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Exploring the effects of threatening stimuli on visual search performance using different experimental designs

Doctoral (PhD) dissertation

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TABLE OF CONTENTS

GENERAL INTRODUCTION

The main topic of the present dissertation is the relationship of cognition and emotions, and the work presented here is about attentional processing of specific threatening cues, and the effects of these stimuli on attentional performance. The topic first came into central interest around the 1940's, 50's with the New Look with regard to perceptual defence (Erdelyi, 1974; Pléh, 2011) which is the process by which stimuli that are emotionally negatively charged are either not perceived or are distorted in perception. Later, this interference, or at least co-dependence, between different cognitive processes and emotions appeared in numerous other theoretical frameworks (see e.g. Czigler, 2014; Czigler, Cox, Gyimesi, & Horváth, 2007; Pataki, 2008).In the past decades, several highly different viewpoints have come to light.

There are three main possibilities according to Strobeck and Clore (Storbeck & Clore, 2007) to describe the relationship of cognitive processes and emotions in general. The first one states that cognitive and emotional processes are independent; the second underscores the role of emotion as a prime factor; while the third one states that emotions are automatic responses to perceived cues, and then, these will guide the different cognitive processes, e.g. attention (see also Pataki, 2002). There is a fourth possibility described by Pessoa (2013), who claims that emotions and cognitive processes interwork or interaction, i.e. act one upon the other. The present dissertation uses the notion claimed by Pessoa, but first it is inevitable to operationalise the main compounds, namely the cognitive process we are going to explore, and how we define emotions.

Thus, the goal of the present dissertation is twofold. First, to show the interaction as Pessoa (2013) described it, using various experimental paradigms (e.g. Study 1, Experiment 1; Study 2, Experiment 1) and different emotions. Hence, Experiment 1 of Study 3 includes other emotions than fear as well. However, this is the only one to do so and the reason behind our decision to focus on negative emotions, and fear in particular, was that even one emotion offers so much possibilities, that without a definite focus, the in-depth analysis using different methodologies would not be a possibility; or at least that would not be within the range of a dissertation. The second goal, and the reason that draw our attention to fear, is the very interesting debate regarding the possible differences of

processing cues with evolutionary and modern origin. The main question is whether these stimuli with different origins are processed differently, or we process them using the same pathway. That is evolutionary relevant threats are processed automatically (Gao, LoBue, Irving, & Harvey, 2017; Isbister & White, 2004; see Öhman & Mineka, 2003 for review) as this was crucial in the survival of human species, while the processing of modern threats might be faster than neutral cues but not automatic. In contrast, others (Fox, Griggs, & Mouchlianitis, 2007; Sander, Grafman, & Zalla, 2003; Sander, Grandjean, & Scherer, 2005; Subra, Muller, Fourgassie, Chauvin, & Alexopoulos, 2017) claim that modern threatening stimuli, that are feared, use the same pathway, or, at least the result of procession is the same, i.e. rapid detection and response. See Table 1 for the studies included in the present dissertation and their short descriptions.

The main focus is on the effects of the emotionally negatively charged, threatening, fear-relevant stimuli on cognitive attentional performance. Throughout the course of the present dissertation we will touch upon the first experiments (Öhman, 1986; Öhman & Soares, 1998) conducted on this respective field. The emergence of the evolutionary theory, that is partly based on the preparedness effect (Seligman, 1971) in fear acquisition such that stimuli that has an evolutionary origin in a sense that it had been of critical importance to survival in the course of human evolution (e.g. the snake) are highlighted, and thus, learning to fear these cues is easier and faster than for equally threatening stimuli that has no evolutionary origin (e.g. the gun). The preparedness effect served as the basis for the later evolutionary theory coined by Öhman (e.g. Öhman, 1986). Importantly, parallel to this the early issues and later changes in the methodology are also discussed in detail.

After the first experiments dealing with evolutionary relevant stimuli only, we move on to more recent studies where the evolutionary theory is challenged as they claim that the emotional relevance (i.e. whether the stimuli is emotionally charged or neutral) is a more important factor in information processing than the evolutionary relevance of the stimuli. Although the advantage of threat-related cues in information processing appears to be a well-established result, we claim that a more integrative approach is necessary: knowing one factor is not enough to draw the final conclusion, other features are also needed. They urge the development of a new, more detailed approach, fear relevance. We also discuss the possible explanations of the antimonic and often mixed

results on the field, while trying to show an alternative to resolve the dispute. Highlighting the effects of the often neglected context (i.e. the stimuli is presented in a congruent or incongruent setting) and emotional arousal (i.e. moderately or highly activating) for a better understanding of the phenomenon.

