MSc Cognitive and Decision Sciences

Threat Perception in Anxious Individuals:

Contributions of semantics and prosody in anxious apprehension vs anxious arousal

Abstract

Most researchers tend to agree that an attentional bias to threatening stimuli is a prominent feature of anxious disorders. The literature looking at cognitive performance and the effects of this attentional bias on the behaviour of anxious individuals appears to be less convergent. This paper argues that the introduction of the previously neglected notions of anxious apprehension vs anxious arousal can explain the inconsistency in those findings. Specifically, a dichotic listening task is used to investigate the differing influences of apprehension and arousal on attention in the presence of threat. The results suggest that anxious apprehension leads to a higher interference of threatening stimuli in attentional processes, while anxious arousal may instead be contributing to sharpened attention in the presence of threat.

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I agree for my work to be shared with students on the course

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Introduction

At any given point, the brain receives as input more information that it is capable of processing, and there are multiple mechanisms, which have evolved to help it sift through and focus its processing power only on those pieces of information that are most important (Driver, 2001). The literature presents evidence to suggest however, that selective attention processes interact with and are influenced by affective processing as well as by the affective value and emotional significance of stimuli (Vuilleumier, 2005). It is generally thought that the valence of emotional stimuli determines the extent to which an external stimulus interferes with attention. For example, since negative emotional stimuli are processed ‘automatically’ because of their evolutionary significance, they might have greater interference with attentive processes compared to neutral or even positively valenced emotional stimuli (Schupp et al., 2004). This is known as a threat bias and animal models suggest that negative emotions have a stronger interference effect on attentive processes, particularly if elicited by threat (Lang, Davis, & Öhman, 2000). In human studies however, threat has been shown to both aggravate as well as enhance attentional control across modalities (Robinson, Vytal, Cornwell, Grillon et al., 2013). The aim of this study is to gain an understanding of what determines whether threat is advantageous or disadvantageous to the individual.

Anxiety

Anxiety disorders, including generalised anxiety disorder (GAD), social anxiety, and post-traumatic stress disorder (PTSD) have also been shown to create similar affect-related biases in attention. It is possible that this type of interference of emotional processing with attention and cognitive control could account for some of the defining characteristics and typical symptoms of anxiety disorders like diminished ability to concentrate and to stay focused, increased forgetfulness, attentional lapses, and high distractibility (Robinson, Krimsky, Grillon, 2013). A prominent theory in the field is attentional control theory, which suggests that anxiety compromises attentional control by upsetting the balance between two parallel attentional systems is the goal-directed top-down system and the stimulus-driven bottom-up system. A central hypothesis in this theory is that anxiety causes more attentional resources to be allocated to the stimulus-driven attentional system and attention to be more focused on task-irrelevant stimuli, and it is assumed that this misbalance in attention causes the threat-bias in anxiety (Eysenck, Derakshan, Santos, & Calvo, 2007).

There are multiple ways in which attentional biases are manifested in anxiety. For example, anxious people have been shown to be faster to orient to threatening stimuli with high emotional value, but there is also evidence to suggest they are also slower at disorienting from non-relevant stimuli with high emotional value (Fox, 2002). Furthermore, attentional biases to emotional stimuli can be formed at different levels of mental computation, including in the sensory-perceptual and the attentional (Robinson, Vytal, Cornwell, Grillon, 2013). While there has been a lot of research on the threat bias in anxiety, there have been mixed findings: even though the majority of studies find that anxiety impairs performance on a variety of tasks, still some studies find that anxious states can have an adaptive function as it can improve performance in uncertain situations by increasing vigilance and improving behavioural mobilisation (Grillon & Charney, 2011). Thus, although there is a growing amount of knowledge on the neuro-cognitive mechanisms that contribute to the development of characteristic symptoms in anxiety, it is still unclear what factors determine whether an anxious state is adaptive and beneficial to the individual, or instead maladaptive and costly.

One possible reason that could explain differing findings is that the studies were looking at different types of anxious states. Studies that find decreased performance look at dispositional or clinical anxiety, whereas studies that find increased performance look at threat-induced or stress-related anxiety. For example, Thomaes et al. (2012) find that in a Stroop task, patients with PTSD have a greater difference in reaction times between neutral and trauma-related words compared to controls. Litz et al. (1996) find that PTSD patients were significantly slower in a modified Stroop task, and although the control groups were delayed when responding to threatening words, patients were significantly slower than controls. In contrast, the findings reported by Grillon and Charney (2011) refer to a threat-induced temporary anxious state and not to an actual anxiety disorder.

Dispositional and clinical anxiety are more closely associated with trait anxious states, and stress-related anxious states are associated with state anxiety. State anxiety is anxiety about a specific event or stimulus that is stressful, and which can be either physical or psychological, whereas trait anxiety is not a reaction to situational stress, but rather a personal characteristic (Spielberger, Lushene, Vagg, & Jacobs, 1971). Levels of state anxiety therefore fluctuate over time and are dependent on environmental factors, whereas levels of trait anxiety are more stable, but differ between people. Thus, the findings summarised above seem to suggest that state anxiety usually contributes to increased vigilance and attention control, as opposed to trait anxiety, which typically decreases attention control and impairs performance.

Although research on anxiety would typically oppose state vs trait anxiety, there is a compelling pattern of interaction between them that affects attention as discussed in Helfinstein, White, Bar-Haim, & Fox (2008). Under normal conditions, trait-anxious individuals have an attentional bias towards threatening stimuli: in Stroop tasks they have delayed reaction times naming the colour of threatening compared to neutral words (Williams, Mathews, & MacLeod, 1996). Additionally, in dot-probe tasks, individuals have faster reaction times to targets displayed in the same location as threatening compared to neutral stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Ijzendoorn, 2007). However, when state anxiety is increased, as it would be in conditions of heightened stress like expecting an interaction with a boa constrictor for snake phobics and expecting to deliver a speech for socially anxious individuals, this attentional bias towards threatening stimuli disappears (Mathews & Sebastian, 1993; Amir, Mcnally, Riemann, & Burns, 1996).

