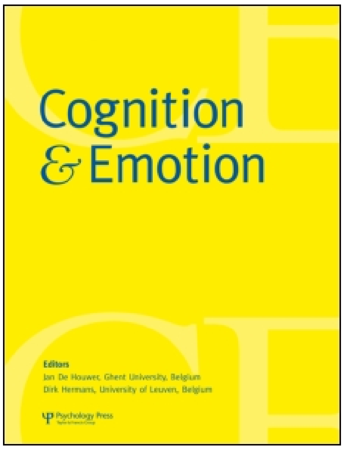

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When time slows down: The influence of threat on time perception in anxiety

Yair Bar-Haim [a]; Aya Kerem [a]; Dominique Lamy [a];Dan Zakay [b]
[a] Tel Aviv University, Tel Aviv, Israel [b] Interdisciplinary Center (IDC), Hertzelia, Israel

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When time slows down: The influence of threat on time perception in anxiety

Yair Bar-Haim, Aya Kerem and Dominique Lamy
Tel Aviv University, Tel Aviv, Israel

Dan Zakay
Interdisciplinary Center (IDC), Hertzelia, Israel

Here, we explored the effect of exposure to threat versus neutral stimuli on time perception in anxious ($n = 29$) and non-anxious ($n = 29$) individuals using predictions from the attentional gate model (AGM) of time perception. Results indicate that relative to non-anxious individuals, anxious individuals subjectively experience time as moving more slowly when exposed to short (2-second) presentations of threat stimuli, and that group differences disappear with longer exposure durations (4 and 8 seconds). Coupled with classic reports of enhanced attentional bias toward threat and diminished attentional control under stress in anxious individuals this finding provides novel insights into low-level cognitive processes that could shape and maintain the subjective experience of anxiety. Findings are discussed in relation to predictions from the AGM and cognitive accounts of anxiety.

Keywords: Anxiety; Attention bias; Time perception; Face; Arousal.

INTRODUCTION

Both state and trait anxiety have been associated with deficits in attention-related cognitive performance (Eysenck, 1992). In particular, relative to non-anxious individuals, anxious individuals have been found to display larger performance costs when task demands require high levels of attentional control (e.g., Bishop, 2009), and to show an abnormally large attentional bias towards threatening information (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Mathews & MacLeod, 2002; Mogg & Bradley, 1998; Williams, Watts, MacLeod, & Mathews, 1997). Anxiety has also been associated with high levels of arousal (Dienstbier, 1989; Hoehn-Saric & McLeod, 2000).

Recent theoretical accounts suggest that cognitive performance deficits in anxiety result from disruption of the balance between bottom-up and top-down attention control processes (Derakshan & Eysenck, 2009; Eysenck, Derakshan, Santos, & Calvo, 2007). According to these models, attentional control is particularly weak in anxious individuals, which boosts the relative contribution of stimulus-driven processes in allocation of attentional priority in anxiety and may account both for the high arousal levels observed in these

Correspondence should be addressed to: Yair Bar-Haim, The Adler Center for Research in Child Development and Psychopathology, Department of Psychology, Tel Aviv University, Tel Aviv 69978, Israel. E-mail: yairl@post.tau.ac.il
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individuals and for the attentional bias they display towards even mildly threatening stimuli. However, there has been no systematic investigation to date of how abnormal arousal levels and attentional regulation deficits interact to generate the cognitive deficits and biases associated with anxiety, and how these factors affect the subjective experience of anxious individuals. In the present study, we tentatively explored these issues by studying the effect of exposure to fearful stimuli on time perception in anxious and non-anxious individuals.

