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Don't Fear the Reaper? The Effects of Stress on Visual Attention and Threat-Processing

Does induced stress cause attentional bias towards negative words?

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Abstract

In the current study, the aim was to investigate whether attentional bias—an automatic and nonconscious pre-attentive process of filtering sensory information for emotional relevance—could be induced in normal students, by manipulating levels of stress. In a within-subject experimental design where each participant completed 3 word search puzzles, it was predicted that the ratio at which participants found negative words to neutral words would positively correlate with the level of induced stress, ranging from low-medium-high. A one-way repeated measures ANOVA revealed no significant results. This may be due to faulty experimental design, as commentaries made by participants revealed that many of them experienced the situation as stressful, and that negative words did seem to "pop out" or "be everywhere." This may suggest that attentional bias was indeed induced, even though instruments used were not able to adequately measure it. Results are discussed, and improvements for studies using word search puzzles to study attention are suggested.

***Keywords**:* stress, threat detection, vigilance, attention, bias

FEAR IS THE MOST ELEGANT WEAPON, YOUR HANDS ARE NEVER MESSY. THREATENING BODILY HARM IS CRUDE. WORK INSTEAD ON MINDS AND BELIEFS, PLAY INSECURITIES LIKE A PIANO. BE CREATIVE IN APPROACH. FORCE ANXIETY TO EXCRUCIATING LEVELS OR GENTLY UNDERMINE THE PUBLIC CONFIDENCE. PANIC DRIVES HUMAN HERDS OVER CLIFFS; AN ALTERNATIVE IS TERROR-INDUCED IMMOBILIZATION. FEAR FEEDS ON FEAR. PUT THIS EFFICIENT PROCESS IN MOTION. MANIPULATION IS NOT LIMITED TO PEOPLE. ECONOMIC, SOCIAL AND DEMOCRATIC INSTITUTIONS CAN BE SHAKEN. IT WILL BE DEMONSTRATED THAT NOTHING IS SAFE, SACRED OR SANE. THERE IS NO RESPITE FROM HORROR. ABSOLUTES ARE QUICKSILVER. RESULTS ARE SPECTACULAR.

To Lauren.

Artwork by J. Holzer, [no title] “Inflammatory essays”, 1979-82

Contents

1. Introduction

That “nothing in biology makes sense, except in the light of evolution” is an often repeated quotation by Theodosius Dobzhansky (1973). In science today, the concepts of evolution (Darwin, 1859) and adaptability (e.g. Barkow, Tooby & Cosmides, 1995) are everywhere, and the theory of evolution by means of natural selection is by many considered one of mankind’s greatest intellectual achievements (Flood, 2015). It is generally accepted as constituting a solid framework for generating hypotheses in both life sciences, and social sciences; in fields ranging from biology and psychology, to economics and computer science, thinkers are influenced and inspired by predator-prey dynamics and intraspecies competition. While the logic and central premises behind the theory of evolution are beyond doubt, its validity empirically proven, and its implications far-reaching, hypotheses regarding the distal origins of human nature cannot be tested, and thus not proved.

Though the concept of evolved mental adaptations—the idea that complex human traits and behaviors may have a strong genetic basis—is controversial (see Buller & Hardcastle, 2000), the requirements for sustaining life—and, thus, fundamental to the evolution of any trait—are generally not contested. For example, LeDoux (2015) lists acquiring nutrients and energy sources, balancing fluids, and thermoregulation as capabilities indispensable to all organisms. Mentioned capabilities are regulated by largely autonomic and nonconscious processes, and mainly relate to maintenance of internal homeostasis. However, a fourth capability exclusively regards the external: namely, detecting and responding to threat in the environment. Taken together, they are considered deep survival mechanisms, and are present in all living organisms (LeDoux, 2015).

The evolutionary advantages of value representation (i.e. evaluating whether something is good or bad) and responding appropriately are hard to overstate. While survival strategies come in endless forms—from behavioral reactions such as fight-flight-freeze; permanent body characteristics such as armor or size; to camouflage; or grouping together—all studied vertebrate species rely on highly similar neural circuits, which are evolved specifically to respond adaptively to threats (Moreno & González, 2007; Whalen, 1998a).

In particular, the amygdala has been singled out at the core of this defensive survival circuit, in part due to its functional connectivity with large parts of the brain. Among many things, the amygdala and related structures are involved in modulating the autonomous nervous system (see chapter 2.1); in triggering dynamic shifts in network balance, and in enhancing sensory processing by up-regulating cortical arousal (see chapter 2.2); and, ultimately, in influencing behavior and moment-to-moment vigilance (see chapter 2.3) (LeDoux, 2015; LeDoux & Phelps, 2008; Whalen, 1998a).

In short, they are able to directly or indirectly influence everything from higher-order cognitive functions to perception, emotions, and physiology (Okon-Singer, Hendler, Pessoa & Shackman, 2015). Furthermore, it has been shown that information processing by the amygdala is highly automatized, and that its output precedes conscious awareness. This is to ensure that threat stimuli are detected independent of current direction of attention (Öhman, 2008). Empirical support for the automaticity of the defensive survival circuits comes from brain imaging studies (e.g. Whalen et al., 1998b), and studies measuring behavioral responses following subliminal exposure to threatening stimuli (e.g. Murphy & Zajonc, 1993).