Table 1 – An overview of the experiments presented in the dissertation

Study nr.	Experiment nr.	Paradigm	Short description
Study 1	Experiment 1	Classical visual search task	Comparing evolutionary relevant and modern threatening cues
	Experiment 2		Addition of a special group - firemen
	Experiment 3		Threat-detection in children
Study 2	Experiment 1	New visual search task	Pilot study - Introducing a novel paradigm
	Experiment 2		Comparing the detection speed for the best representatives of evolutionary and modern threatening stimuli
	Experiment 3		Using several other objects per stimulus category
Study 3	Experiment 1	Number matrices	Effects of emotionally charged stimuli on search performance
	Experiment 2		Comparing the effects of arousal level and origin of threat
	Experiment 3		Validation of the proposed paradigm using touch-screen

Visual search

The effects of emotional information on cognition have been mostly done using visual search paradigms. One of the most influential model of visual search had been proposed by Treisman (Treisman, 1988, 1993; Treisman & Gelade, 1980). The model proposes that specific characteristics, sensory features such that orientation, colour, and size are preattentive (i.e. automatically coded), and therefore, processing of these stimuli is parallel to each other and does not require focused attention. Importantly, the model assumes that these features come first in perception, and specialised maps are in charge for the coding of these (Treisman, 1985), that form feature maps from the information that goes through them. For instance, the distribution of different colours is coded on a colour map, while the orientation of different lines appears on an orientation map. By themselves, these features are not only coded, but could be detected automatically, for instance, if one wants to find a red line among green ones regardless of the orientation.

In contrast, if one wants to detect a red line with a particular orientation among green ones with various orientations, then the separately coded information (maps) has to be connected first. This process is called conjunction and could be implemented in three different ways. The coded features fit into (1) a priori frameworks, e.g. we know that the sky is blue, and the grass is green, hence if we are outside, or looking outside, and detect blue and green colours simultaneously, then we will likely combine colour blue with the position of the sky, and colour green with the position of the ground. When a priori knowledge is not available or proven to be wrong in the certain situation, we have the possibility to use the (2) master map of localizations (or the master map, in short). The master map contains the locations of all perceived features and is constantly refreshed as we scan the visual field. By directing focused attention to a certain point of the master map, we retrieve the list of features that are present there. Then, this knowledge could be compared to a priori knowledge and, thus, recognise the object upon a match. However, outside of focused attention (3) the different features could still be combined by themselves, and this may result in illusory conjunctions, i.e. incorrect combinations.

Given such a complex task that requires conjunction, first, the distinctive features need to be detected and processed, and only then could the comparison start, therefore parallel processing is not possible. Results of previous research support this idea. The first

one to do so was Treisman and Gelade (1980). Participants in their experiments saw various numbers of distractors (non-target objects) which they had to ignore and respond only when they found the distinct one (target) among them. When this target object had a distinctive feature, e.g. subjects were to find a blue S between green X distractors the time that it took them to indicate this did not change with the increasing number of distractors; due to parallel processing. In contrast, when the target was a green T among green X distractors, the time participants needed to find the target increased with the number of distractors. According to Tresiman and Gelade, in the latter case respondents mapped the visual area (parallel processing), but then they had to direct the focus of their attention to the possible targets one by one. Since focal attention is relatively slow, and they had to scan (on average) half of the cues presented, this is a rather time-consuming task to do. Especially in contrast to the first case, when distinctive features draw attention to themselves.