Whereas objective time progresses linearly and in constant units, the subjective experience of time can be dramatically affected by variations in external stimulation and by the cognitive state of the subject (Droit-Volet & Meck, 2007). Recent research on subjective time perception has demonstrated that prospective and retrospective judgements of duration (i.e., whether the subjects learn they should time the interval before or after its presentation) rely on different cognitive processes. Specifically, in a prospective paradigm, participants are informed that they will have to estimate the duration of a target before the target is presented. In a retrospective paradigm, participants become aware of the need to estimate duration only after the target duration has ended. While retrospective judgements mainly engage memory processes, prospective judgements depend on attention allocation policy of the executive system (e.g., Zakay, 1993) and on arousal level (e.g., Zakay, Nitzan, & Glicksohn, 1983). Thus, prospective judgement tasks are particularly well suited to the study of the interaction between attention and arousal in information processing.

Recent studies on the effects of emotional stimuli on prospective time perception in the general population suggest that the duration of emotionally loaded stimuli (e.g., facial expressions, tones of voice) are systematically overestimated relative to neutral stimuli, and that negatively valenced stimuli are perceived to last longer than positive or neutral stimuli (Droit-Volet, Brunot, & Niedenthal, 2004; Noulhiane, Mella, Samson, Ragot, & Pouthas, 2007). For instance, Rinot and Zakay (2000) showed that the duration of aversive tones is overestimated relative to that of neutral tones. However, Angrilli, Cherubini, Pavese, and Manfredini (1997) showed that stimulus arousal level dramatically modulates the effects of stimulus emotional valence on time perception. They systematically manipulated affective valence and stimulus arousal and reported that for low-arousal stimuli, the duration of negative stimuli was judged to be shorter than the duration of positive stimuli, whereas for high-arousal stimuli, the duration of negative stimuli was judged to be longer than the duration of positive stimuli.

These results have been interpreted within the scope of cognitive models of time perception that assign a pivotal role to attention control and arousal mechanisms in time perception, and specifically in prospective timing (Block & Zakay, 1997; Gibbon, Church, & Meck, 1984; Zakay & Block, 1995). The attentional gate model (AGM) is currently the most widely accepted account for the mechanisms underlying prospective timing (Zakay & Block, 1997). This model suggests that prospective timing involves the following component processes (see Figure 1). A pacemaker emits pulses at a rate that is typically constant but may be affected by arousal level: high levels of arousal increase the frequency of pacemaker signals. The flow of pulses reaches an attentional gate. The more attentional resources are allocated to timing,

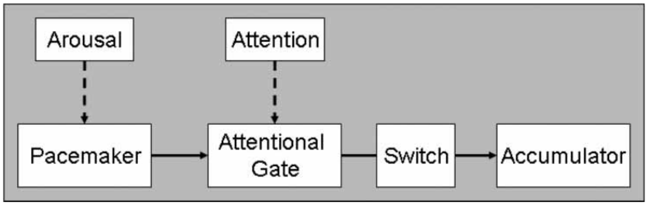

Figure 1. *Schematic of the attentional gate model (AGM).*

the more pulses are allowed by the gate to pass through a switch to an accumulator. The pulses are counted in the accumulator. The subjective count is a representation of the duration of an interval elapsing between the opening and the closing of the switch. During reproduction of a target interval the number of ongoing pulses that are counted in the accumulator is constantly compared with the number of pulse counts stored in reference memory. When a match is obtained, the reproduction is terminated.

Numerous studies employing dual-task paradigms have provided support for the AGM by showing that high arousal and increased attentional resources allocated to timing during a target time interval (both of which, according to the model, should increase the number of pulses accumulated during that interval), are indeed associated with duration overestimation, that is, reproduced intervals that are systematically longer than the target interval (Burle & Casini, 2001; Wearden, O'Rourke, Matchwick, Min, & Maeers, 2009).

The very few studies that have investigated time perception in anxiety have relied on retrospective time judgements (Sarason & Stoops, 1978; Watts & Sharrock, 1984). Only one study has used a prospective time judgement task. Using a temporal bisection task, Tipples (2008) measured the perceived duration of face stimuli displaying fearful, angry, happy, and neutral facial expressions. He found that overestimation of the duration for angry and fearful expressions positively correlated with individual differences in self-reported negative emotionality, which are likely to be also associated with differences in anxiety.

