotions are recognized as fast as others. The differences in perception of facial emotional expressions are mediated by a cluster of endogenous and exogenous factors (Wilson, 2017). Attention can be exogenously directed by saliency, which typically is triggered by or attracted to stimuli that are biologically determined to be important and have a rather automatic influence on directing attention (Theeuwes, 1991; Theeuwes & Burger, 1998; Wilson, 2017; Yantis & Jonides, 1984; Yantis, 1996). Attention can also be endogenously directed by relevance, which is characterized by personally relevant goals, such as abinding by task demands, and is largely under an individual's control (Hopfinger et al., 2000; Posner & Petersen, 1989; Wilson, 2017).

One of the first studies that researched the processing of emotionally discrepant faces was done by Hansen and Hansen. They found an angry superiority effect, also known as the face-in-the-crowd effect (Hansen & Hansen, 1998; LoBue, 2009). This effect refers to the finding that threatening or angry faces are detected more efficiently among a crowd of distractor faces than happy or non-threatening faces (Pinkham et al., 2010). After this study, lots of other research followed which also found a similar superiority effect (Feldmann-Wustefel et al,. 2011; Gilboa-Schechtman et al., 1999; Horstman & Bauland, 2006; Lipp et al., 2009; Pinkham et al., 2010).

The reason for this superiority effect to occur would be that biologically and evolutionarily, all "negative," or distressing emotions, like fear, disgust, or anxiety, can be thought of as "survival-mode" emotions: They signal to the body and brain that our survival and well-being may be at risk, and are specifically designed to motivate behaviors and bodily responses that can most effectively deal with those risks and threats (Montgomery, 2012).

Even though this angry superiority effect is well-known, there have been studies which found an emotional superiority effect for happy facial expressions, which states that a negativity preference is not always the case (Becker et al., 2011; Calvo & Nummenmaa, 2008; Hodsoll et al., 2011; Juth et al., 2011). A research done by Svegar and his colleagues showed that happy facial expressions are heavily prioritized by the human cognitive system (Svegar, 2013). Angry expressions are initially prioritized by the human cognitive system, because people benefit from early detection of potential threat in the environment, but in later cognitive processing, happy expressions are given the priority, because smiling is a valuable mechanism for forming and maintaining cooperative relationships (Mehu et al., 2007; Scharlemann et al., 2001; Svegar, 2013).

The findings of these studies reveal quite some inconsistencies in theories about emotion superiority effects, since both happy- and angry superiority effects are suggested. To research these inconsistencies on visual search for emotional faces, Savage and his colleagues did a variety of experiments to investigate the role of stimulus sets in mediating happiness versus anger superiority effects using both the NimStim and Ekman & Friesen databases (Ekman & Friesen, 1971; Savage et al., 2013; Tottenham et al., 2009). They found a range of both happy- and angry emotional superiority effects as a function of the stimulus sets used. It was suggested that whether happy or angry target faces are detected more efficiently appears to depend on emotional-expressions-related confounds that differ across stimulus sets selected from different face databases rather than the valence or the intensity of the emotional expression (Savage et al., 2013).

Another study which further investigated the role of stimulus properties in the detection of happy- and angry facial emotions is presented by Stuit and his colleagues. This fairly recent study aimed to better understand the emotional superiority effect by examining the low-level image features, namely spatial frequency and orientation contrasts, associated with attracting the initial eye movement between two expressions (Stuit et al., 2021).

They tried to find spatial frequency and orientation contrasts that have predictive value concerning which image out of two will be perceived first. This was done by converting the images to Fourier spectra, combining the two spectra and adding a label indicating which image was perceived first. The dataset of all these converted images and corresponding labels was the input for machine learning which tries to find the spatial frequencies and orientations relevant for prediction. Eventually, there were a few AI models for decoding which image will be perceived first based on the stimulus properties of the images.

It was concluded that initial eye movements can be predicted using the differences in either the structure information or the spatial-frequency contrast information in the face images. These results suggest that low-level image features can serve as better predictors for initial eye movements than the emotional content itself (Stuit et al., 2021).

What can be derived from both studies of Savage and Stuit is that the previously mentioned inconsistencies about emotion superiority effects can be solved by the finding that stimulus properties affect the detection of stimuli, and not the emotion of the face (Savage et al., 2013; Stuit et al., 2021). Based on these conclusions, participants do not have a more efficient detection towards specific stimuli because of the emotional content of the face, but because the stimulus properties of one stimulus are detected more efficiently than the stimulus properties of the other stimulus. Because every stimulus consists of different stimulus properties, each stimulus is detected differently which is the explanation why the inconsistencies in emotion superiority effects were found.

However, the previously mentioned inconsistencies about emotional superiority effects in healthy research subgroups are not found in studies which use participants suffering from an anxiety disorder. Clinical research involving anxiety patients states that people suffering from anxiety have an attentional bias towards negative emotional information (anger, sadness and disgust) (Bradley et al., 1999; Bradley et al., 2000; Juth et al., 2005; Mogg et al., 2000). Furthermore, the higher their anxiety level is, the more biased the patient seems to be (Bar-Haim et al., 2005; Bradley et al., 1998; Fox et al., 2002, Mogg & Bradley, 1999). In contrast to research using healthy participants, studies consisting of anxious participants never found a happy superiority effect.

This seems peculiar, because as the research done by Savage and Stuit showed, the stimulus properties affect the detection of stimuli, and not the emotional content of the faces itself (Savage et al., 2013; Stuit et al., 2021). Because this is shown in the healthy research, it is expected that the superiority effects found in anxiety research vary too because of the different stimulus properties every stimulus has. However, the only effect found in the anxiety research was an angry superiority effect. The question is why no inconsistencies were being found in anxiety research and why there is such a clear effect in this clinical subgroup, suggesting an angry superiority effect.

Based on the conclusions of healthy research that the detection of stimuli is determined by the stimulus properties, there may be a chance that anxious people detect specific stimulus properties more efficiently than others. If this is correct, the detection of stimulus properties in anxious people is different than the detection of stimulus properties in healthy people. This may be the reason why in healthy research both superiority effects have been found, and in the anxiety research only one superiority effect. To elucidate this, this thesis will look into the question if the threat bias seen in anxious people is a visual instead of an emotional problem.