While the notion of state vs trait anxiety has been useful to researchers in terms of classifying different types of anxious states, it does not offer an explanation as to the mechanisms that contribute to the distinctiveness between these two different types of anxiety. Importantly, Robinson, Letkiewicz, Overstreet, Ernst, and Grillon (2011) show that although increasing levels of state anxiety in healthy subjects is a commonly used procedure when investigating anxiety disorders, the effects of the threat of shock paradigm typically used do not necessarily translate neatly into the effects that dispositional and clinical anxiety have. Specifically, they look at two common aspects of anxiety disorders, the negative affective bias and diminished conflict adaptation. They show that the threat of shock paradigm has an effect on healthy individuals, such that it indeed creates a negative affective bias in emotional processing, however it *does not* cause a decrease in cognitive flexibility as participants maintained similar levels of conflict adaptation. Thus, while the threat of shock paradigm may translate some cognitive characteristics of anxious disorders onto healthy participants, it is not capable of inducing *all* aspects of impaired cognition in dispositional anxiety. This might suggest that these two different types of anxious states have distinct underlying mental mechanisms and it will be greatly beneficial for future research to shift the focus from classifying types of anxiety based on their causes to distinguishing them based on the mechanisms by means of which they are realised.

	Attentional bias to threat
Trait anxiety	Increased
Trait + State anxiety	Decreased

	Hemisphere activity
Anxious apprehension	LH increased (RH decreased)
Anxious app. + arousal	LH decreased (RH increased)

Figure I: Comparison between the trait/state anxiety vs. the anxious apprehension/arousal divisions

One such distinction between anxious states has been put forward by Heller, Nitschke, Etienne, and Miller (1997), who propose that anxious arousal and anxious apprehension are two functionally distinct components of anxiety. In their paper, the researchers note that those studies which look at psychological disorders and anxious states presupposing anxious arousal typically find increased right hemisphere activity. Conversely, the studies which look at psychological disorders presupposing anxious apprehension, typically find increased *left* hemisphere activity. In the experiment they designed to specifically address the discrepancies in the literature concerning anxious arousal vs. anxious apprehension, they compared brain activation patterns of anxious apprehension while also manipulating anxious arousal by means of emotional narratives that were previously used to elicit arousal or not and observed that across conditions. Participants who scored high on anxious arousal had an increased left hemisphere frontal activation compared to controls, and this was a result of a decrease in right hemisphere activity. Furthermore, while listening to narratives designed to elicit anxious arousal, participants high in anxious apprehension showed a significant increase in the right parietal hemisphere. This pattern of interaction is comparable to the one previously discussed in the case of trait and state anxiety, as demonstrated in *Figure I* above.

While to the best knowledge of the author of the present paper, a comprehensive correlational study investigating the extent to which anxious apprehension maps onto trait anxiety and anxious arousal onto state anxiety does not exist, there are several reasons to believe that this might be the case. Firstly, the definitions of the terminology overlap: the scale on the State-Trait Anxiety Inventory (STAI) used to assess trait anxiety is described to rate "feelings of apprehension, tension, nervousness, and worry" (Spielberger, 1983: p.2). Moreover, anxious apprehension is described as verbal rumination over worries and concerns about the future and goes along with tension and restlessness (Nitschke, Heller, Palmieri, & Miller, 1999). Furthermore, studies looking at participants scoring high on the trait scale of the STAI find increases in left hemisphere activation. This is expected from participants with high scores on anxious apprehension, because this component of anxiety has a strong verbal aspect and language processing is typically left-lateralised (Heller, Nitschke, Etienne, & Miller, 1997; Hickok & Poeppel, 2007). Additionally, Sass et al. (2010) point out that similarly to EEG studies observing increased activation over the left hemisphere for participants with high anxious apprehension, a similar pattern is found by studies looking at participants with obsessive-compulsive disorder, generalised anxiety disorder, and trait anxiety.

The P300 response is a modality independent event-related brain potential, which is thought to reflect later-stage processing like stimulus evaluation or context updating. It is typically associated with cognitive resource demands related to the task, such that as task difficulty increases, so does the P300 amplitude (Fisher et al., 2010; Fabiani, Gratton, & Coles 2000; Stewart et al., 2010). P300 latency on the other hand is associated with stimulus evaluation and categorisation such that in a task where accuracy and not speed is the focus, as difficulty increases, so does the P300 amplitude (Coles, Gratton, & Fabiani, 2000). According to Kramer and Parasuraman (2007) the redirection of cognitive resources from the task at hand will result to a decrease in the P300 amplitude, thus making the P300 amplitude a good measure for resource allocation and mental workload in perceptual and cognitive processing of stimulus evaluation.

Box I: The P300 event-related brain potential as an indicator of attentional resources allocation

Finally, there is independent evidence from the literature on attention control that suggests trait anxiety as well as anxious apprehension have a negative effect on attentional processes. For example, Bishop (2009) conducts an imaging study on participants during a task with either high or low demands on attention to examine the extent to which anxious apprehension affects the control of selective attention in the context of low perceptual load. The results indicate that indeed, participants scoring high on trait anxiety had decreased activation of the dorsolateral prefrontal cortex, an area typically associated with attention control. Significantly, state anxiety was controlled for in the analysis, suggesting that it does not contribute to deficits in attentional control. Similarly, electrophysiological findings suggest that anxious apprehension may contribute to decreased recruitment of attentional resources as evidenced by a decreased P300 ERP amplitude in anxious-apprehensive participants compared to controls. Moser, Moran, and Jendrusina (2012) show that anxious apprehension, but not anxious arousal, is associated with a diminished error positivity, a P300-like component. They further find that two early ERP correlates, the error-related negativity and correct-response negativity, are increased in individuals with anxious apprehension, but not those with anxious arousal, and advocate that this is why anxious-apprehensive people had a decreased P300.

In summary, the threat-related attentional bias is a prominent feature of anxious states that can contribute to eminent symptoms in clinical populations. Still, there are discrepancies in the literature regarding the effects of this bias as some researchers observe it enhances attention and others observe it aggravates it. These inconsistencies in findings could be explained with the fact that studies looking at state anxiety find improved attention whereas studies looking at trait anxiety find impaired attention. While the state / trait dichotomy is widely used it does not contribute to a mechanistic understanding of anxious states. This is why this study will use the anxious arousal / apprehension dichotomy, which closely maps onto the state / trait one, but could also contribute to understanding the mechanisms involved in the interference of emotional stimuli to attentional processes. This study is going to look at threat perception and in line with the literature discussed above we expect to see an increasing attentional bias towards threatening stimuli as a function of anxious apprehension, but not influenced by anxious arousal.