Can the AGM account for such overestimation of the duration of threatening or negative stimuli in anxiety? On the one hand, threatening stimuli are known to increase arousal level, which according to AGM should indeed lead to duration overestimation. On the other hand, however, the study of threat-related attentional biases in anxiety has shown that anxious individuals allocate more attention to threat-related than to neutral stimuli, as reflected by delayed disengagement from threatening information (Derakshan & Eysenck, 2009; Fox, Russo, Bowles, & Dutton, 2001; Yiend & Mathews, 2001). According to the AGM, increased attention allocation to threat should occur at the expense of attention to time and therefore lead to time underestimation, that is, to a pattern of behaviour that is the opposite of that reported by Tipples (2008). Accordingly, Tipples (2008) interpreted his findings as resulting from enhanced arousal rather than from attention-based processes.

However, it is important to consider the time frames involved in each type of study. On the one hand, several studies have indicated that the mechanisms underlying prospective estimations of durations of up to 2–3 seconds are different from the mechanisms underlying longer durations (e.g., Fortin & Couture, 2002; Hancock, Arthur, Chrysler, & Lee, 1994; Poppel, 1988). In particular, judgements of durations exceeding 2–3 seconds are thought to rely primarily on attentional processes, whereas judgements of briefer durations (less than 2 seconds) are thought to be highly affected by arousal level, similar to sensory processes. On the other hand, experiments aimed at investigating threat-related attentional biases typically involve brief exposure durations (e.g., up to 500 ms), because the relevant processes (e.g., preattentive processing, first attentional shift or first eye fixation) unfold early after display onset.

Based on these distinctions, it should be expected that prospective time estimations are differentially modulated by emotional valence in anxious relative to non-anxious individuals as a function of stimulus exposure durations. In the present study, we tested the predictions following from the AGM in a prospective judgement task with anxious and non-anxious participants. On each trial, participants viewed a face displaying either a fearful or neutral expression, for a variable target interval (2, 4 or 8 seconds) and were required to manually reproduce the target interval. For the short target duration, we expected anxious individuals to overestimate the duration of fearful faces to a larger extent than non-anxious individuals, with no differences between anxiety groups for neutral faces. For the long target durations we expected either no group-related differences or a pattern opposite to that expected for the short durations, namely, underestimation of the duration of fearful faces in anxious individuals.

These predictions were based on the following rationale. The attention of anxious individuals is known to be initially summoned by and maintained on even mildly threatening information while the attention of non-anxious individuals is not (see Bar-Haim et al., 2007, for a review). As a result, anxious individuals should display higher levels of arousal than non-anxious individuals in response to threatening stimuli. At short durations, time perception is thought to be influenced mainly by arousal level. Accordingly, anxious individuals should overestimate the duration of threat stimuli to a larger extent than non-anxious individuals due to increased arousal. However, the anxiety-related attentional bias to threat should not lead to underestimation of the duration of threat stimuli because at short intervals, attention is held to play little or no role in time perception.

At longer time intervals, arousal levels most probably return to baseline and thus time estimation of longer durations may depend more heavily on attention mechanisms. In addition, the studies that have investigated the difficulty encountered by anxious individuals in disengaging their attention from threat have typically not included time frames exceeding 2 seconds. Thus, it is not clear for how long attention remains captured by threat in anxious individuals. Accordingly, we may expect either no anxiety-related difference in duration judgements exceeding 2 seconds if attention is effectively disengaged from threat by then. Alternatively, if anxious individuals' attention remains locked on threat over longer time intervals, anxious individuals should underestimate the duration of threat stimuli relative to non-anxious individuals.