The relevance of this thesis is that there clearly is a difference in findings between research with healthy participants, which shows inconsistencies in the found emotional superiority effects, and research with anxious participants, which only found one superiority effect. The reason for these differences in findings is never investigated, however, to research this may be of great importance. If anxiety patients have a shifted detection of stimulus properties, treatment can be developed based on these findings to fit the patient's needs, help reducing the bias towards specific stimulus properties and eventually treat the anxiety disorder. This treatment can be based on AI methods which can be used to find out which stimulus properties are relevant for the detection of stimuli, as shown in the research of Stuit (Stuit et al., 2021). Because the stimulus properties are so important for decoding facial emotions, this thesis will focus on the effect of stimulus properties on anxious people.

This thesis is seperated into three sections. The first section focuses on stimulus properties directly affecting the detection of faces and if the effects found in the anxiety research can be explained by the stimulus properties of different stimulus sets. The second section will consider if there is a possibility that stimulus properties can influence the efficiency of detecting faces indirectly. The third and last section will discuss the indirect effect of stimulus properties on detection efficiency, namely if the ERP signals measured in anxiety research can be elicited from differences in spatial frequency and orientation contrasts. These results will be combined into a conclusion to answer the question if the threat bias seen in anxious people is a visual instead of an emotional problem. Lastly, a few particularities about the anxiety research and a suggestion for further treatmentm will be discussed.

Section I: Research Design

Research Method

Based on the conclusions that the low-level image features affect the detection of stimuli and not the emotion itself in healthy people, this section investigates if the stimulus properties can directly affect the detection of stimuli in anxious people (Savage, et al., 2013, Stuit, et al., 2021). To research this, the study of Savage and his colleagues (Savage, et al., 2013) was used. They found both happy- and angry superiority effects across different stimuli which were conducted from two large datasets of face images, namely NimStim and Ekman & Friesen. Therefore, they stated that it appears that the stimulus materials used in their experiments may be critical in determining whether a happiness or anger superiority effect is observed.

Savage mentioned every exact stimulus used in the experiments and which superiority effect was found when presenting that specific stimulus to a participant. This means that it is very clear which superiority effect was found in combination with which exact stimulus.

With this knowlegde, the stimuli used in the anxiety research can be investigated. If a stimulus is researched in the study of Savage and shows an angry superiority effect, this effect occurs because that stimulus contains of those specific stimulus properties that cause a more efficient detection. If this exact stimulus is used in the anxious research, the angry superiority effect suggested here may also be found because of the specific stimulus properties, and not because a specific emotion is detected, as being stated in the anxiety studies.

Based on these suggestions, the stimuli sets used in study of Savage will be compared to stimuli sets used in anxiety research. If the same stimulus sets used in the study of Savage show the same superiority effects as in the anxiety research, is can be suggested that the angry superiority effect shown in anxiety research occured because of the stimulus properties of those specific stimuli, and not because of the emotions itself.

Materials

The literature used to report the healthy research concerning the role of different stimulus sets, namely NimStim and Ekman & Friesen, on the found emotional superiority effect was the research done by Savage and his colleagues (Savage et al., 2013). Because this section focuses on the direct effect of stimulus properties, and thus the stimulus sets used, the stimulus sets used in the study of Savage are reviewed.

In one of the experiments done, the faces were drawn from the Ekman and Friesen Pictures of Facial Affect database (Ekman & Friesen, 1976), and consisted of six male individuals (EM, GS, JB, WF, PE, and JJ), each providing an angry, a happy, and a neutral expression. Here, happy faces were found faster, more efficiently, and with fewer errors than angry faces, clearly showing a happiness superiority effect.

The final experiment directly investigated the effect of different stimulus materials on visual search for emotional expressions. The faces used were drawn from the NimStim database (Tottenham et al., 2009), which offers three degrees of happiness, closed mouth, open mouth, and exuberant; and two degrees of anger, closed mouth and open mouth. Pictures of nine male Caucasian faces (Models 20, 21, 22, 24, 25, 30, 32, 34, and 37; Tottenham et al., 2009) with neutral, angry, happy, and exuberantly happy expressions (codes CA-C, AN-O, HA-O, and HA-X) served as background and target stimuli. In this experiment, they found that angry faces were found faster than happy faces, suggesting an anger superiority effect. However, exuberant faces were detected even faster and more efficiently than angry faces.

The literature used to report the anxiety research investigating the found emotional superiority effect in anxious pariticpants was done making use of WorldCat and Google Scholar. The inclusion criteria were that the studies should consist of participants which are diagnosed with an anxiety disoder. Furthermore, the stimuli should make use of facial images with broad-band spatial frequency, i.e. they contain a combination of both low and high spatial frequencies. This type of image can be decoded via spatial frequency content, because they consist of a range of low and high spatial frequencies (Harel et al., 2016; Stuit et al., 2021). The importance of having broad-band spatial frequency images is when images can be decoded, this means that the emotions of the stimuli have different spatial frequency contents. Based on the theory that stimulus properties affect the detection of stimuli, having different spatial frequency contents would make sure that this effect can occur in the experiments.

The exluding criteria includes research consisting of schematic faces. These stimuli are highly stereotyped and somewhat artificial expressions of emotion (Frishen et al., 2008). Furthermore, they lack ecological validity (Pinkham et al., 2010; Stein & Sterzer, 2012). Because this thesis investigates the process of detecting faces and the role of stimulus properties in real faces, these stimuli are not relevant for this literature review.

Based on the inclusion criteria for the anxiety research, ten relevant studies consisting of anxious participants were included in this literature review. The exact studies used can be found in Appendix A. All of them concluded that anxious people had a bias towards threatening and/or angry faces and thus they showed an angry superiority effect. Eight of them used the NimStim dataset and two of them used the Ekman & Friesen dataset.

Section I: Results

When investigating the stimulus sets used in the anxiety research, none of the anxiety studies which made use of the NimStim and/or Ekman & Friesen dataset describes which exact stimuli they used in their experiments, and thus the anxiety research used in this literature review is missing methodological information. Therefore, no stimulus sets can be compared and no possible similarities can be found between the study of Savage and the anxiety research to make a suggestion about the reason of the superiority effects found.

To find out which exact stimuli were used in the anxiety research, an email was send to all the authors of the studies that were used for this literature review, asking if they were able to give te specific details of the stimuli they used. The authors that were contacted can be found in Appendix A. No responses were received, so this research could not be continued.