Based on evolutionary theory, it has been hypothesized that our attentional and perceptual systems are biased toward detection of threat, as false negatives (i.e. failing to call wolf when one is present) are more costly than false positives (Öhman, 2008). Regarding mentioned negativity bias, Hibbing, Smith & Alford (2014) argue that it reflects "the fact that humans generally tend to respond more strongly, to be more attentive, and to give more weight to negative elements in their environment" (p. 303). Attentional bias and hypervigilance were quickly implicated in a range of mental disorders including anxiety and depression (MacLeod, Mathews & Tata, 1986), but studies increasingly show that it is a general response to threat (Pratto, John & Tesser, 1991) and can be induced in normal, non-anxious subjects (Green, Rogers & Eliman, 1995; Mogg, Mathews & Macgregor-Morris, 1990).

Notebaert, Crombez, Van Damme, De Houwer and Theeuwes (2011) have highlighted the need for methodological improvement in the study of visual attention and threat detection, and argue that an ideal instrument should feature perceptually similar stimuli; present several competing stimuli at once; but without making attention to threatening stimuli an inherent goal objective. The word search puzzle paradigm fits all these criteria, and is thus a candidate worthy of evaluation.

The present study aimed to further test the hypothesis that stress causes attentional bias towards negative stimuli, and to test the validity of the word search puzzle paradigm as an instrument to measure it. In a within-subject experimental design, participants were asked to complete 3 word search puzzles, within which equal numbers of negative and neutral words were hidden. Levels of stress-induced arousal were manipulated by instructions suggesting the amount of time subjects had available, and by subliminally exposing participants to pictures of fearful facial expressions. It was predicted that the level of stress would positively correlate with numbers of negative words found.

In the following chapters, I will go into detail about human biology and cognition, starting with stress physiology; followed by the effects of stress on the brain; and cognitive-emotional responses to stress, with a focus on vigilance and attentional bias.

2. Theoretical background

2.1 The Physiology of Stress

Within the field of psychology, agreement on a general definition of stress is hard to find. Depending on which definition you choose, stress is either "out there", e.g. a hungry lion (Dickerson & Kemeny, 2004) or within ourselves and dependent on appraisal – what is stressing to some, might be perceived as a challenge by others (Harvey, Nathens, Bandiera & LeBlanc, 2010). It can also be in reference to the generally consistent and more easily detectable physiological responses during, and following, a stressful event (Kemeny, 2003; McEwen & Sapolsky, 1995). In medicine, focus is typically on the response to stress; physiology and stress reactions are measured without worry about causality. Next, I will describe the two major systems contributing to our generally adaptive physiological responses – upon detection of a potential threat, and in the face of apparent danger.

Once a potentially threatening object has been detected, and the defensive survival circuit triggered, the next thing to happen (*within seconds*) is the activation of the sympatho-adrenomedullary pathway. By way of the hypothalamus, the medulla of the adrenal gland is stimulated, and the hormone adrenaline is secreted. Adrenaline, in turn, causes arousal of the sympathetic part of the autonomous nervous system, and secretion of noradrenaline (Kemeny, 2003). Among other things, this causes increased blood pressure and heart rate, increased blood flow to skeletal muscles and to the brain, and perspiration. In short, it is preparing our body for a "fight-or-flight" situation (Ljung & Friberg, 2004).

Simultaneously, a slower system (*within minutes*), consisting of the hypothalamus, the pituitary gland, and the cortex of the adrenal glands, and referred to as the "HPA-axis", is activated, and the hormone cortisol is secreted into the bloodstream. The effects of cortisol are mainly related to energy mobilization, as it causes the liver to release glucose into the bloodstream. Though activation of the HPA-axis is a comparatively slow process, glucose levels are typically elevated for hours following a stressful situation. In combination, activation of the two systems causes major physiological changes; the body is preparing for immediate action, while digestion and long-term maintenance are down-prioritized (Kemeny, 2003). In addition to their effects on the peripheral nervous system, cortisol and noradrenaline bind to receptors in the brain. Here, their effects are related to neural communication and functional adaptation in network dynamics (Hermans, Henckens, Joëls & Fernández, 2014).

The physiological responses to a stressful situation are detected and monitored by a sense called interoception, and translated into neural signals. These signals are continuously interpreted by the brain, and provide information about the state of the body (Craig, 2008). In response to environmental stressors, maintenance of internal homeostasis is thus achieved by means of various feedback and feedforward loops (Sapolsky, 1998).

2.2 Stress and the Brain

Regardless of how stress is defined, it is both initiated and regulated by the brain. Whether caused by cognitive appraisal (Lazarus, 1982), or by primitive information processing bypassing conscious awareness (LeDoux, 1998), excitation of the amygdala in response to a stressful situation radically changes the dynamics of neural communication patterns (Hermans et al., 2014). Thanks to its connectivity within the brain, the amygdala can initiate defensive reactions and learned behaviors in response to threat, and influence everything from basic physiology to emotional-cognitive functions such as perception and attention (LeDoux, 2015; Okon-Singer et al., 2015).