LANGUAGE

Language comprehension is an ideal medium for studying the interactions between attentional and affective processes because it requires the integration of information from multiple channels (semantics, prosody[1], facial expression, gesture) which can all potentially carry emotional information, allowing for a controlled manipulation in experimental settings (Paulmann and Kotz, 2008). Indeed, the effect of emotion on attention has been investigated in a variety of modalities. In terms of auditory attention, Ceravolo, Frühholz, and Grandjean (2016) use a dichotic listening auditory dot-probe task to show that emotional prosody can influence auditory spatial attention. Specifically, they show that reaction times are significantly faster when the target tone is presented in the same location as the emotional prosody and significantly slower when it was presented in the opposite location. This suggests that auditory spatial attention is indeed affected by emotional prosody, similarly to visual attention.

Similar to studies investigating anxious states, laterality effects have also been found in linguistic studies: Erhan, Borod, Tenke, & Bruder (1998) look at emotion perception using syllable stimuli spoken with an emotional prosody. They found that there is a left ear advantage for processing emotional stimuli as indicated by significantly faster reaction times when the stimuli were presented in

[1] The patterns of stress and intonation in spoken language are referred to as prosody. A distinction is typically made between linguistic and emotional prosody, the former carrying grammatical information like the type of sentence (declarative, interrogative) and the latter conveying emotional information. In this paper the word "prosody" will be used to refer to emotional prosody exclusively.

the left ear. Their results support the right hemisphere hypothesis, which states that linguistic stimuli carrying emotional information are processed in the right hemisphere, while non-emotional linguistic stimuli are processed in the left hemisphere. The fact that there are distinct processing paths for linguistic vs emotional linguistic information means that interference between the two is a possibility, however, their study design does not explicitly address that, especially because they did not have neutral stimuli for comparison. Furthermore, they use syllables, which as a linguistic unit do not carry any semantic information, and therefore an interference between semantic and emotional processing cannot be observed in this design. Erhan et al., (1998) also looked at the N100, an ERP correlate that is too early in order to give any information about attentive processes.

Wambacq and Jerger (2004) design a study to look at the effect of negative emotion on attention using an oddball task with words instead of syllables. The stimuli have either neutral or negative valence and either high or low arousal and are produced with either a neutral or a negative tone of voice. These manipulations allow them to look at the interactions between emotion and attention more directly than previous studies and recorded a later ERP correlate, which allows the researchers to draw conclusions concerning attention. They observed that the P3a amplitude is larger for the stimuli with emotional information of either semantic or prosodic type compared to neutral stimuli, suggesting that emotionally charged linguistic stimuli require an increase in the recruitment of attentional resources. A strong point in their study design is that it is able to compare the neurophysiological responses to threat of semantic and prosodic type distinctly. This is important because it has been suggested that an increase in the P300 for emotional linguistic stimuli could be due to the fact that they have different acoustic characteristics (Gaeta, Friedman, & Hunt, 2003). Still, they observe that both negative semantics and negative prosody result in a larger P300 response.

In summary, the literature on language comprehension indicates that the linguistic medium is ideal for testing attentional biases as effects have been observed on many levels of linguistic processing, though studies typically use stimuli below the sentence level. Further, even though the distinct processing paths for emotional vs non-emotional linguistic information present a comfortable medium for investigating selective attention processes in anxious populations, no study seems to have used linguistic stimuli to address attentional biases in anxiety.

AIM OF THE STUDY

The purpose of this study is to build on findings in two traditionally separate fields of study, namely affect-related attentional biases in anxiety and language processing. It aims to re-introduce the division of anxious arousal and anxious apprehension, because it can explain previous discrepancies in the literature on threat-biases in anxiety. For this purpose, this paper implements a focused attention dichotic listening task and used task-irrelevant linguistic stimuli with differing levels of threat in participants with differing levels of arousal and apprehension. Participants were asked to attend one ear while playing the stimulus in the other ear to observe the level of interference of emotional stimuli to a given task. Because previous studies only used less naturalistic stimuli like syllables and words, this paper uses sentence-level stimuli. It is expected that threatening stimuli will interfere more with task-directed attention. Since Wambacq and Jerger (2004) show that the P3a component was significantly larger for bi-dimensional stimuli compared to stimuli with negative semantics or negative prosody only, this paper anticipates that interference will be greatest when the stimuli were threatening in meaning as well as in intonation, but that there will also be a significant interference when only one element is present. Furthermore, we predict that this interference will be modulated by anxious apprehension, but not by anxious arousal (Bishop, 2009).

METHODS

PARTICIPANTS

All participants were recruited via Prolific, where the pre-screening was set to include an age range (18-65 y.o.) and English as a first language. The subjects were 43 adult native English speakers, 15 males and 25 females, aged between 18 and 60 years (mean = 31.3 years), 35 right-handed and five left-handed. For ethical considerations, participants were asked to self-select and not take part in the study if they had been diagnosed with a neurological condition or otherwise felt the nature of the stimuli could harm them. Participants were paid £7.50/hour for participating in this remote study (gorilla.sc), which took around 30 minutes to complete including detailed instructions and a training session.

ANXIETY MEASURES

Participants were asked to fill out two questionnaires before beginning the experiment to assess their levels of anxious arousal and anxious apprehension. The Anxious Arousal sub-scale of the Mood and Anxiety Symptoms Questionnaire (MASQ-AA) (Watson et al., 1995) and the Penn State Worry Questionnaire (PSWQ) (Meyer, Miller, Metzger, & Borkovec, 1990) were used, respectively. Each questionnaire consisted of 16 questions and was rated on a 1 – 5 Likert scale and scores ranged from 16 to 80. For arousal, scores are summed, whereas for apprehension some questions had negative (inverted scores), for example if a person responded with a 5 ("Very typical of me") on item number 10, "I never worry about anything." their recorded score for this item would be 1.