METHOD

Participants

Participants were 58 undergraduate students selected out of a pool of 278 into high- and low-trait anxiety groups based on their scores on Spielberger's State-Trait Anxiety Inventory trait scale (STAI-T; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The anxious group consisted of 29 participants (24 female, mean age = 22.24 years, $SD = 4.51$, mean STAI-T = 57.42, $SD = 6.36$). The non-anxious group consisted of 29 participants (21 female, mean age = 22.59 years, $SD = 2.08$, mean STAI-T = 26.63, $SD = 2.64$). The two groups differed significantly on trait anxiety scores, $t(56) = 24.08$, $p < .0001$, and did not differ on age and gender distribution, $p\text{s} > .50$.

Time reproduction task

Stimuli. The fixation display consisted of a white cross (New Courier font, size 18) in the centre of the screen. The stimuli of the time reproduction task were chromatic photographs of faces of 8 actors (4 females) who displayed either a fearful or a calm expression (all with mouth closed). Therefore, there were 16 different face stimuli. Stimuli were taken from the NimStim faces data set (Tottenham et al., 2009). Each photograph subtended 8×12 cm and appeared in the centre of the screen.

Procedure. Subjects were seated in a dimly lit room at a distance of 60 cm from the centre of a 19″ CRT monitor. Stimulus presentation was controlled using EPrime software. Each trial began with the presentation of the fixation display for 800 ms. It was immediately followed by the face stimulus, which was presented for a variable duration, 2 s, 4 s, or 8 s. A question mark then appeared in the centre of the screen cuing the participants to reproduce the duration of the face stimulus, by pressing the space bar twice: once to signal the beginning of the reproduction interval and once to signal its end.

Conditions of face valence and time intervals were equally probable and randomly mixed in presentation. The experiment began with a practice phase of 5 trials displaying 5 calm faces not used in the experimental phase. The experimental phase consisted of 144 trials divided into 3 blocks of 48 trials each. Participants were allowed a short rest after each block.

Participants were instructed to attend to the faces and to attempt to remember them for a subsequent recognition test. They were also told that they would be asked to reproduce the duration for which each face was displayed, and were explicitly instructed to refrain from counting during the time reproduction task. Participants were told that the time reproduction task and the face memorisation task should be assigned equal priority. There was no recognition test at the end of the experiment: upon debriefing, participants were informed that announcement of the face memorisation task was aimed at ensuring that they divided their attention between time and stimulus encoding.

Time estimation outcome—the duration estimation ratio. The dependent variables used in analyses were duration estimation ratios. That is, the mean durations reproduced by a participant in a certain condition divided by the actual stimulus duration in that same condition. Thus, a ratio of 1 indicated perfectly calibrated duration estimation; a ratio superior to one corresponded to duration overestimation, and a ratio inferior to 1 corresponded to duration underestimation. We used the duration estimation ratio rather than the raw data because it affords a meaningful comparison between duration conditions (2 s, 4 s, 8 s) not attainable with the raw scores (Block & Zakay, 1997).

RESULTS

Mean duration estimation ratios and standard error are presented in Table 1. For each subject, ratios were sorted by time interval and emotion. A trial that exceeded its cell's mean by more than 2.5 standard deviations was excluded from the analyses (less that 1% of all trials).

An Analysis of Variance (ANOVA) with Group (anxious, non-anxious) as a between-subjects factor, and Duration (2, 4, 8 seconds) and Emotion (fearful, calm) as within-subject factors was conducted on the mean duration estimation ratios. The main effect of Duration was highly significant, $F(2, 112) = 115.15$, $p <$ .0002. Follow-up comparisons showed that duration estimation ratios were significantly higher in the 2-s relative to the 4-s stimulus duration, 1.36 vs. 1.09, $F(1, 56) = 95.87$, $p < .0001$, and in the 4-s relative to the 8-s stimulus duration, 1.09 vs. 0.89, $F(1, 56) = 128.82$, $p < .0001$. *T*-tests against 1 (the unbiased duration estimation ratio) showed that in the 2-s and 4-s conditions, participants significantly overestimated stimulus duration, $ts(56) = 7.19$ and 2.79, $ps < .0001$ and .007, respectively, whereas in the 8-s condition they underestimated it, $t(56) = -4.80$, $p < .0001$.