The amygdala is extensively and reciprocally connected with the sensory cortex of each modality as well as with the thalamus, and continually receives sensory information from the environment. Automatically, and preceding conscious awareness, the information is processed and objects are evaluated largely based on valence (i.e. a simple form of value-representation) (Pessoa, 2010; Whalen, 1998a). The amygdala mainly responds to novel, ambiguous, and emotional stimuli, but what counts as emotional is largely species-dependent (Öhman & Mineka, 2001). In humans and non-human primates, conspecific faces are especially potent triggers due to their informative value in nonverbal communication, and in determining friend from foe (Whalen et al., 2013). The fact that fearful faces trigger the amygdala to a higher degree than angry faces has been interpreted as directly related to their inherent ambiguity. In the case of an angry face, the source of the threat is obvious, while in the case of a fearful face, the threat is unknown and more information necessary (Whalen, 1998a).

Detection of a potential threat causes, among other things, stimulation of nuclei in the brain stem regulating arousal. Subsequent release of neuromodulators, such as dopamine, serotonin, noradrenaline and acetylcholine, increases neural excitability and lowers the threshold for further sensory processing. Additionally, cortical arousal changes the dynamics of executive control and attentional networks, leading to vigilance and further scanning of the environment, as well as biasing pre-attentive filter processes to prioritize detection of threats (Hermans et al., 2014).

The amygdala has long been known as a key structure of the defensive survival circuit (LeDoux, 1997; 2015). However, recent advances indicate that attempts to understand the brain by mapping function to structure can at best provide half the story (Honey et al., 2008). Increasingly, emergent properties of neural networks involving multiple parts of the brain are studied using tools such as functional connectivity magnetic resonance imaging (fcMRI). For example, Hermans and colleagues (2014) claim that acute stress leads to observable changes in neural connectivity, and suggest that stress-related hormones and neurotransmitters released as part of the stress response modulate these changes. More specifically, neuroendocrine changes in response to stress are associated with down-regulation of the executive control network, and up-regulation of the salience network. The salience network involves regions associated with autonomic control, interoception, arousal, and attention; as such, it is understood as being involved in the integration of survival-related functions, and in promoting fear and vigilance.

In summary, the brain reacts to threat by releasing stress hormones and catecholamine neuromodulators. These, in turn, arouse the central nervous system, causing shifts in network balance, and a state of vigilance. In addition to behavioral changes, activation of the salience network is associated with a reallocation of neural resources from endogenous attentional processes to exogenous attentional processes, making emotional or threatening stimuli more perceptually salient.

2.3 Vigilance and Attentional Bias

"Everyone knows what attention is," according to American psychologist William James (1890). "It is taking possession of the mind, in clear and vivid form, of one out of what seems several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence" (p. 404). While James' definition of attention seems to satisfy everyday usage of the term, it has since become clear that attentional processes are complex. According to Egeth and Yantis (1997), the focus of attention is determined by competing exogenous and endogenous mechanisms.

Exogenous mechanisms primarily direct attention to objects based on physical properties, such as color or contrast, and are frequently referred to as "bottom-up" or "stimulus-driven". Endogenous mechanisms, on the other hand, direct attention to objects of subjective importance (i.e. based on internal goals, mood, and motivation) and are referred to as “top-down” or “goal-directed”. To give an example, for a cat, reacting fearfully to an ambushing cucumber would be the case of responding instinctively—bottom-up—to the physical properties of the stimulus. The fact that the cucumber is harmless is lost due to its resemblance to a snake—which is a naturally conditioned threat stimulus—and elicits an automatic behavioral reaction (LeDoux, 2015). If you instead present the cucumber slowly and in a predictable manner, the same situation will activate endogenous mechanisms. They recruit higher-order cognitive systems and integrate contextual information—such as knowledge about cucumbers—to change its meaning, and inhibit nonconscious reactions to threat. As previously mentioned, activation of the salience network in response to stress reallocates neural resources from endogenous mechanisms to exogenous mechanisms and, not surprisingly, the amygdala has been implicated in facilitating this shift. In addition to shifting the balance of the attentional mechanisms in favor of rapid, but coarse, sensory processing, stress also leads to vigilance and attentional bias towards negative or threatening stimuli in the environment (Hermans et al., 2014).

Pratto, John and Tesser (1991) introduced the concept “automatic vigilance”, describing it as a quick and effortless mechanism for the pre-attentive selection of threat-related information. In addition to nonconscious evaluation of naturally occurring stimuli, they claim that accurate evaluative judgment of nonconsciously processed semantic content is also possible. This indicates that higher cognitive functions that have become automatic (e.g. reading) can recruit structures involved in value representation (e.g. the amygdala), without accessing knowledge of the actual semantic meaning of the word. Thus, words with negative connotation can be processed and evaluated as threatening even following subliminal exposure.