STIMULI

The stimuli were 208 sentences falling in either of four conditions: TSTP - threatening semantics and threatening prosody; NSNP - neutral semantics and neutral prosody; TSNP - threatening semantics and neutral prosody; NSTP - neutral semantics and threatening prosody. In order to make the stimuli and fillers sound more naturalistic, lines were used from popular movies: *Pulp Fiction, In Brugges, In the Name of the Father, Goodfellas, Big Lebowski, Death at a Funeral, Eastern Promises, In the Loop, Notting Hill*. Lines were selected to be stimuli if they contained words from a list of threatening words. The list comprised words with ratings of 5 or above on arousal and below 5 on dominance and valence as indicated by the extended version of the Affective Norms for English Words (Warriner, Kuperman, & Brysbaert, 2013). Items the list were rated in an online task to ensure people perceive them as threatening (Busch -Moreno, 2017).

Lines with threat appearing after the second syllable (at least) were selected as stimuli or edited so as to only contain threat after the second syllable. For each threatening sentence we created a neutral one with the same number of syllables and an identical beginning, as illustrated in Table I below. This matching between threatening and neutral stimuli allows for comparison between them. Fillers were sentences neutral in valence and low in arousal and dominance, and rated as such in a previous experiment (Busch-Moreno, 2017). The resulting 120 sentences were rated by 21 native English speakers to ensure they were indeed perceived as threatening and neutral respectively. We made an online survey using Gorilla (gorilla.sc) and asked participants to rate the stimuli on an 8-point Likert scale where 0 signified "Not at all threatening" and 8 signified "Very threatening". Threatening sentences, which were below 4 and neutral sentences, which were rated above 2, were excluded. There was a significant difference between threatening and neutral sentences ($p<.05$).

Threatening	Neutral
"*They're gonna* kill her."	"*They're gonna* come over."
"*I'm gonna ba*sh his fucking head."	"*I'm gonna ba*ke sourdough bread."

Table I: Matching between threatening and neutral stimuli

The stimuli were recorded by a female native English speaker in both a threatening and a neutral tone of voice and the fillers were recorded with a neutral tone only. Since it can be challenging to produce sentences with incongruent semantics and prosody, when speaking with a threatening tone of voice the speaker was instructed to imagine she really intended to hurt someone she despised (i.e. the CEO of a large pharmaceutical corporation) and when speaking with a neutral tone of voice to imagine she was in an office setting and was conversing with someone in a nonchalant manner. The stimuli and fillers were recorded in two sessions and were presented to the speaker in a random order with silent gaps between them. The recordings were made in an acoustically isolated chamber using Rode NT-1A microphone. The amplitude resolution was set to 16 bit and the sample rate to 44.1 kHz. The acoustic characteristics of the audio files were then extracted using Praat (Boersma & Weenink, 2007). Stimuli, which did not sound threatening enough were re-recorded. The analysis of the final selection of stimuli showed that the median pitch of the sentences with neutral prosody was significantly smaller than that of sentences with threatening prosody: pairwise comparisons were made between conditions with neutral vs conditions with threatening prosody and were all statistically significant at the one percent significance level ($p<0.001$).

Audacity was used to create the dichotic stimuli. The sentences were trimmed to have no leading or following silences, then normalised and paired with a filler of the same (or inaudibly different) duration in two versions: one dichotic stimulus with the stimulus in the right ear and the filler in the left ear and one with the stimulus in the left ear and the filler in the right ear. To avoid order effects, the stimuli were ordered in 16 different pseudo-randomised lists so that:

- there were no semantically matching pairs in a block
- there was an equal number of stimuli played per ear
- there was an equal distribution of both versions of the dichotic stimuli

We used balanced randomisation to assign participants to one of the 16 lists of randomised stimuli.

TASK

In order to assess the differing level of interference for each type of stimulus, a forced attention task was used and participants were asked to direct their focus on the ear in which the fillers were played, while stimuli were played in the other ear. The dichotic audio files were played in a pseudo-randomised order and were divided in ten blocks with a self-timed break in between. Since for each block participants had to focus on a different ear, blocks were also randomised, however there were always five blocks with focus on the left ear and five with focus on the right. In order to make sure participants were not only attending to prosodic features or key threat-related words, we used a task which did not ask participants to attend to the emotional valence of the stimuli. It has previously been suggested that asking for a judgment on the valence of stimuli can reduce laterality effects because this would require subjects to focus on the semantic label (Techentin, Voyer & Klein, 2009). Instead, here a target detection task was used, where participants were shown a target word and were asked press "Y" if they heard the word and "N" if they did not. Half the time the target word was present in the filler and half the time it was not, but it was never present in the stimulus. In order to avoid effects from working memory (D'Anselmo, Marzoli, & Brancucci, 2016) the target was not displayed until 500 ms after the end of the audio. The target word remained on the screen until there was a response and the next audio was played after 1000 ms.

RESULTS

The first part of the experiment consisted of two questionnaires to assess the anxiety levels of participants. The results were Anxious Arousal (AAR): M = 23.9, MED = 20, SD = 10.3 and Anxious Apprehension (AAP): M = 49.6, MED = 53, SD = 11.6. Three participants with an accuracy at or close to chance level were excluded from analysis, as they must have been either not following the instructions, not eligible for the study, or experiencing technical problems. The resulting average accuracy was 88.2%, indicating that most participants understood the task and that it was manageable. Reaction times below 400ms and above 5000ms, which were with an accuracy at or close to chance level, were also excluded from the final analysis. Since this was an online study, it is possible that sometimes participants were just rushing through and not paying attention to the task. Finally, despite having conducted prior surveys on the perceptions of the stimuli, eight from the total of 208 stimuli had an accuracy at or close to chance level, so they were also excluded from the analysis. The remaining trials were analysed in SPSS v.25 using a 2 (Ear in which the stimulus was presented: Left or Right) x 2 (Semantics: Neutral or Threatening) x 2 (Prosody: Neutral or Threatening) x 2 (Anxiety measure: Low or High) mixed analysis of variance with the last factor only being between subjects. We conducted two separate ANOVAs for AAR and AAP as a between-subjects factor, because the anxiety measures were highly correlated that it was better not to test them factorially. We recoded the variables below the median "low" and above the median "high".