The main effect of Emotion was also significant, $F(1, 56) = 4.73$, $p < .04$, and was qualified by a 3-way interaction of Group × Emotion × Duration, $F(2, 112) = 7.20$, $p < .002$, suggesting that anxious and non-anxious participants differed in their pattern of time reproduction to the fearful and calm faces in the different stimulus duration conditions. No other effect approached significance, all $ps > .18$.

To explicate the three-way interaction, separate follow-up ANOVAs with Group and Emotion as factors were conducted for each of the durations (2 s, 4 s, and 8 s). For the 2-s duration, the interaction between Emotion and Group was significant, $F(1, 56) = 7.90$, $p < .007$. Follow-up paired comparisons within each group indicated that, as expected, anxious participants judged 2-s intervals to be longer when the face displayed a fearful expression than when it displayed a calm expression, $t(28) = 2.52$, $p < .02$. Non-anxious participants displayed a non-significant trend in the opposite direction, $t(27) = 1.28$, $p > .20$ (Figure 2). For the 4-s duration, the main effect of Emotion was significant, $F(1, 56) = 4.04$, $p < .05$, with slightly larger overestimations of the exposure durations of fearful faces relative to calm faces, 1.10 vs. 1.09, respectively. All other effects were non-significant, $Fs < 1$. No significant effects were observed for the 8-s condition, all $ps > .14$.

Table 1. *Mean time estimation ratios (estimated time divided by actual exposure time) and standard deviations for the anxious (n = 29) and non-anxious (n = 28) groups as a function of stimulus exposure duration and stimulus emotional valence*

Duration	*Group*	*Emotion*	*Mean ratio*	*SD*
2000 ms	Anxious	Calm	1.36	0.33
		Fear	1.42	0.37
	Non-anxious	Calm	1.35	0.46
		Fear	1.32	0.74
4000 ms	Anxious	Calm	1.10	0.20
		Fear	1.12	0.23
	Non-anxious	Calm	1.07	0.27
		Fear	1.09	0.27
8000 ms	Anxious	Calm	0.89	0.14
		Fear	0.89	0.14
	Non-anxious	Calm	0.88	0.20
		Fear	0.90	0.22

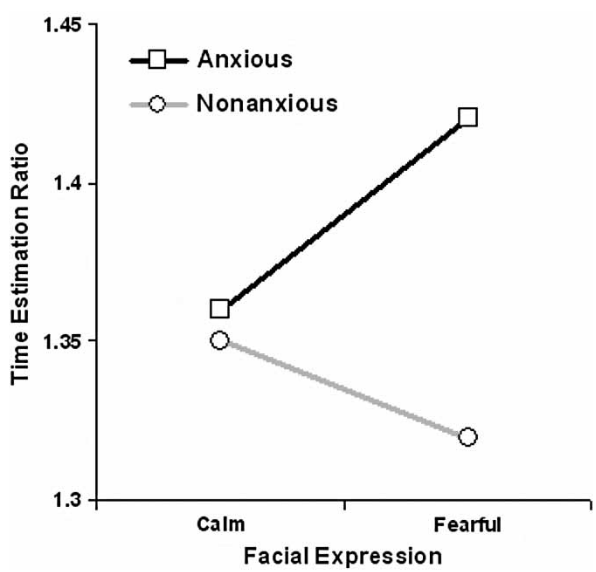

Figure 2. *Group × Stimulus Valence interaction effect at 2-second stimulus exposure durations.*

DISCUSSION

The main finding from the present study is that the modulation of subjective time perception by stimulus valence in anxious relative to non-anxious individuals is strongly dependent on the duration of the stimulus. With short exposure durations (2 seconds), anxious individuals perceived threat stimuli to last longer than neutral stimuli, whereas non-anxious individuals did not. There were no anxiety-related differences in time perception with stimulus exposures exceeding 2 seconds (i.e., 4- and 8-second durations). We interpret these findings as reflecting enhanced arousal in anxious individuals in response to mild threat stimuli at early stages of stimulus evaluation. With extended exposure to the threat stimulus, anxious individuals appear to become habituated to the stimulus and/or to succeed in regulating their heightened arousal. These findings are consistent with the predictions from the attentional gate model (Zakay & Block, 1997), according to which increased arousal leads to time overestimation, and with previous studies showing that changes in arousal elicited by external stimuli are typically short lived.