Based on the healthy literature, it can not be excluded that the stimuli used in these anxiety researches directly caused faster detection of the faces based on the stimulus properties. However, the question if stimulus properties directly affect detection in anxious people remains unresolved.

Section II: Introduction

The previous section shows that there is inconclusive evidence that the stimulus sets directly affect the detection of faces. Therefore, another approach is needed to look into the question if anxious people detect specific stimulus properties, rather than specific emotions, more efficient than others. Because the direct effect can not be proven, the following section will investigate the indirect effect of stimulus properties on the detection of stimuli.

In healthy research, this indirect effect of stimulus properties on the detection efficiency of faces has already been found in healthy participants (Stuit et al., 2021). However, it is not known if this same effect applies to anxious people as well. This results in researching if stimulus properties can indirectly affect the detection of stimuli in anxiety. Before this can be researched, it is important to find out if it is even possible that anxiety disorder affects the visual perception. This is crucial, because we first need to know what the likelihood is that anxiety disorders affect the visual systems before we can suggest that anxious people detect some stimulus properties more efficiently than others in comparison to healthy people.

Section II: Research Design

Method

To investigate if anxiety influences the visual perception, a literature research was done looking for evidence that anxious participants showed a modulation of the visual systems compared to healthy participants.

Materials

This literature research was conducted from studies, found on either WorldCat or Google Scholar, that discussed the interaction between anxiety disorder and visual perception, and if there were any differences of the visual systems in anxiety participants compared to healthy participants.

Two studies were found which both researched the visual perception in anxiety. The first study discussed the early visual information processing in participants with trait anxiety compared to healthy pariticipants (Berggren et al., 2015). The second study researched contrast sensitivity in anxious people compared to healthy people (Laretzaki et al., 2010).

Section II: Results

The research of Berggren sought to further recent evidence relating to individual differences in trait anxiety influencing early information processing through manipulation of perceptual demands and the ability to detect a critical stimulus during a primary visual search task (Berggren et al., 2015). In general, the imposition of perceptual load was successful, increasing reaction times and error rates in the primarty task but also reducing detection sensitivity for the additional stimulus. Meanwhile, self-reported trait anxiety level was associated with shorter reaction time judgements and improved detection for the additional stimulus, regardless of the level of perceptual load. The results therefore support the hypothesis that trait anxiety corresponds with improved visual detection, despite equivalent performance in the primary visual search task.

A study researched contrast sensitivity in people with anxiety was done by Laretzaki and her colleagues (Laretzaki et al., 2010). Contrast sensitivity is a basic subcomponent of spatial visual perception, which may be at the root of bottom-up feature processing in the visual search tasks and the affective picture viewing paradigms. Because contrast processing has been evaluated psychophysically (Kulikowski, 1975; Kulikowski, 1976; Pokorny and Smith, 1997; Murray and Plainis, 2003) and physiologically (Murray and Kulikowski, 1983; Murray et al., 1987; Mihaylova et al., 1999), using the P100 wave of Visual Evoked Potentials (VEPs) as a measure of the integrity of precortical and early visual processing, this study investigates the contrast sensitivity in anxiety by measuring the P100 signal. This signal was measured when presenting 8%- and 12% stimulus contrasts in a low- and a high-trait anxiety pariticipants subgroup.

They found that in the low trait anxiety group, the more intense the contrast stimulus the greater was the latency reduction. So, they demonstrated that anxious anticipation accelerates the cortical processing of visual pattern stimuli in low but not in high anxious subjects, in a stimulus intensity-dependent manner (Laretzaki et al., 2010).

Based on these conclusions, anxiety traits do seem to affect the early visual processing, and thus the visual perception.

Section III: Introduction

The previous section shows that anxiety does influence the visual perception which suggests that the visual features probably do play a role in the detection of faces in anxious patients. However, the literature does not provide enough information to proof that the visual features have a direct effect on stimuli detection (see *Section I*). Although no conclusion can be drawn it do seems plausible, because it works this way in healthy participants, as shown in Savages' study (Savage et al., 2013). So there is a reason to accept the suggestion that visual sensitivity does have a relation with the detection of faces in anxiety.

To try and proof this theory, this section investigates the indirect effect of stimulus properties on the detection of stimuli. Because ERPs are a much used metric in the research of detecting happy- and angry stimuli in anxiety, this section focuses on this aspect. The anxiety research uses these ERP measurements in combination with visual search tasks to show that people suffering from anxiety have an angry superiority bias. They do this by showing that anxious people have modulated ERP signals when they search for angry facial emotions amongst neutral faces compared to happy facial emotions amongst neutral faces.

A meta-analysis done by Torrence and Troup systematically searched for articles that used the dot-probe task with facial expressions and measured neural correlates with ERP (Torrence Troup, 2017). They found that attentional biases towards fearful and angry facial expressions can be seen in early ERPs time-locked to face onset, N170 and N2pc. Furthermore, the P1 and P2 also seem to be enhanced from angry and fearful faces.

In this section, it is going to be researched if there is a possibility that the ERPs measured in the anxiety research are elicited from the stimulus properties. If the suggestion that the stimulus properties influence the detection of faces is correct, then the ERP signals measured in the anxiety research are elicited from the stimulus properties itself and not from the facial emotional expressions, as being suggested in this clinical research.

Section III: Research Design

Method

To investigate if there is a reason to suggest that the specific ERP signals elicited in the anxiety research can be elicited from stimulus properties rather than the emotion of the faces, a literature research has been done. Because the study of Stuit stated that spatial frequency and orientation contrasts have an effect on the detection of stimuli, these stimulus properties will also be researched in this section (Stuit et al., 2021).

Materials

To investiage the ERPs measured when anxious participants detected threatening stimuli in comparison with when they detected happy stimuli, the meta-analysis by Torrence and Troup was used in this section (Torrence & Troup, 2017).

The part of the literature research which discussed the ERP signals elicited from stimulus properties was conducted from studies found on WorldCat and Google Scholar that researched the role of several ERPs concerning spatial frequency and orientation contrasts.

Section III: Results

P1

The P1 signal is a much researched ERP signal when it comes to spatial frequency contrasts in combination with face stimuli. In a study which researched the effect of happy- and angry emotions on P1 in healthy participants, they found enhanced P1 amplitudes to angry and happy versus neutral face cues (Samantha et al., 2017). However, studies using anxious participants only show enhanced P1 amplitudes when angry faces were presented (Torrence Troup, 2017). This shows a discrepancy, which suits with the obeservation that healthy subjects show both an angry- and happy superiority effect when anxious people only show an angry superiority effect.