Accuracy

For accuracy, there was a main effect of Semantics, $F(1, 38) = 6.69$, $p = .013$, with participants being more accurate in neutral semantics conditions ($M = .90$) compared to the threatening semantics conditions ($M = .89$). There was also a main effect of Prosody, with participants being more accurate for neutral prosody ($M = .91$) compared to threatening prosody conditions ($M =.89$). Furthermore, an interaction between Semantics and Prosody was also observed for accuracy ($F(1, 38) = 7.717$, $p = .008$) which demonstrates that when both semantics and prosody were neutral (NSNP condition) participants were significantly more accurate ($M = .92$) compared to conditions in which any kind of threat was present ($M_{NSTP} = .89$; $M_{TSNP} = .89$; $M_{TSTP} = .89$).

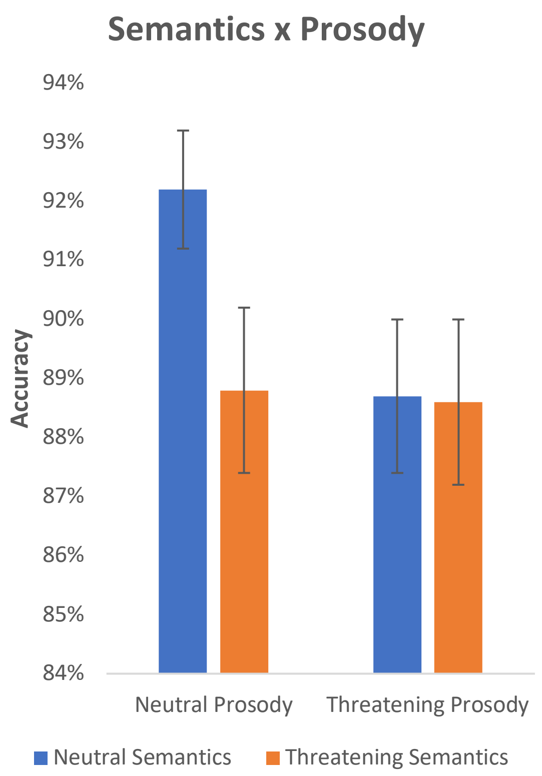

Figure II: Accuracy levels across conditions

Although the main effects and the interaction might suggest that the presence of threat in either of the two channels is causing an increase in errors, a Semantics x Prosody x AAP was also significant ($F(1, 38) = 7.67$, $p = .013$). High-AAP participants were most accurate when both semantics and prosody were neutral ($M_{NSNP} = .91$), similarly to the effect observed in the Semantics x Prosody interaction, however in this case, there was the following additive effect for conditions with threat: while threat present in one channel only decreased the accuracy almost the same amount ($M_{NSTP} = .89$; $M_{TSNP} = .89$), when threat was present in both channels, high-AAP participants were even less accurate ($M_{TSTP} = .87$), as illustrated in *Figure III*. Low-AAP participants were also most accurate when both semantics and prosody were neutral ($M_{NSNP} = .93$), however in one-channel threat conditions they were actually slower ($M_{NSTP} = .88$; $M_{TSNP} = .89$) than in the both-channels threat condition ($M_{TSTP} = .90$). There were no significant effects of Ear for accuracy.