It is of interest to note that we did not observe underestimation of the duration of threat relative to neutral stimuli in any of the tested stimulus durations. According to the AGM, increased attention to threat stimuli should be associated with underestimation of the duration of these stimuli. Based on the fact that attention is known to affect time perception only with durations that exceed 2 to 3 seconds, the absence of duration underestimation of threat stimuli in our anxious participants suggests that the threat-related attentional bias that is associated with anxiety may occur at early stages of processing and that anxious individuals may be able to disengage their attention from the threat stimulus within a few seconds. This conclusion is consistent with the observation that anxiety-related attentional bias is typically observed with short exposure durations (subliminal exposure and 500 ms exposure) but not with longer (> 1000 ms) exposures (Bar-Haim et al., 2007).

With the intermediate exposure duration (4 seconds), participants overestimated the duration of threat faces more than the duration of neutral faces, regardless of their anxiety level. This finding is unlikely to reflect increased arousal in response to the fearful face. Indeed, such a response did not occur in non-anxious individuals with short exposure times (2 seconds) and there is no principled reason to assume delayed arousal in these individuals: arousal effects are typically immediately triggered by the arousing event. A more plausible account for the emotion-based finding in the 4-second exposure duration may be related to avoidance of the threat stimulus. In non-anxious individuals, findings pointing to attentional avoidance from threat-related stimuli have been reported (Wilson & MacLeod, 2003). In anxious individuals, a pattern of hypervigilance–avoidance relative to threat stimuli has been documented in an eye-movement study with spider phobics (Pflugshaupt et al., 2004). This study showed that during visual exploration spider phobics detected spider stimuli faster, fixated closer to them during initial search but fixated further from them subsequently. Such avoidance measured by eye movements became evident only after 1700 ms of stimulus exposure.

Our data also revealed a main effect of exposure duration such that the shorter exposures (2 and 4 seconds) were overestimated, whereas the long exposure duration (8 seconds) was underestimated. This pattern is consistent with the extant time estimation literature (Block & Zakay, 1997).

To further validate our conclusions, it will be useful to use trial-by-trial psychophysiological measures of arousal (e.g., galvanic skin response, heart period, and heart period variability) in future research. Such measures would provide a direct assessment of the enhanced arousal early in processing, in response to threat stimuli in anxious relative to non-anxious individuals, that was inferred from the present study based on the attentional gate model. More minimally, participants could rate the faces on arousal value, which then could be related to the time perception data. In addition, future research may wish to directly test the association between attention biases, anxiety, and time estimation by adding a classic attention bias measure to the research protocol. Finally, an additional caveat of the present study has to do with the lack of external index of participants' attention to the face stimuli. Such an index could be an actual memory test at the end of procedures or eye tracking during task performance. Without such an index, it may not be possible to be absolutely sure that participants are in fact attending to the faces, particularly at the longer exposure durations.

In conclusion, this preliminary study provides evidence suggesting that relative to non-anxious individuals, anxious individuals subjectively experience time as moving more slowly when processing mild threats. Practically, this suggests that anxious individuals' daily experience of threat could exceed that of non-anxious individuals by a significant amount of subjective time. Coupled with the enhanced attentional bias toward threat and diminished attentional control under stress typically observed in anxious individuals (Bar-Haim et al., 2007; Derakshan & Eysenck, 2009; Eysenck et al., 2007), the finding that anxious individuals subjectively experience time as moving more slowly when processing mild threats provides a novel insight into low-level cognitive processes that shape and maintain the subjective experience of anxiety.

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