Similarly, Murphy and Zajonc (1993) claim that affective reactions can occur with minimal stimulation (e.g. subliminally) and that they can influence or alter subsequent evaluation of other objects. In fact, they argue that emotional or threatening stimuli that are processed outside of conscious awareness are particularly effective at this, as they create a state of free-floating anxiety, with potential for nonconscious affect to “spill over” to unrelated stimuli. Observed selective-processing effects have persisted for minutes to hours following stress exposure (Gilboa-Schechtman, Revelle & Gotlib, 2000; Sweeny, Grabowecky, Suzuki & Paller, 2009) and possibly reflect the effects of long-lasting connectivity changes involving the default mode network and hubs of the salience network in the aftermath of a stressful event (Clemens et al., 2017).

In summary, the brain responds to stressful situations by releasing hormones such as adrenaline and cortisol in the bloodstream. These hormones contribute to energy mobilization and prepare the body to fight or flee. Additionally, they bind to receptors in the brain, influencing emotion and cognition, as well as leading to heightened alertness and vigilance. Once aroused, attentional processes shift from endogenous to exogenous mechanisms, and perceptual and sensory processes become particularly tuned to detecting threat in the environment.

The current study aimed to induce attentional bias by experimentally manipulating stress-levels, and to test whether similar dynamics apply to abstract concepts such as words, as to naturally threatening objects. This was tested using word search puzzles prepared to contain equal numbers of negative and neutral words. In total, participants completed three puzzles under three different conditions. The ratio of negative to neutral words was then calculated and compared within-subjects to investigate if there was a stress-dependent effect.

3. Method

3.1 Participants

In total, 14 persons participated, where 9 were female and 5 were male. Participants were recruited at the department of social sciences at Lund University, and all of them were students at the university. All participants were between 20 and 27 years old, with a mean age of 24.9 years, and with Swedish as their primary language. Participants each completed all sets of the experiment; however, data from 5 participants were discarded due to a misunderstanding regarding which combinations of letters would count as words.

3.2 Experimental design

In the experiment, there were a total of three trials (see Figure 1), and each trial consisted of looking at a computer screen displaying a sequence of faces for 30 seconds, and then encircling the first 10 words found within the word search puzzle. Within each puzzle, an equal number of negative and neutral words, matched for length and frequency of use, were hidden. All words were between 4 and 8 letters long, and participants were instructed to ignore any words shorter than that.

Trial (A) was designed to be relatively free of stress, while the others (B and C) represented two levels of stress-induction. In (A), participants were instructed to take their time to complete the task, while in both (B) and (C), they were asked to complete the task as quickly as they could, and with a timer ticking in the background. Additionally, (C) involved subliminal exposure to pictures of fearful facial expressions (masked by pictures of neutral facial expressions), whereas the same procedure in (A) and (B) only involved neutral facial expressions.

The procedure of inducing stress by subliminally exposing participants to pictures of fearful facial expressions consisted of flashing fearful faces for 33ms, masked by a neutral face of the same person for 177ms. This sequence repeated itself randomly, including a total of 15 faces, and for a duration of 30 seconds.

Once the subliminal exposure procedure was over, participants searched for words hidden with a word search puzzle until 10 were found. All participants were allowed to search until they found all 10 words, also in time pressure conditions.

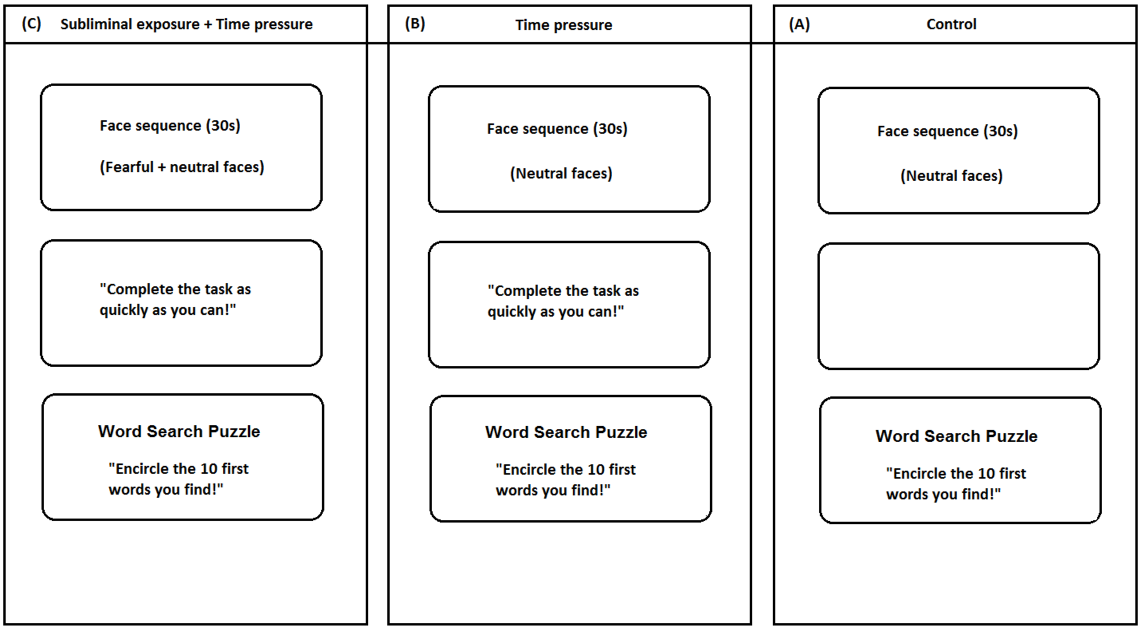

Figure 1. Three experimental trials (C, B, A)

3.3 Procedure

The experiment was conducted on one computer at the Psychology Department of Lund University, in a quiet room with little disturbance. Before the experiment started, participants were informed that the experiment included some aspect of stress, and were asked whether they still wished to participate. They were told that the experiment aimed to measure the relationships between time pressure, tunnel vision, and the ability to divide attention. They were then instructed to encircle the first 10 words, consisting of 4 letters or more, that they could find. Once informed about the nature of the task, all participants signed an informed consent and were then assigned to do each trial in random order.