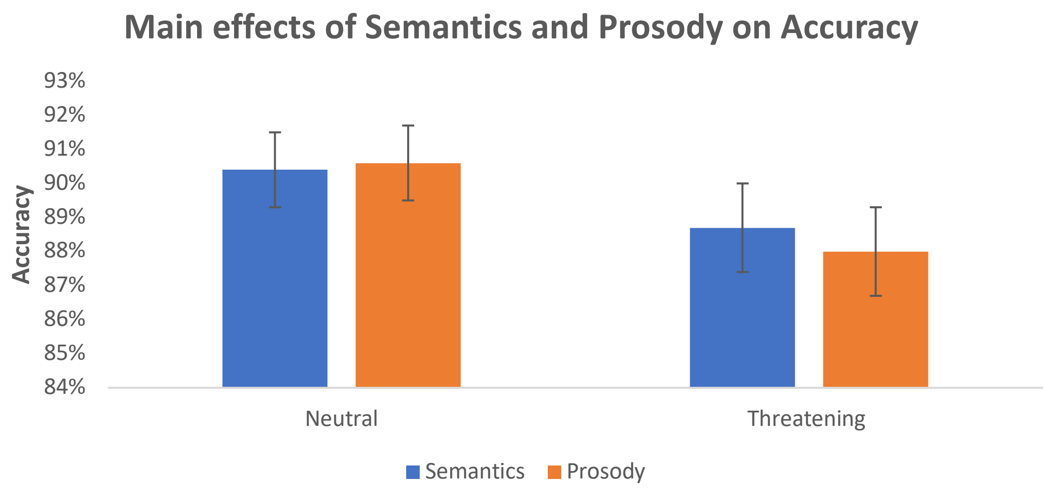

Figure III: Effects of threat on accuracy

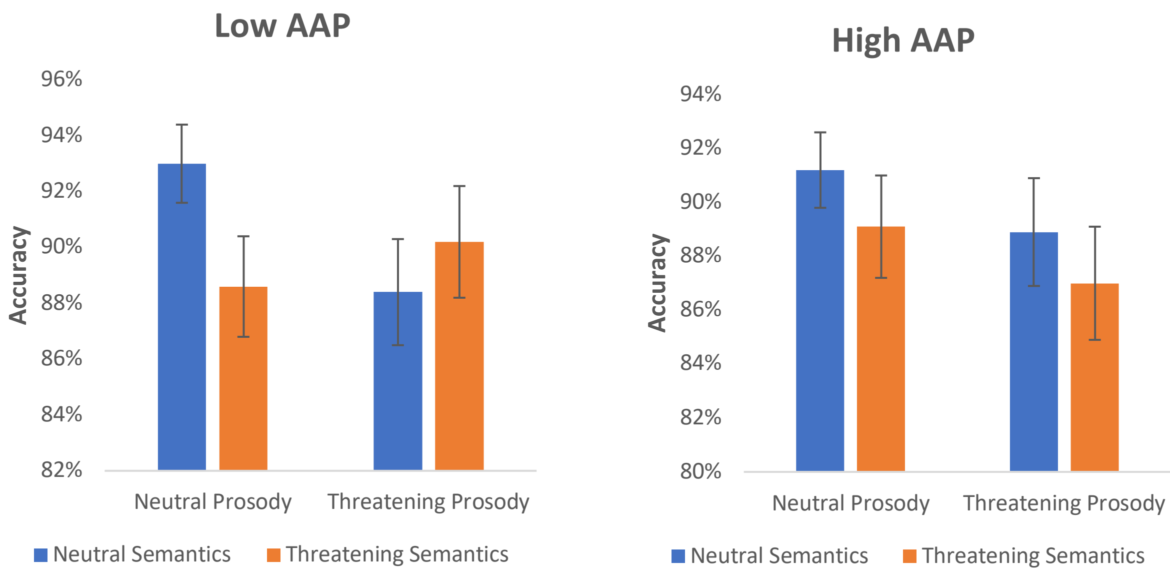

Figure IV: The effect of anxious apprehension on accuracy across conditions

Reaction times

A main effect of Prosody was observed for reaction time, $F(1, 38) = 7.221$, $p = .011$, with participants being faster in the neutral prosody conditions ($M = 918.22$) than for the threatening conditions ($M = 949.61$). A significant interaction between Semantics and Prosody was also observed, $F(1, 38) = 4.283$, $p = .045$, with participants being fastest in the neutral semantics and neutral prosody condition ($M_{NSNP} = 902.11$), slower in the threatening semantics only condition ($M_{TSNP} = 934.34$) and slowest in both conditions with threatening prosody ($M_{NSTP} = 950.35$; $M_{TSTP} = 948.86$).

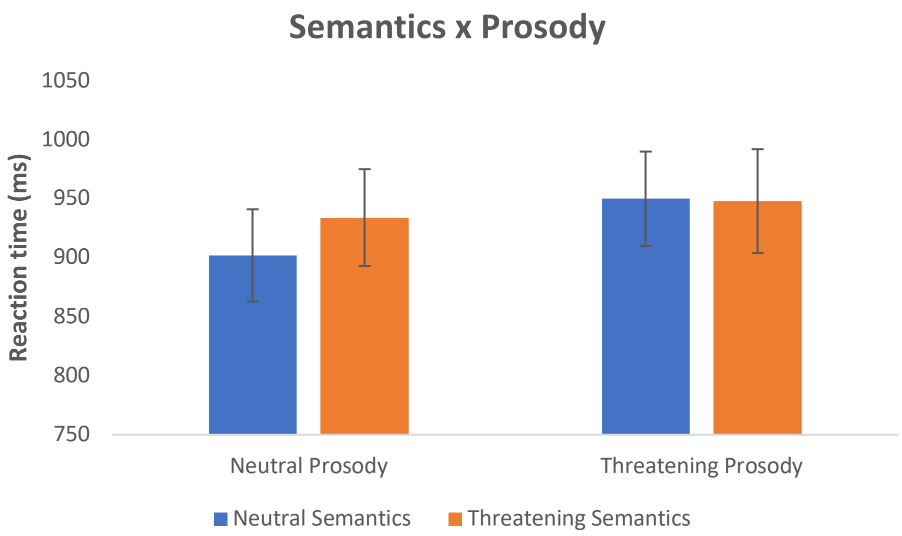

Figure V: Effects of Threat on Reaction time

A Prosody x AAR interaction was also found to be significant for reaction time, F(1, 38) = 1.342, p = .019). Low-AAR participants were slightly faster for neutral prosody (M = 937.91) compared to threatening prosody (M = 940.68), and high-AAR participants were much faster for neutral prosody (M = 896.31) and even slower for threatening prosody (M = 954.06). The Prosody x AAP interaction was not significant (F(1, 38) = 3.772, p = .06) for reaction time, nor was the Semantics x Prosody x AAP interaction (F(1, 38) = 772.7, p = .7). A significant Ear x Prosody x AAP interaction was also observed, F(1, 38) = 7.221, p = .039.

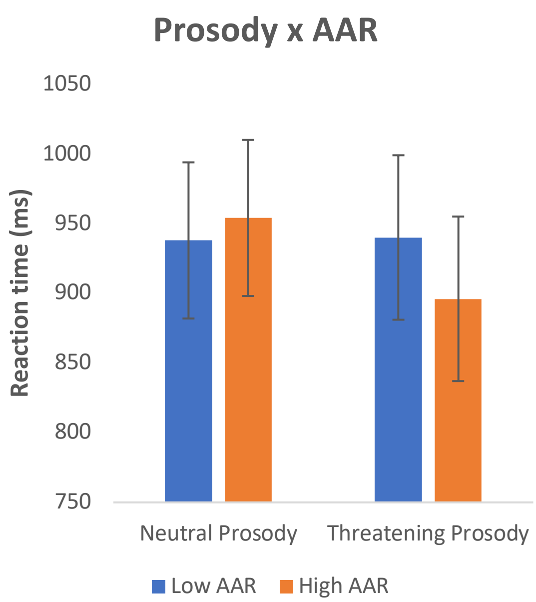

Figure VI: Effects of threatening prosody between groups with high vs low anxious arousal

Discussion

Threat bias

The main aim of this experiment was to investigate the effects of threatening cues on attentional processes in two different types of anxious states. Additionally, we wanted to enquire into the distinct contributions of semantics and prosody to the detection of threatening stimuli in the environment. To these purposes, we asked participants to attend to neutral fillers in one ear while playing stimuli in the other. There were four conditions of stimuli ranging from completely neutral through threatening in one channel only to threatening in both channels. We analysed the effects of these four different conditions on the accuracy and reaction times of participants with varying degrees of anxious arousal and anxious apprehension. The first hypothesis of this study was that the presence of threat in the stimuli will interfere with attentional processes, thus lowering the accuracy and increasing the reaction times of all participants. The main effects of semantics and prosody on accuracy (*Figure III*) as well as the effect of condition on accuracy (*Figure II*) support this hypothesis. Specifically, the main effects demonstrate that when threat is present in either the semantic or the prosodic channel, it causes participants to make more errors. Moreover, the interaction effect shows that when both semantics and prosody are neutral in the NSNP condition, participants have higher accuracy compared to all other conditions. The results show that the accuracy rate does not drop even further in the TSTP condition when both channels convey threat, therefore this interaction seems to suggest that there is no additive effect of threat content when it is present in two different linguistic channels: the stimuli seem to have an equal distractive effect regardless of the 'doubling' of threatening cues in the TSTP condition. Also, given that there were no significant differences between the semantic threat only and prosodic threat only conditions, we cannot attribute distraction effects to acoustic differences.