In most studies which made use of ERP signals in anxious participants, researches recorded event-related potentials (ERPs) during the presentation of spatial frequency-manipulated images (Jeantet, et al., 2019; Nakashima, et al., 2008). By filtering original images of faces spatially, they created low spatial frequeny and high spatial frequency face stimuli.

In ERPs, low spatial frequency facial images evoked the largest P1 amplitude compared to high spatial frequency face images (Jeantet, et al., 2019; Nakashima, et al., 2008). These results indicate that, in the early stages, the earliest processing, which is associated with the P1 component, is more sensitive to low spatial frequency information contained in face stimuli.

Another study which researched the eliciation of the P1 signal examined the effects of low and high spatial frequency filtering on brain processing of complex pictures depicting pleasant, unpleasant, and neutral scenes (Alorda, et al., 2007). They observed that unpleasant pictures elicited more enhanced P1 amplitudes than neutral pictures when they were conveying predominantly low spatial frequency information, but not when they were conveying exclusively high spatial frequency information. These results show that low and high spatial frequency information product differential effects on brain processing of affective stimuli over the primary visual cortex.

Based on these results, it shows that the P1 signal is indeed influenced by the spatial frequency contrasts of images and faces.

An ERP study done by Yang and Chan researched the effects of different spatial frequencies and orientations on human brain activity (Yang & Chan, 2015). They found that the amplitude of the P1 component was higher when subjects were viewing gratings at vertical orientation than horizontal orientation.

This study shows that the P1 signal is influenced by orientation contrasts.

P2

A study done by Andrea and his colleagues examined the role of spatial stimulus frequencies in the early visual processing of natural scenes which were progressively revealed in a sequence of steps by adding high or low spatial frequencies (Andrea, et al., 2013). As high spatial frequencies were added in the low-pass condition (with only low spatial frequencies), or low spatial frequencies were added in the high-pass condition (with only high spatial frequencies), the amplitude of the P2 signal increased. This shows that the P2 signal is sensitive to the spectral power of the visual input rather than tuned to a specific range of spatial frequencies.

Because this study presented that the spatial frequency content is important for eliciting the P2 signal, it can be suggested that P2 is sensitive to broad-band spatial frequency stimuli, which are stimuli that contain multiple spatial frequencies. Every type of face image has a different spatial frequency and thus another content range. Because the P2 is elicited by spatial frequency content, P2 should differ between every face detected. It can be concluded that the P2 signal is sensitive to the spatial frequency content, and thus that P2 can be influenced by visual features.

The same ERP study which proves the influence of orientation contrasts on the P1 signal shows that the P2 component was higher when subjects were viewing gratings at vertical orientation than horizontal orientation (Yang & Chan, 2015).

This study shows that the P2 signal is influenced by orientation contrasts.

N170

A fair amount of research looked into the relation of the N170 signal and spatial frequency contrasts. Most studies recorded event-related potentials during the presentation of spatial frequency-manipulated facial images and concluded that high spatial frequency information elicited larger N170 amplitudes than did LSF information (Jeantet, et al., 2019; Nakashima, et al., 2008; Tian, et al., 2018).

Apart from these studies, a research done by Flevaris and her colleagues examined the influence of spatial filtering on the N170-effect and they found that the N170-effects elicited by upright faces were similar across low- and high-spatial frequency scales (Flevaris, et al., 2008). These findings demonstrate that the N170-effect can be influenced by both low- and high-spatial frequency channels.

Based on these studies, it can be suggested that spatial frequency contrasts do have an big impact eliciting the N170 signal.

The impact of orientation contrasts on the N170 component was discusses by Jacques and his colleagues which researched if face perception is tuned to a specific orientation based on the N170 signal (Jacques et al., 2014). They indicated that the N170 signal is preferentially tuned to horizontal information.

Therefore, this study shows that orienation contrasts influence the elicitation of the N170 signal.

N2pc

A study done by O'Donnell and his colleagues investigated the functional properties and topographic distribution of event-related potentiak (ERP) components elicited by visual discrimination of orientation, spatial frequency, spatial location, and color (O'Donnell, et al., 1997). They showed that the N2pc was sensitive to orientation, spatial frequency, and location.

Conclusion

The first section of this thesis discussed the likelihood that stimulus properties have a direct effect on the detection of stimuli in anxious people. Because the literature involving anxious participants is missing methodological information, it was not possible to investigate this direct effect. However, literature with healthy participants show that stimulus properties directly affect the detection of stimuli (Savage et al., 2013). Therefore, there is a chance that the same effect goes for the anxiety subgroup and thus that the efficiency of detecting stimuli in anxious people can be directly influenced by stimulus properties.

Because there is insufficient proof to conclude that stimulus properties affect face detection directly, the indirect effect of stimulus properties was researched in the second and third section. Before this indirect effect could be researched, the second section investigated the probability of anxiety influencing the visual perception. Based on studies researching the role of anxiety on visual perception, it is concluded that anxiety influences contrast sensitivity and improves the visual detection, and thus anxiety does have an influence on the visual perception.

Building on these previous findings, the third section researched if stimulus properties have an indirect effect on the detection of stimuli by looking at the possibility if stimulus properties influence the elicication of ERP signals measured in anxiety research. Based on the elicited ERP signals in these studies using anxious participants, literature research was done to investigate if these ERP signals could also be elicited from differences in stimulus properties, specifically spatial frequency and orientation contrasts.

Surprisingly, the literature research showed that all the measured ERP signals, which are used in anxiety research to proof that anxious people have an angry superiority bias, can be influenced by both spatial frequency and orientation contrasts. This makes it very clear that there is a possibility that the ERP signals are not elicited by the emotional content of the faces, but by the differences in spatial frequency and orientation contrasts that these stimulus properties have. So, the stimulus properties do have an indirect influence on the detection of stimuli in anxious people.

Based on the conclusions that stimulus properties possibly affect the detection of stimuli in anxious people, it is suggested that the threat bias seen in anxious people is a visual instead of an emotional problem. Because anxious people have these visual problems, which are expressed in perceiving specific spatial frequencies and orientation contrasts more efficiently than others, threatening stimuli are detected faster because they have the spatial frequencies and orientation contrasts which anxious people detect more efficiently. The reason why no happy superiority effects were found can be explained in the same way: because anxious people detect stimulus properties of other stimuli more efficiently compared to the stimulus properties of the happy stimuli, the happy stimuli are detected slower and therefore, no happy superiority effect has been found.