Next followed a procedure consisting of passively watching a sequence of faces randomly flashing on a computer screen for 30 seconds, where in one trial (C) pictures of fearful facial expressions were flashed subliminally and masked with a neutral version of the same face (see Figure 2). In the other two trials (B) and (A), only neutral faces were shown.

Depending on which trial participants were doing, an additional instruction to do the task as quickly as possible was given once the face sequence had ended. A ticking timer was then placed next to the participant with the aim to induce a stronger stress response.

Participants completed the whole experiment in 10-15 minutes. Each trial was on average 3-5 minutes long, and the next trial followed the previous without breaks.

After each trial had been completed, participants were debriefed about the purpose of the study, and their questions were answered. Using open-ended questions, they were also asked to briefly describe their experiences during the experiment. It was revealed that many participants experienced the situation as stressful and many made comments about the negative words.

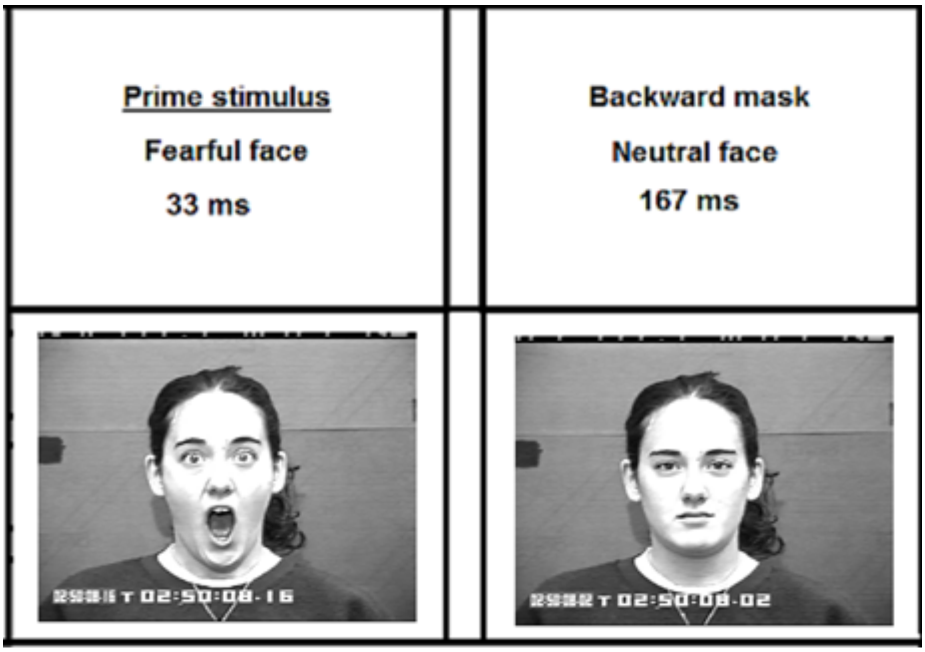

Figure 2. Subliminal exposure to fear

3.4 Material

A total of 48 different words were used to create the word search puzzles. 24 Swedish words with negative emotional connotations were taken from Blomberg and Öberg (2015) and from Blomberg (2016), and an equal number of neutral Swedish words, matched for word length and frequency of use (Larsen, Mercer & Balota, 2006), were taken from the Stockholm-Umeå corpus (Ejerhed, Källgren, Wennstedt & Åström, 1992).

In total, 30 unique word search puzzles were created; each belonging to one of three sets, and each containing 16 word pairs. For example, the words "björk" and "skräck" were a pair in one set, and both would appear somewhere within the puzzles belonging to that set. Thus, within each set, the same matched pair of words would appear, but in different types of constellations. For the full list of word pairs used, see Appendix.

The word search puzzles were generated using http://tools.atozteacherstuff.com/word-search-maker/wordsearch.php (2017-04-10), 13x13 letters, with words hidden horizontally and vertically, and with some overlap (see Figure 3).

The material used for the subliminal exposure was acquired from "The Extended Cohn-Kanade Dataset (CK+): A complete dataset for action unit" (Lucey et al., 2010). A total of 30 pictures of facial expressions were used, with half depicting a neutral facial expression and half depicting a fearful facial expression of the same person.

The software used to program the subliminal exposure procedure is called PsychoPy (Peirce, 2007), and the procedure consisted of randomly alternating pictures of neutral and fearful facial expressions for a total of 30 seconds. Fearful expressions were shown for 33ms and then masked by a neutral face, which was shown for 177ms.