A similar pattern can be observed in the effects of threat on reaction time: in conditions with neutral prosody participants were significantly faster compared to conditions with threatening prosody. Although in the case of reaction time the effect of semantics was not significant at the chosen level of α ($F(1, 38)$ $p = .11$), *Figure V* depicts the interaction between semantics and prosody and illustrates that while participants were faster in the both-channels neutral condition, they were significantly slower to respond in conditions with threat. These findings are in line with previous research suggesting that the bottom-up stimulus driven attentional system can be in conflict with the top-down goal oriented attentional system (Vuilleumier, 2005). Emotional stimuli, and especially high arousal negative valence stimuli indicating potential threat, are hypothesised to be of high salience and to therefore interfere with attentional processes. The main effects of semantics and prosody, as well as the effect of threat on accuracy and reaction time across conditions offer supporting evidence for this argument.

The dual competition model proposed by Pessoa (2009), however, suggests that the effects of threat on top-down attentional processes are not binary, but rather continuous. He proposes that it is not just the presence of threat that predicts distractibility from a task, but rather the *amount* of threat that will determine the amount of resources required to be shifted away from the task at hand and onto the high-salience threatening stimulus instead. The above effects do not support this hypothesis, however the three-way interaction between semantics, prosody, and anxious apprehension does offer some support for this claim. As depicted in *Figure IV*, the observed effect of stimulus condition for all participants seems to suggest the presence of any threat in the stimuli leads to the same level of interference with goal-directed attention. However, this effect is the result of low-AAP participants being more accurate in the both-channels threatening condition than in the one-channel threatening conditions, whilst high-AAP participants were even less accurate in the TSTP condition compared to both NSTP and TSNP. Thus, at least for one of the groups in the experiment, an additive effect of threatening cues was observed, providing evidence for the notion that the relationship between threat and attention is continuous and not binary. These results are also in line with the findings of Wambacq and Jerger (2004), who show an additive effect of emotional semantics and prosody on the P300 ERP component, which can be used as a measure of attentional resources.

APPREHENSION VS AROUSAL

This pattern of results also supports our second hypothesis that anxious apprehension, but not anxious arousal, makes people more sensitive to threat. The results indicate that while AAP modulates accuracy across conditions, there was no such effect of AAR. This suggests that indeed AAP, but not AAR, causes an increase in the threat-related attentional bias observed in anxiety disorders (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Ijzendoorn, 2007). However, we only observed this effect for accuracy, and not for reaction time, and in the literature on attentional control these two measures are taken to indicate two different phenomena (Eysenck, Derakshan, Santos, & Calvo, 2007). An important distinction is typically made between processing effectiveness (measured by accuracy) and processing efficiency (measured by reaction time). Specifically, effectiveness denotes the performance in a given task, whereas efficiency stands for the "the relationship between the effectiveness of performance and the effort of resources spent (…) with efficiency decreasing as more resources are invested to attain a given performance level" (Eysenck et al., 2007, p. 336). This conception of the two measures can give an intriguing reading to our results. In particular, although we can be positive that AAP has a significant impact on task performance because of the observed effect on accuracy, since there was no corresponding effect on reaction time, we cannot yet draw conclusions about the effort of resources spent; therefore, this question needs to be investigated further in future research employing, for example, an EEG design.

As already mentioned, there was no significant effect of AAR on either accuracy or reaction times across conditions. There was, however, a significant interaction between anxious arousal and prosody, as depicted in *Figure VI.* The graph shows that while there was little difference in the reaction times of the low-AAR group for neutral compared to threatening prosody, there was a substantial difference in the reaction times of the high-AAR group. Importantly, however, although high-AAR participants seem to be slightly slower than low-AAR participants for the neutral prosody conditions, in the threatening prosody conditions they were actually reacting much faster. For comparison, although not significant ($p = .06$), the interaction between prosody and AAP (*Figure VII*) shows an opposite pattern. Similarly to AAR, there was little difference in the reaction times of the low-AAP group for neutral compared to threatening prosody and high-AAP participants were slightly slower than low-AAP participants in neutral prosody conditions. However, unlike the high-AAR group, who were faster when threat was present, the high-AAP group was *slower* in threatening compared to neutral prosody conditions. This result is in accordance with Bishop (2009), who reports decreased attentional control in anxious apprehensive patients, when controlling for AAR. It is also in line with Grillon and Charney (2011), who find that state anxiety improves performance and suggest this could be due to a heightened attentional bias. Thus, our results partially support the second hypothesis of this study, namely that anxious apprehension, but not anxious arousal, increases the interference of threatening stimuli in attentional processes.

The fact that high-AAR participants performed better in the presence of threat only in prosodic conditions, but not in semantic (Semantics x AAR: p= .47) could be explained by perceptual rather than attentional processes. It has been suggested that imminent threat of shock can sharpen the attention in the same modality the threat is detected in (Cornwell, Echiverri, Covington, & Grillon, 2008). Thus, it is possible that high-AAR participants were faster when threat was present because they were more attentive listeners. A dominant hypothesis in threat perception is that in the face of imminent threat, attention will be directed towards the threatening stimulus in a focused attentional stance rather than a distributed one (Fanselow, 1994). If this were the case, then in our design participants would be directing focused attention toward the stimulus and away from the task, therefore reacting more slowly. However, they were actually faster, thus suggesting that heightened attention may not be necessarily focused only towards the threat. Indeed, the results reported by Cornwell et al. (2008) suggest that attention is focused *in the same modality*, not towards the individual threatening stimulus. However, since there were not enough significant effects from the AAR group, this needs to be investigated further in an environment where AAR is better controlled.