Discussion

This thesis aimed to find proof if there is a reason to suggest that the threat bias seen in anxious people is a visual instead of an emotional problem. Because research using healthy participants show that the stimulus properties have an effect on the detection of stimuli, this literature review focuses on the direct and indirect effect of stimulus properties on the detection of stimuli in anxious people. Based on research used in this review, it is very plausible that stimulus properties have an indirect effect on the detection of stimuli, because the ERP signals measured in anxiety research can be elicited from differences in stimulus properties like spatial frequency and orientation contrasts. Therefore, the reason why only angry superiority effects are shown in anxiety research can be explained by the fact that anxious people detect specific stimulus properties more efficiently than others, and thus detect stimulus properties of threatening emotions faster than the stimulus properties of happy emotions.

Now that the suggestion is made that stimulus properties influence the efficiency of detecting faces in both healthy and anxious people, what is still remarkable is that clinical research only seems to find a threat bias in anxious participants, in contrast to studies using healthy participants which find both angry- and happy superiority effects. Even though anxious people detect some stimulus properties faster than others, every stimulus has different stimulus properties, so why are only the threatening emotions detected faster and not the happy emotions?

As being shown in the first section, it is important to consider what kind of stimuli are being used in the anxiety research and it can not be excluded that specific stimuli used causes faster detection of specific faces based on their individual stimulus properties. Therefore, the emotion itself should not matter to the detection efficiency. However, the question still remains why only an angry superiority effect has been found.

Anxiety research does make use of different types of stimuli. The studies previously mentioned in the first section all consist of stimulus sets with photographic images (see *Appendix A*). However, there are five other researches found during the literature research which made use of schematic faces as stimuli in their experiments. All these studies found an angry superiority effect when using anxious participants. However, as far as the literature review goes, all of the non-clinical studies using schematic faces exclusively report angry superiority effects (Dickins & Lipp, 2014; Fox et al., 2000; Juth et al., 2005; Kennett & Wallis, 2019). This suggests that the properties of schematic faces can only be associated with angry superiority effects.

Apart from the stimuli being used, there seems to be a more major problem concerning the found angry superiority effect in anxiety research. A meta-analysis done by Quinlan critically appraised the fear response hypothesis and the associated claim that humans have an evolutionary propensity to detect threats automatically in their immediate visual environment (Quinlan, 2013). This analysis focused on reports of visual search experiments in which participants were tested with speeded oddball tasks in which the search displays contained photographic images of naturally occurring entities. In such tasks, participants have to judge whether all the images are from one category or whether the display contains a distinctive image. The evidence, which has been used to support the fear response hypothesis, is assessed against a series of concerns that relate to stimulus factors and stimulus selection. It is shown that when careful consideration is given to such methodological details, it becomes very difficult to defend the fear response hypothesis. It is concluded that, at present, the fear response hypothesis has no convincing empirical support. This also fits the hypothesis that the stimulus properties cause the detection efficiency and not the semantical content of the face.

However, Quinlan does not discuss the anxiety subgroup in his analysis, which means that his conclusion is based on research using healthy participants only. Therefore, there is a possibility that the same suggestion can be drawn for anxiety research, but this anxiety subgroup is just not discussed in this analysis. There is also another possibility that anxiety patients are an exception to the rule and the conclusion drawn by Quilan does not apply for them.

What can be concluded from this meta-analysis is that the threat bias found in the anxiety research may not be correct and should be considered very carefully.

One last aspect that needs to be investigated to answer the question why anxiety research only seems to find an angry superiority bias is that there might be a so-called publication bias. Dickersin & Min define publication bias as the failure to publish the results of a study on the basis of the direction or strength of the study findings (Dickersin & Min, 1993). This non-publication introduces a bias which impacts the ability to accurately synthesize and describe the evidence in a given area. Research has shown causes of publication bias ranging from trialist motivation, past experience, and competing commitments; perceived or real lack of interest in results from editors, reviewers or other colleagues; or conflicts of interest that would lead to the suppression of results not aligned with a specific agenda (Song et al., 2010).

This non-publication resulted from conflicts of interest may be a reason why a happy superiority effect has never been mentioned in anxiety research. Because researchers want to be consistent with previous research, consciously or unconsciously, they may only mention the angry superiority bias in their papers. This is an important factor that should not be forgotten.

What can be concluded is that there is a certain amount of evidence to doubt the found effect of only angry superiority effects.

Even though this thesis concludes that there is a possibility that anxious people detect specific stimulus properties more efficiently than others in comparison to healthy people, this is never further investigated in the literature. Until now, every anxiety research states that anxious people show only an angry superiority effect because they detect the threatening emotions faster and do not take into account the stimulus properties hypothesis. Therefore, treatment for anxiety does not take into account the possibility that anxious people have shifted visual perception concerning stimulus properties.

A much used treatment for anxiety is the attention bias modification treatment (AMBT). The goal of AMBT is to reduce anxiety by reducing attention bias towards threat, which refers to the preferential tendency to allocate attention to threat-related information rather than nonthreat information (Mogg & Bradley, 2016).

A meta-analysis done by Mogoase and her colleagues provided a review of the clinical effect of attentional bias modification (AMB) in different clinical conditions, among which anxiety disorder (Mogoase et al., 2014). They found that the therapeutic benefit of ABM is rather small for anxiety and that more efficient procedures are needed. Furthermore, several studies show that the delivery of ABM training did not result in anxiety reduction and therefore this treatment method was not very effective (MacLeod & Clarke, 2015; Ollendick et al., 2019; Waters et al., 2019). Based on these conclusions, ABMT may not be as effective as was hoped for in the treatment of anxiety disorder. This can be explained by the fact that ABMT is based on the theory that anxious people have attentional biases towards threatening faces. By shifting the attention towards happy facial expressions, anxiety is tried to be reduced. However, if the conclusion of this thesis is true that anxious people detect specific spatial frequencies and orientation contrasts faster than others, the focus point of AMBT is wrong.

Now the question is if there is a possible substitute for ABMT which will have an effect on anxiety disorder. A possible treatment which will affect the visual perception is perceptual learning, which can be defined as a long lasting improvement in a perceptual skill following a systematic training, due to changes in brain plasticity at the level of sensory or perceptual areas. It is specific for basic stimulus features suggesting a long-term modification at early stages of visual analysis such as spatial frequency and orientation contrasts (Frontiers media, 2015).