In trials (A) and (B), a loop was programmed to randomly shuffle pictures of neutral facial expressions. Faces were shown for 177ms, and the procedure also lasted 30 seconds.

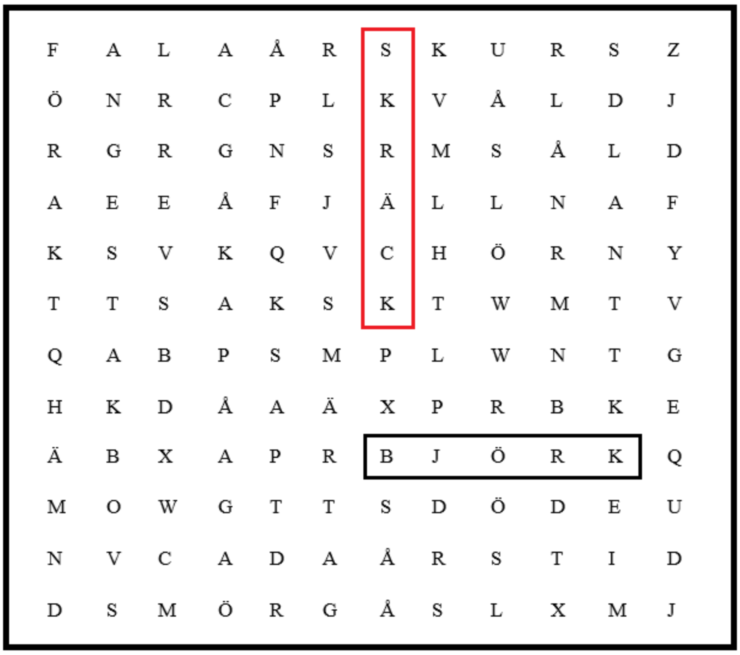

Figure 3. Example of a matched pair within a word search puzzle

4. Results

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean negative-to-neutral word ratios dependent on stress level did not differ statistically significantly between trials ($F(1.248, 9.981) = .397$, $p < .588$). Interestingly, results suggest that an effect may indeed exist, as ratios in (A), (B) and (C) predictably increased. However, standard deviations also increased, which could possibly explain this trend (see Table 1).

For further analysis, see Discussion.

	Mean	Std. Deviation	N
StressA	,74000	,279687	9
StressB	,84556	,431744	9
StressC	,96333	,672756	9

Table 1. Descriptive statistics

5. Discussion

In this study, the aim was to test the hypothesis that psychological stress leads to reallocation of attentional resources, and that stimuli of emotional negative valence—and, thus, potentially threatening—are prioritized by automatic, nonconscious and pre-attentive filter mechanisms. In an experiment consisting of three trials, word search puzzles were used as instruments to measure attentional bias towards negative words. In each trial, stress was manipulated as the independent variable, and it was predicted that the ratio at which participants found negative to neutral words would positively correlate with the level of induced stress.

Analysis of the data revealed no statistically significant results; however, this is likely explained by a small number of participants (N=9) and, potentially, by a small effect size. The mean ratio of negative to neutral words did increase in each trial, which may suggest that there indeed is an effect which further testing could reveal. Standard deviations also increased in each trial, which suggests individual differences in general threat-processing, and in sensitivity to stress. Provided that any trend may be purely down to chance, further speculation about the results seems unjustified.

Evolutionary theory suggests that detection of threat should be a preconscious capability shared by all living organisms. This seems to be the case, as threat detection and subsequent avoidance of harmful objects or substances have been observed in species ranging from bacterial cells to higher mammals (LeDoux, 2015). In vertebrates, a subcortical neural circuit involving the amygdala has been genetically preserved, and it is widely recognized as a defensive survival circuit (Moreno & Gonzalez, 2007). Advances in neuroscience further support the hypothesis that stress leads to functional adaptation within the brain, as upregulation of large-scale neural networks associated with vigilance and enhanced sensory processing is observed in direct response to situations perceived as stressful (Hermans et al., 2014).

Furthermore, responses to threat are suggested to be largely automatized as they are elicited similarly regardless of whether the stressor has been consciously perceived or not (Whalen et al., 1998b). Thus, the emotional meaning of a stimulus—whether it is good or bad—can be appraised before it has been fully processed by perceptual systems (LeDoux, 1998). In several studies, responses are larger to subliminally presented stimuli than to consciously perceived stimuli (e.g. Murphy & Zajonc, 1993; Sweeny et al., 2009); therefore, Murphy and Zajonc suggest that subliminal exposure to negative emotional material can trigger a state of free-floating anxiety, allowing the conscious mind to misattribute the cause of anxiety to unrelated stimuli. This is consistent with the proposal that the amygdala activates particularly strongly to fearful facial expressions, as they are an important indicator of threat, but not of the nature of the threat (Whalen, 1998a). In this study, the purpose of subliminally exposing participants to pictures of fearful facial expressions was to induce an anxious state in response to the stressful situation, with the expectation that free-floating anxiety would affect the rate at which negative words were detected.