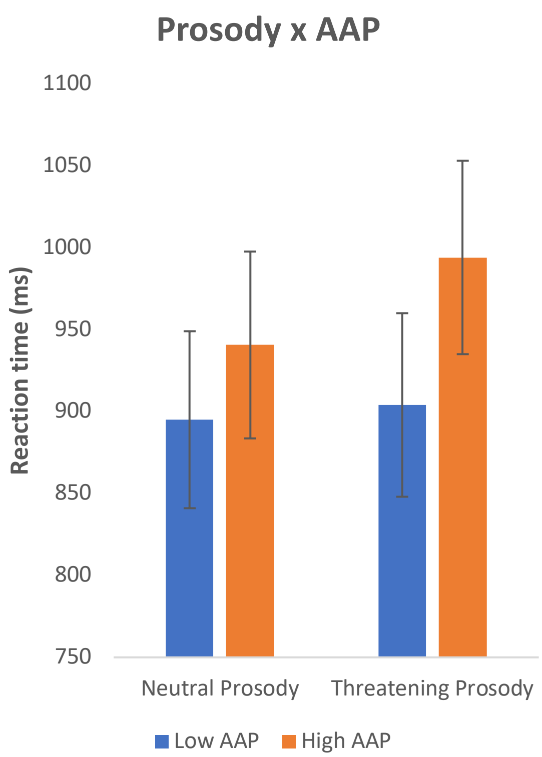

Figure VII: Effects of threatening prosody between groups with high vs low anxious apprehension

Finally, it should be noted that the interaction between semantics, prosody, and anxious apprehension could indicate one more thing. We observed that for low-anxious individuals, the accuracy was indeed highest in the NSNP condition, but unexpectedly it was actually *higher* in the TSTP condition compared to the other two threatening conditions. This indicates that it is non-congruent conditions which had the lowest accuracy in low-AAP groups, whereas the two congruent conditions had higher accuracy. One possible explanation is that in non-congruent conditions an expectancy violation was causing participants to be shifting attentional resources away from the task at hand. Specifically, it is held to be the case that expectancy deviations result in greater difficulties with integration (Paulmann & Kotz, 2008), and this can have an effect on accuracy (Astesano, Besson, & Alter, 2004). Thus, the one-channel only threatening conditions could have been causing more errors not because of the threat, but because of difficulties integrating the mismatching information from semantic and prosodic channels.

LIMITATIONS

Although the results from the experiment offer support to our hypotheses, there are a number of limitations that could have prevented the emergence of even more robust results. An important point was raised above regarding the effects of congruency on attention that could have contaminated effects from threat this study intended to explore. One possible solution to this problem would be to substitute the NSTP condition with a non-speech utterances with appropriate linguistic prosody as well as threatening prosody. A similar paradigm was developed by Ceravolo, Frühholz, and Grandjean (2016) to test the effect of prosody independently from semantics on auditory spatial attention. Further, since this was an online experiment we did not have any way to prevent other distractions participants may have had, like auditory or visual distractions in their environment. Another disadvantage of the remote study is that we could not control the anxious arousal variable and this resulted in a very skewed distribution, since very few participants had high arousal scores. Another limitation that could be easily overcome is that we did not have any measure for participants' working memory capacity. Since the investigation is essentially looking at differences in the distribution of attentional resources, and people with lower working memory capacity are more likely to get distracted, it is good research practice to relate levels of distraction to working memory capacity (Eysenck, Derakshan, Santos, & Calvo, 2007). The only effect we observed for Ear was very confusing since it did not even demonstrate the well-established right ear advantage for processing semantic information and left ear advantage for processing prosodic information. This could be due to the fact that these advantages are demonstrated in right-handed individuals (Costanzo et al., 2015), whereas we did not include handedness as a pre-screening criterion. Finally, we analysed the data using a repeated measures approach for which we had to bundle all trials of the same type in a single data point per participant, which eliminates the variance between stimuli. Although the stimuli were very closely paired so as to decrease as much as possible the effect of this bundling, perhaps another approach to statistical analysis could have been able to retain the rigour as well as the variance between stimuli.

IMPLICATIONS FOR FUTURE RESEARCH

The fact that effects of threat were observed on accuracy as well as on reaction time suggests that the post-hoc nature of the experimental design was not a problem. Previous studies using auditory and linguistic stimuli typically have a task, in which the participant knows the target in advance and is required to respond on-line, whilst still listening to the stimuli (Grimshaw, Kwasny, Covell, & Johnson, 2003; Grimshaw, Seguin, & Godfrey, 2009). While this design is appropriate for behavioural studies, it could pose a problem for studies using EEG. Specifically, brain potentials related to working memory, response preparation, pre-motor and motor processes could interfere with and contaminate the signals from the brain potentials of interest, namely those elicited during perception and those related to attentional processes (Luck, 2014). Some EEG studies avoid this obstacle by making an ERP recording without instructing participants with any particular task (Schupp et al., 2004). However this approach could be problematic, especially in studies investigating attentional processes, since having no task could leave participants not attending to stimuli or even mind-wandering and activating the default mode network and visual imagery, which would clearly meddle with the results. The current design also eliminates the challenge that studies investigating processing of semantics vs prosody often face, namely that they are not synchronised; specifically, prosody is perceived almost immediately, but processing of emotion in semantic content may not occur until a later stage of the sentence (i.e. when a threatening word appears) (Kotz & Paulmann, 2007). With our post-hoc design however, results on both accuracy and reaction time can still be observed, therefore effectively overcoming this obstacle. Therefore, in addition to the findings related to the original purposes of this study, it further provides evidence for the validity of a post-hoc task. Future studies testing similar cognitive phenomena, but using EEG, could make use of the design proposed here. In particular, the same design could be employed in an investigation looking at the P300 brain response as a measure of attentional resources and attention shifting.

CONCLUSION

This study addressed the discrepancies in the literature on threat-related attentional biases in anxiety by introducing the concepts of anxious apprehension and anxious arousal from the literature on language processing. The results from the dichotic listening task indicate that 1) threat in the environment detected by a stimulus-driven bottom-up attentional system interferes with goal-directed top-down attentional resources and 2) semantics and prosody have equal contributions to threat detection. However, 3) threatening cues are additive and in a continuous relationship with distractiveness only for people who are anxious apprehensive and 4) anxious arousal contributes to sharpened attention and decreases distractiveness. In addition to these findings, we have also contributed with a task design which would be useful for the future investigation of this or other questions with EEG studies.

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