To create a training set for this type of treatment, it is necessary to find out which exact stimulus properties attract more attention and which properties attract less attention in anxious people. By using AI models, as in the study of Stuit, it can be shown which stimulus properties affect the attention of anxious people. With this knowledge, an effective training set can be build.

It is expected that this treatment based on perceptual learning can be very helpful when it comes to treating anxious people. If the suggestion is correct that the visual perception is modulated in anxiety, perceptual learning can possibly help anxiety patients to reduce their modulated detection for specific stimulus properties and therefore help treating anxiety.

In summary, the suggestion can be made that anxious people have problems in their visual perception which results in some stimulus properties that are detected more efficiently than others. This is also the reason why only angry superiority effects have been found in the anxiety research. This visual detection hypothesis is a very important aspect to keep in mind, because treatment should be based on the problems of the patient and are otherwise not effective.

Luckily, recent AI methods should make it possible to create the right treatment, based on the conclusion of this thesis. Even though the beginning is made to proof the existence of visual problems in anxious research, further research should investigate this much more by doing experiments directly researching the detection of specific stimulus properties. Additionally, furhter research should investigate the role of perceptual learning in treating anxiety and the effectiveness of this treatment when making use of AI models to build the training sets.

References

Alorda, C., Serrano-Pedraza, I., Campos-Bueno, J. J., Sierra-Vazquez Vicente, & Montoya, P. (2007). Low spatial frequency filtering modulates early brain processing of affective complex pictures. *Neuropsychologia*, 45(14), 3223–3233. https://doi-org.proxy.library.uu.nl/10.1016/j.neuropsychologia.2007.06.017

Andrea, D. C., Serena, M., & Maurizio, C. (2013). Early spatial frequency processing of natural images: an erp study. *Plos One*, 8(5). https://doi-org.proxy.library.uu.nl/10.1371/journal.pone.0065103

Bar-Haim, Y., Lamy, D., & Glickman, S. (2005). Attentional bias in anxiety: a behavioral and erp study. *Brain and Cognition*, 59(1), 11–22. https://doi-org.proxy.library.uu.nl/10.1016/j.bandc.2005.03.005

Becker, D. V., Anderson, U. S., Mortensen, C. R., Neufeld, S. L., & Neel, R. (2011). The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General*, 140, 637– 659. doi:10.1037/a0024060

Berggren, N., Blonievsky, T., & Derakshan, N. (2015). Enhanced visual detection in trait anxiety. *Emotion* (Washington, D.c.), 15(4), 477–83. https://doi-org.proxy.library.uu.nl/10.1037/a0039449

Bradley, B., Mogg, K., Falla, S., & Hamilton, L. (1998). Attentional bias for threatening facial expressions in anxiety: manipulation of stimulus duration. *Cognition and Emotion*, 12(6), 737–753.

Bradley, B. P., Mogg, K., White, J., Groom, C., & de Bono, J. (1999).Attentional bias for emotional faces in generalized anxiety disorder. *Br J Clin Psychol.*, 1999 Sep;38(3):267-78.

Bradley, B., Mogg, K., & Millar, N. (2000). Covert and overt orienting of attention to emotional faces in anxiety. *Cognition and Emotion*, 14(6), 789–808.

Calvo, M. G., & Nummenmaa, L. (2008). Detection of emotional faces: salient physical features guide effective visual search. *Journal of Experimental Psychology. General*, 137(3), 471–94. https://doi-org.proxy.library.uu.nl/10.1037/a0012771

Dickersin, K., & Min, Y. I. (1993). Publication bias: the problem that won't go away. *Annals of the New York Academy of Sciences*, 703, 135–148. https://doi.org/10.1111/j.1749-6632.1993.tb26343.x

Dickins, D. S., & Lipp, O. V. (2014). Visual search for schematic emotional faces: angry faces are more than crosses. *Cognition Emotion*, 28(1), 98–114. https://doi-org.proxy.library.uu.nl/10.1080/02699931.2013.809331

Ekman, P. & Friesen, W. V. Constants across cultures in the face and emotion. *J. Pers. Soc. Psychol.*, 17(2), 124–129. https://doi.org/10.1037/h0030377 (1971)

Ekman, P., & Keltner, D. (1997).Universal facial expressions of emotion. Segerstrale U, P. Molnar P, eds. *Nonverbal communication: Where nature meets culture*, 27-46.

Feldmann-Wustefeld, T., Schmidt-Daffy, M., & Schubo, A. (2011). Neural evidence for the threat detection advantage: differential attention allocation to angry and happy faces. *Psychophysiology*, 48(5), 697–707. https://doi-org.proxy.library.uu.nl/10.1111/j.1469-8986.2010.01130.x

Flevaris, A. V., Robertson, L. C., & Bentin, S. (2008). Using spatial frequency scales for processing face features and face configuration: an erp analysis. *Brain Research*, 1194(C), 100–109. https://doi-org.proxy.library.uu.nl/10.1016/j.brainres.2007.11.071

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently?. *Cognition emotion*, 14(1), 61-92.

Fox, E., Russo, R., & Dutton, K. (2002).Attentional bias for threat: evidence for delayed disengagement from emotional faces. *Cognition and Emotion*, 16(3), 355–379.

Frischen, A., Eastwood, J. D., & Smilek, D. (2008). Visual search for faces with emotional expressions. *Psychological Bulletin*, 134(5), 662–676. https://doi-org.proxy.library.uu.nl/10.1037/0033-2909.134.5.662

Frontiers Media SA. (2015). Learning to see (better): improving visual deficits with perceptual learning.

Gilboa-Schechtman, E., Foa, E., & Amir, N. (1999). Attentional biases for facial expressions in social phobia: the face-in-the-crowd paradigm. *Cognition Emotion*, 13(3), 305–318.

Gucluturk Yagmur, Guclu Umut, van Gerven, M., & van Lier, R. (2018). Representations of naturalistic stimulus complexity in early and associative visual and auditory cortices. *Scientific Reports*, 8(1). https://doi-org.proxy.library.uu.nl/10.1038/s41598-018-21636-y

Hansen, C. H. & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology*, 54, 917–924. doi:10.1037/0022-3514.54.6.917

Harel, Y., Lavigne, C., D'Hondt, F., & Lepore, F. (2016). The decoding of emotional facial expressions across different spatial frequency bands: an ERP study. *Social Affective Neuroscience Society*. DOI:10.13140/RG.2.1.4543.5763

Hodsoll, S., Viding, E., & Lavie, N. (2011). Attentional capture by irrelevant emotional distractor faces. *Emotion*, 11(2), 346–353.