Interestingly, Bergen and Julesz (1983)wrote down a highly similar theory, where they call the basic units of perception textons, that are preattentive cues, and, therefore can be processed automatically. These could be, for instance, colour, orientation, size, length, width, end of a line, or crossing of more lines, etc. The experiments of Bergen and Julesz also supports the notion that targets with highly distinctive features 'pop-out' of the background (distractors), and thus, can be rapidly detected. To prove their theory, they conducted two experiments. The target was always a letter L. In the first case, 35 Ts served as background, in the other case 35 Xs served as distractors; with otherwise matching features. A fixation cross was presented first, then one of the previous described setting appeared for a short period of time, followed by a mask. Subjects had to indicate whether the target was present or absent. Target present trials accounted for half of the cases, and target letters appeared in random places. Interestingly, and in contrast to the method Treisman used, Bergen and Julesz manipulated the stimulus onset time, and not the number of distractors. To detect the L among Xs was found to be quite an easy task, responded were accurate in the vast majority of cases with just 160 ms stimulus onset time – a result similar to the control situation, when there was only the target present without distractors. In the other setting, when they had to find letter L among Ts, they only reached 62% accuracy with 300ms stimulus onset time, nearly the double compared to the previous case.

Later, when Bergen and Julesz increased the number of distractors, their results were again similar to that of Treisman and Gelade (1980). With L being the target among Xs – the easier task –, the accuracy only decreased rather slowly and by only a few percentages. Conversely, when Ts served a distractors accuracy dropped rapidly. According to the authors this preattentive visual processing serves as an early admonitory system that helps direct attention, shows salient stimuli, distinct textons, and, therefore, where one should look at. Taking together, the number of distractors is irrelevant when there is only one distinctive feature, hence the processing is automatic. In contrast, when there is more features one has to consider when selecting the appropriate target, the time to respond increases with the number of distractors, thus, the processing of the stimuli can no longer be considered automatic.

Nonetheless, the research mentioned here did not deal with the possibility, that not all of these features or textons are equal in the sense that not all of them are equally salient. Indeed, Wolfe and colleagues (Wolfe, 1994; Wolfe & Horowitz, 2004) were successful in grading these features and created three categories based on the quality and quantity of previous evidence suggesting a particular feature to be preattentive. There are (1) undoubtedly guidingand primary features that could be described as previous research (e.g. Bergen & Julesz, 1983; Treisman & Gelade, 1980) did so. These include, for instance, colour, motion, orientation, and size. However, some other features (2), e.g. increasing luminance, depth, shape, end of the line, and curvature, are still likely to be automatically processed, but are somewhat less pronounced. And, there are features (3) that does not, or just to some extent, are automatically processed, and are less salient in a visual search task, such as novelty, alphanumeric category, colour change, faces, own name, and semantic category. In his latest review, Wolfe (2007) draws attention to other important factors as well beside the number of distractors. For instance, whether the presence or absence of a target is to be detected, the difference between target and distractor, the difference within distractors, the distance between the presented objects, the distribution of this distance (e.g. same or random), and the uniqueness of the target. An early experiment (Wolfe, Yee, & Friedman-Hill, 1992)showed that curvatures and curved lines have an advantage in visual processing as respondents were faster to find them among straight lines compared to when they had to find a straight line among curved ones. Furthermore, LoBue (2014) showed that the detection of curvilinear shapes is also

faster than rectilinear (V-shaped) cues with the same periodical changes, when they had to be found among the same set of distractors, i.e. straight lines or circles.

More recently, during the last decade, the trend of research in visual search has shifted towards more complex scenarios and settings. The context appeared as an important factor, as Wolfe and colleagues (Wolfe, Võ, Evans, & Greene, 2011) argue that future research should focus on transferring the knowledge gathered from previous research on experiments with more complex visual parameters and pictures that show real-life scenarios. They claim that previous results should be used to understand the surrounding word. Their experiment serves as an example to the possible controversy in this transformation. Participants had to find a loaf of bread while several other articles for personal use served as distractors, however, there were two different background. The objects either appeared on a plain white, and therefore simple background, or on an image of a kitchen, that could be considered as more complex, and thus, more distracting. Strikingly, the results showed that participants found the target faster when there was a picture of a kitchen in the background. Wolfe and colleagues concluded that albeit the more demanding procession of the complex scene compared to the simple one, the effect of context helped participants to overcome the disadvantage and find the target faster.

Moreover, new picture analysing techniques and the need for ecologically valid methods provided a possibility to open to these more complex scenes, rather than just the basic unit. The paper of Liu and colleagues (Liu et al., 2011) serves as a great example for this, where they created an algorithm that identifies the salient regions of a static image, that are likely to draw attention of people. They underscore the importance of low level visual features such as contrast, the centre-surround histogram, and colour spatial distribution. The importance of controlling for these low-level visual features will be touched upon in experiments presented in this dissertation (see e.g. Experiment 3 of Study 1, Experiments 2 and 3 of Study 2, and Experiment 3 of Study 3).