Word search puzzles are not widely used to study search behavior; as such, their validity and reliability are not confirmed. However, Notebaert and colleagues (2011) remark that in most studies where visual attention and threat detection have been studied, threat-stimuli are often singular; differ perceptually from neutral stimuli; and are instrumental to performing the task. They suggest that capture of attention is best investigated in experimental paradigms with a varying number of competing stimuli, and argue that an adaptation of the visual search paradigm, in which attention to threatening stimuli is not an inherent goal-objective, would be a methodological improvement and theoretically relevant. The use of word search puzzle potentially constitutes such an adaptation, as words (matched for length and frequency of use) do not differ in perceptual saliency based on stimulus characteristics, but only in their emotional value. Additionally, word search puzzles provide a number of competing stimuli, and detection of threatening words is not instrumental to the task.

While the experimental design seems theoretically valid, several implementation errors and weaknesses were discovered. For example, the use of certain longer words, such as “vrede” (*eng.* wrath) meant that shorter words within those words, such as “rede” (*eng.* nest), were relatively frequently found. Not only are such words-within-words shorter and easier to find, they also tend to be neutral at a much higher rate than emotional. As a ratio of negative to neutral words could only ever reflect attentional bias under conditions of equal probability, data was discarded in cases where participants had encircled task-irrelevant words. This, of course, meant that the statistical analysis was never likely to reveal any statistically significant results but, as noted, counting them would not have helped. Having at least 20 participants with valid sets of data would have been ideal, but due to time pressure that was not possible. Another design flaw and potential confound is that participants after finishing one trial immediately would start the next one. This means that participants who started with the high stress trial (C) could have experienced lingering and elevated stress levels throughout the experiment, thus making it harder to detect differences between trials. A solution to this could be to wait for at least a few minutes between each trial, or to design a between-subjects experiment. Additionally, in communication with participants following the experiment, it became clear that several neutral words, such as “chef” (*eng.* boss) or “hals” (*eng.* neck) were open to interpretation, and their connotations dependent on context. LeDoux (2015) mentions that such interpretation bias has been observed in studies with patients suffering from generalized anxiety disorder; it is not unconceivable that a similar bias is evoked in response to stress in normal participants, which might explain why “neutral” words were found at a higher rate than by chance alone. Further commentaries revealed that some trials were more stressful than others, and several participants specifically mentioned (C) as causing anxiety, despite any awareness of being exposed to fearful faces. Comments about negative words “being everywhere” or “popping out” were also common.

To conclude, using word search puzzles to study visual attention and threat-processing might have some merit, but careful consideration of word choices is necessary. The use of English words rather than Swedish might help to improve a number of weaknesses encountered in this study. In particular, validated words that fit the criteria of being of equal length, share similar emotional value, and frequency of use are widely available; as such, creating puzzles free of design flaws would be considerably easier. Furthermore, potential restrictions should be considered regarding the freedom to encircle any word; one idea would be to program a digital word search puzzle, making unintended, task-irrelevant words impossible to encircle. This would ensure that a reliable, unbiased ratio could be calculated, even if task-irrelevant words had appeared within the puzzle by coincidence. An additional idea would be to collect data using an eye tracker, as search behavior more reliably could be mapped and analyzed. This could enable further investigation of findings suggesting that whereas some people are drawn to threatening or unpleasant stimuli, others will endogenously redirect their attention away from them, and avoid them (e.g. Aue, Hoeppli, Piguet, Sterpenich & Vuilleumier, 2013).

Conclusion

Natural selection is the primary mechanism driving adaptive evolution. Thus, minds and behaviors are commonly analyzed and understood in terms of dynamics relating to survival and reproduction. In particular, the ability to detect threat in the environment has been singled out as crucial to all species. While the current studied failed to support the hypothesis that stress leads to increased vigilance, and facilitates detection of negative or threatening stimuli, the evolutionary logic behind it is impossible to discard. It is very likely that the type of stress induced in a laboratory setting is too weak to elicit the strong reactions associated with a true emergency; as such, vital functions of the human mind seem beyond scientific study at current. Future studies should aim to create more realistic conditions under which behavioral responses are measured. Provided that long-term psychological impact to participant's well-being can be avoided, ethical reconsiderations regarding experimental protocol may be motivated.

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Appendix

List of negative and neutral word-pairs, matched for length and frequency of use

Set 1

Negative	Freq.	**Neutral**	Freq.
Skam	22	Boll	17
Förakt	18	Årstid	18
Ångest	13	Smörgås	13
Våld	46	Hörn	47
Orolig	57	Granne	56
Sorg	51	Bevis	54
Ilska	17	Byxa	23
Mord	40	Hals	40

Set 2

Negative	Freq.	**Neutral**	Freq.
Kris	55	Torg	44
Kaos	18	Grej	20
Krig	131	Chef	121
Skada	140	Insats	121
Hämnd	13	Såld	13
Plåga	25	Fjäll	24
Vapen	87	Vuxen	86
Smärta	50	Årskurs	50

Set 3

Negative	Freq.	**Neutral**	Freq.
Raseri	6	Fakta	6
Vrede	18	Vinka	18
Tortyr	4	Krokig	4
Avsky	23	Tunna	24
Hata	15	Ratt	15
Döda	63	Pjäs	62
Skräck	23	Björk	23
Chock	14	Morot	15