Hopfinger, J. B., Buonocore, M. H., & Mangun, G. R. (2000). The neural mechanisms of top-down attentional control. *Nat Neurosci*, 3(3), 284–291.

Horstmann, G., & Bauland, A. (2006). Search asymmetries with real faces: Testing the anger-superiority effect. *Emotion*, 6, 193–207. doi:10.1037/ 1528-3542.6.2.19

Jacques, C., Schiltz, C., & Goffaux, V. (2014). Face perception is tuned to horizontal orientation in the N170 time window. *Journal of vision*, 14(2), 5-5.

Jeantet, C., Laprevote, V., Schwan, R., Schwitzer, T., Maillard, L., Lighezzolo-Alnot Joelle, & Caharel Stephanie. (2019). Time course of spatial frequency integration in face perception: an erp study. *International Journal of Psychophysiology*, 143, 105–115. https://doi-org.proxy.library.uu.nl/10.1016/j.ijpsycho.2019.07.001

Juth, P., Lundqvist, D., Karlsson, A., & Öhman, A. (2005). Looking for foes and friends: Perceptual and emotional factors when finding a face in the crowd. *Emotion*, 5, 379 –395. doi:10.1037/1528-3542.5.4.379

Kennett, M. J., & Wallis, G. (2019). The face-in-the-crowd effect: Threat detection versus iso-feature suppression and collinear facilitation. *Journal of vision*, 19(7), 6-6.

Kessels, R. P., Montagne, B., Hendriks, A. W., Perrett, D. I., & de, H. E. H. (2014).Assessment of perception of morphed facial expressions using the emotion recognition task: normative data from healthy participants aged 8-75. *Journal of Neuropsychology*, 8(1), 75–93. https://doi-org.proxy.library.uu.nl/10.1111/jnp.12009

Laretzaki, G., Plainis, S., Argyropoulos, S., Pallikaris, I. G., & Bitsios, P. (2010). Threat and anxiety affect visual contrast perception. *Journal of Psychopharmacology*, 24(5), 667-675

Lipp, O. V., Price, S. M., & Tellegen, C. L. (2009). Emotional faces in neutral crowds: Detecting displays of anger, happiness, and sadness on schematic and photographic images of faces. *Motivation and Emotion*, 33, 249 –260. doi:10.1007/s11031-009-9136-2

LoBue, V. (2009). More than just another face in the crowd: superior detection of threatening facial expressions in children and adults. *Developmental Science*, 12(2), 305–13. https://doi-org.proxy.library.uu.nl/10.1111/j.1467-7687.2008.00767.x

MacLeod, C., & Clarke, P. J. (2015). The attentional bias modification approach to anxiety intervention. *Clinical Psychological Science*, 3(1), 58-78.

Mao, Q., Pan, X., Zhan, Y. & Shen, X. (2015).Using Kinect for real-time emotion recognition via facial expressions. *Frontiers Inf Technol Electronic Eng*, 16, no. 4, 272–282.

Mehu, M., Grammer, K., & Dunbar, R. I. M. (2007). Smiles when sharing. *Evolution and Human Behavior*, 28, 415-422.

Mogg, K., & Bradley, B. P. (1999). Some methodological issues in assessing attentional biases for threatening faces in anxiety: a replication study using a modified version of the probe detection task. *Behaviour Research and Therapy*, 37(6), 595–604.

Mogg, K., Millar, N., & Bradley, B. P. (2000). Biases in eye movements to threatening facial expressions in generalized anxiety disorder and depressive disorder. *Journal of Abnormal Psychology*, 109(4), 695–704.

Mogg, K., & Bradley, B. P. (2016). Anxiety and attention to threat: cognitive mechanisms and treatment with attention bias modification. *Behaviour Research and Therapy*, 87, 76–108. https://doi-org.proxy.library.uu.nl/10.1016/j.brat.2016.08.001

Mogoaşe, C., David, D., & Koster, E. H. (2014). Clinical efficacy of attentional bias modification procedures: An updated meta-analysis. *Journal of Clinical Psychology*, 70(12), 1133-1157. Montgomery, J. (2012).Emotions, Survival, and Disconnection. *Psychology Today*. https://www.psychologytoday.com/us/blog/the-embodied-mind/201209/emotions-survival-and-disconnection

Nakashima, T., Kaneko, K., Goto, Y., Abe, T., Mitsudo, T., Ogata, K., Makinouchi, A., & Tobimatsu, S. (2008). Early erp components differentially extract facial features: evidence for spatial frequency-and-contrast detectors. *Neuroscience Research*, 62(4), 225–35. https://doi-org.proxy.library.uu.nl/10.1016/j.neures.2008.08.009

O'Donnell, B. F., Swearer, J. M., Smith, L. T., Hokama, H., & McCarley, R. W. (1997). A topographic study of erps elicited by visual feature discrimination. *Brain Topography*, 10(2), 133–143. https://doi-org.proxy.library.uu.nl/10.1023/A:1022203811678

Ollendick, T. H., White, S. W., Richey, J., Kim-Spoon, J., Ryan, S. M., Wieckowski, A. T., Coffman, M. C., Elias, R., Strege, M. V., Capriola-Hall, N. N., & Smith, M. (2019). Attention bias modification treatment for adolescents with social anxiety disorder. *Behavior Therapy*, 50(1), 126–139. https://doi-org.proxy.library.uu.nl/10.1016/j.beth.2018.04.002

Petras, K., Jacobs, C., Ten Oever, S., & Goffaux, V. (2018). Multivariate classification of eeg data reveals spatial frequency dominance patterns during broad band image processing. *Journal of Vision*, 18(10), 1082–1082. https://doi-org.proxy.library.uu.nl/10.1167/18.10.1082

Pinkham, A. E., Griffin, M., Baron, R., Sasson, N. J., & Gur, R. C. (2010). The face in the crowd effect: anger superiority when using real faces and multiple identities. *Emotion*, 10(1), 141–146.