Word Search Puzzles (Example from each set; 30 versions were used)

1a

S	R	E	B	Y	X	A	I	A	Y	Z	E	V
L	N	H	T	V	W	D	S	T	I	D	O	Å
N	F	H	B	I	Z	A	Z	M	L	I	L	L
F	W	P	O	X	Å	N	G	E	S	T	V	D
Ö	C	Y	L	C	Q	S	W	N	K	U	Y	I
R	K	J	L	V	T	H	N	M	A	J	H	V
A	A	J	G	B	D	Z	H	I	A	K	S	Y
K	V	L	C	T	S	O	R	G	H	S	Å	W
T	Z	Q	M	B	G	B	W	P	N	K	R	F
C	M	G	O	E	S	M	Ö	R	G	Å	S	T
N	H	Ö	R	N	X	D	T	Z	X	M	T	T
D	C	H	O	C	K	B	S	B	E	V	I	S
S	F	K	T	S	Q	O	R	O	X	J	D	W

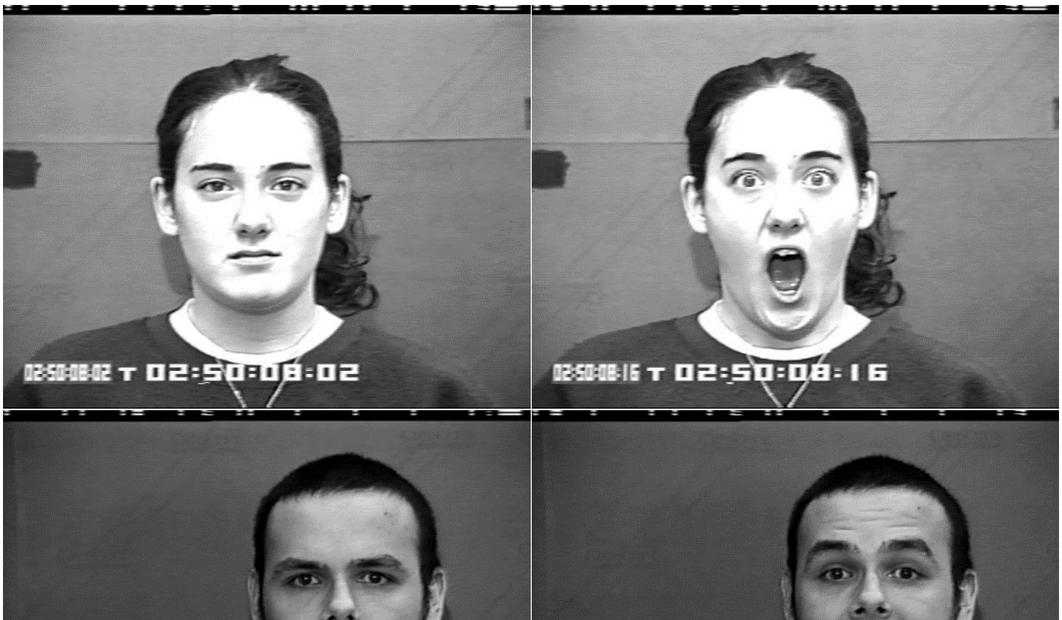
1b

V	Y	O	T	T	K	E	Q	S	C	H	E	F
U	S	N	K	F	K	H	J	R	G	P	X	O
X	S	M	Ä	R	T	Ä	T	K	E	Q	L	G
E	L	K	O	I	N	M	C	X	U	E	B	N
N	T	A	S	N	Q	N	Q	R	L	T	Y	P
W	O	H	W	S	L	D	S	Y	A	F	Z	J
G	R	Å	T	A	F	Z	K	R	I	S	K	A
P	G	R	L	T	F	J	Ä	L	L	N	R	B
S	Y	S	M	S	K	E	D	A	M	G	I	U
E	Z	K	S	Å	L	D	A	E	B	R	G	O
J	C	U	H	V	X	R	V	A	P	E	N	A
Y	X	R	B	L	Q	V	A	T	R	J	E	T
H	S	S	N	J	M	P	L	Å	G	A	F	A

1c

A	V	S	K	Y	J	Q	J	P	P	A	N	J
T	H	A	L	S	E	Y	K	G	Z	Z	I	U
S	K	R	Ä	C	K	T	U	N	N	A	W	F
E	M	U	U	C	E	O	H	F	M	R	R	L
J	O	L	W	K	U	M	F	A	Y	M	D	O
T	R	B	Q	I	K	R	O	K	I	G	E	D
Z	D	J	A	G	X	N	E	T	I	B	O	Ö
U	E	Ö	V	I	N	K	A	A	M	B	N	D
E	V	R	E	D	E	N	P	M	W	A	U	N
G	Å	K	A	T	V	T	O	R	T	Y	R	H
Z	V	Q	C	L	I	Y	E	B	J	P	O	A
U	Q	S	I	K	Y	P	F	H	W	A	T	T
A	O	R	A	S	E	R	I	S	H	L	N	I

Pictures of facial expressions used for the subliminal exposure procedure (Examples, 3/15)




00:02:06:17 T 00:02:06:17
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