Posner, M. I., & Petersen, S. E. (1989). The attention system of the human brain. *Annual Reviews in Neuroscience*, 13, 25–42.

Quinlan, P. T. (2013). The visual detection of threat: A cautionary tale. *Psychon Bull Rev*, 20:1080-1101. DOI 10.3758/s13423-013-0421-4

Ratliff, M. S. & Patterson, E. (2008). Emotion recognition using facial expressions with active appearance models, Proceedings of the Third IASTED International Conference on Human Computer Interaction. *ACTA Press*, Anaheim, CA, USA, 138–143.

Samantha, D., Akeesha, S., Amishi, J., & Tracy, A. D.-T. (2017). Emotional cue validity effects: the role of neurocognitive responses to emotion. *Plos One*, 12(7). https://doi-org.proxy.library.uu.nl/10.1371/journal.pone.0179714

Savage, R. A., Lipp, O. V., Craig, B. M., Becker, S. I. & Horstmann, G. In search of the emotional face: Anger versus happiness superiority in visual search. *Emotion*, 13(4), 758 (2013).

Scharlemann, J. P. W., Eckel, C. C., Kacelnik, A., & Wilson, R.K. (2001).The value of a smile: Game theory with a human face. *Journal of Economic Psychology*, 22, 617-640.

Song, F., Parekh, S., Hooper, L., Loke, Y. K., Ryder, J., Sutton, A. J., Hing, C., Kwok, C. S., Pang, C., &

Harvey, I. (2010). Dissemination and publication of research findings: an updated review of related biases. *Health technology assessment* (Winchester, England), 14(8), iii–193. https://doi.org/10.3310/hta14080

Stein, T., Sterzer, P. (2012). Not just another face in the crowd: detecting emotional schematic faces during continuous flash suppression. *Emotion* 12(5): 988.

Stuit, S. M., Kootstra, T. M., Terburg, D., van den Boomen, C., van der Smagt, M. J., Kenemans, J. L., & Van der Stigchel, S. (2021). The image features of emotional faces that predict the initial eye movement to a face. *Sci Rep.*, 2021 Apr 15;11(1):8287.

Svegar, D., Igor, K., & Polic, M. (2013). Happy face superiority effect in change detection paradigm. *Psychological Topics*, 22(2), 249–269

Theeuwes, J. (1991). Exogenous and endogenous control of attention: the effect of visual onsets and offsets. *Perception Psychophysics*, 49(1), 83–90.

Theeuwes, J., & Burger, R. (1998). Attentional control during visual search: The effect of irrelevant singletons. *Journal of Experimental Psychology: Human Perception and Performance*, 24(5), 1342–1353.

Tian, Y. I., Kanade, T. & Cohn, J. F., (2001). Recognizing action units for facial expression analysis, IEEE Transactions on Pattern Analysis and Machine Intelligence. 21, no. 2, 97–115.

Tian, J., Wang, J., Xia, T., Zhao, W., Xu, Q., & He, W. (2018). The influence of spatial frequency content on facial expression processing: An ERP study using rapid serial visual presentation. *Scientific reports*, 8(1), 1-8.

Torrence, R. D., & Troup, L. J. (2018). Event-related potentials of attentional bias toward faces in the dot-probe task: A systematic review. *Psychophysiology*, 55(6), e13051.

Tottenham, N (2009). The NimStim set of facial expressions: Judgements from untrained research participants. *Psychiatry* Res.168(13), 242–249.

Vuilleumier, P. & Schwartz, S. (2001).Emotional facial expressions capture attention. *Neurology*, 56(2), 153–158.

Waters, A. M., Candy, S. G., Zimmer-Gembeck, M. J., Groth, T. A., Craske, M. G., Bradley, B. P., & Mogg, K. (2019). A school-based comparison of positive search training to enhance adaptive attention regulation with a cognitive-behavioural intervention for reducing anxiety symptoms in children. *Journal of Abnormal Child Psychology : An Official Publication of the International Society for Research in Child and Adolescent Psychopathology*, 47(11), 1821–1840. https://doi-org.proxy.library.uu.nl/10.1007/s10802-019-00551-4

Wilson, K. E. (2017).We Are What We Attend To: Individual Differences in Attention and Personality. University of Toronto

Yang, L., & Chan, L. L. (2015, August). An ERP study about the effects of different spatial frequencies and orientations on human brain activity. *In 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* (pp. 6202-6205). IEEE.

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance*, 10(5), 601–621.

Yantis, S. (1996). Attentional capture in vision. In Converging operations in the study of visual selective attention, Vol. xxv, pp. 45–76. Washington, DC, US: American Psychological Association.

Appendix A

Attentional Bias for Emotional Faces in Children With Generalized Anxiety Disorder (2008).

Used stimulus set: NimStim
Author contacted: A. Waters

Biased attention to threat in paediatric anxietydisorders (generalized anxiety disorder, socialphobia, specific phobia, separation anxiety disorder) as a function of 'distress' versus 'fear' diagnostic categorization (2014).

Used stimulus set: NimStim
Author contacted: A. Waters

Stimulus-driven attention, threat bias, and sad bias in youth with a history of an anxiety disorder or depression (2015).

Used stimulus set: NimStim
Author contacted: C. M. Sylvester

Covert and overt orienting of attention to emotional faces in anxiety (2000).

Used stimulus set: NimStim
Author contacted: B. P. Bradley

Biases in Eye Movements to Threatening Facial Expressions in Generalized Anxiety Disorder and Depressive Disorder (2000).

Used stimulus set: NimStim
Author contacted: B. P. Bradley

Some methodological issues in assessing attentional biases for threatening faces in anxiety: a replication study usinga modfied version of the probe detection task (1999).

Used stimulus set: NimStim
Author contacted: B. P. Bradley

Attentional bias for emotional faces in generalized anxiety disorder (1999).

Used stimulus set: NimStim
Author contacted: B. P. Bradley

Attention bias for threatening facial expressions in anxiety: manipulation of stimulus duration (1998).

Used stimulus set: NimStim
Author contacted: B. P. Bradley

Attentional Biases for Facial Expressions in Social Phobia: The Face-in-the-Crowd Paradigm (1999).

Used stimulus set: Ekman & Friesen
Author contacted: E. Gilboa-Schechtman

Through the Eyes of Anxiety: Dissecting Threat Bias via Emotional-Binocular Rivalry (2012).

Used stimulus set: Ekman & Friesen
Author contacted: T. Hendler