The role of emotions in attentional processes

According to a review (Compton, 2003) emotions has to do with highly important events, and objects, and, therefore, they must have an advantage in information processing. Indeed, Vuilleumier (2005) showed that emotions do have an effect on cognitive, and more particular, in attentional processes, supports this idea. Further, he claims that emotions elicit adaptive responses and influence perception. In this review, Vuilleumier (2005) highlights several behavioural testing methods to study this influence, and argues that emotional valence (i.e. positive or negative) is a more salient feature than other visual parameters.

The first paradigm to study if, and how emotions could influence perception was the Stroop-test. The classical test (Stroop, 1935) consists of different colour names written in congruent (e.g. BLUE with blue ink) or incongruent (BLUE with red ink) colours, and the subject had to name the colour of the ink, while ignoring the meaning. This is a rather easy task when the colours are congruent, however, requires quite the attentional capacity, when incongruent. The difference between congruent and incongruent settings is measured by reaction time, i.e. how much time does it take to name the colour of one word or a block (e.g. 10) of words. The assumption behind emotional Stroop is that if the meaning of the emotionally charged words (e.g. death, failure, fear) attract more attentional capacity, then, the time of naming its colour increases; compared to neutral words (e.g., paper, lamp, rug) with otherwise same parameters (e.g. length). Wentura and colleagues (Wentura, Rothermund, & Bak, 2000), for instance, showed 100 adjectives, half of which had negative and the other half had positive meaning. According to their results respondents on average are slower to name the colour of negative adjectives, compared to positive ones.

However, as a recent meta-analysis (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007) shows, the results obtained from such experiments are often mixed. They found that emotional Stroop only works in block design, which means that if several words with the same emotional valence (e.g. positive) are shown in a series, then, the overall time that it took participants to name their colours will be longer than when they have to name the colours of words that are very similar, identical in length, but different in valence (e.g. neutral).

The results of the aforementioned paradigms using visual search to describe the effects of emotions are more consistent compared to emotional Stroop tests. Most recent studies (see e.g. Humphrey, Underwood, & Lambert, 2012; Pilarczyk & Kuniecki, 2014) are using more complex stimuli set – the way Wolfe (2007) suggested a transition regarding visual search tasks. These studies demonstrated the emotional influence on visual cognition using more ecologically valid stimuli sets, and often use more sophisticated techniques, such as an eye-tracking device or touch-screen to obtain more reliable reactions; which motivated us to seek for novel paradigms. They support the idea of Vuilleumier (2005) and claim that emotional valence is the most important preattentive feature, that, if present, has the advantage over other visual features.

Fear

Previously we focused on emotionally charged stimuli in general. We decided to include that first experiment dealing with multiple emotions to show this diverse nature and to show the limitations that are hard to overcome even when the focus is narrowed down to one emotion, i.e. fear. Fear has been chosen to be the subject of further experiments because it is well embedded in several theoretical approaches and is often the subject of previous empirical work, and thus, the effects of fear is well-established in the literature, however there are still numerous questions and unexplored areas left to answer. However, as the literature review showed only one emotional category offers so diverse options and raises so many questions that covering all would be impossible within the present dissertation. Hence, with the exception of the first experiment in Study 1 we will focus solely on the effects of threatening stimuli on different aspects of visual cognition, and its manifestation in the behaviour.

Fear is a basic and ancient emotion (Ekman & Friesen, 1971; Ekman, Sorenson, & Friesen, 1969) that is highly important when it comes to survival. It could help recognizing a situation and deciding whether it is safe or threatening, whether one may approach it, or it is better to run away. Phobia, in contrast, could be seen as the excessive version of an adaptive defensive mechanism, that is no longer helpful, and, thus, may be categorised as maladaptive; at the same time, this might be the price humans pay to survive (Mobbs, Hagan, Dalgleish, Silston, & Prévost, 2015). The origin and development of phobias and fear has long been the subject of interest and debate.

Specific phobia is classified as an anxiety disorder, and one of the most common mental disorders. It is characterized by persistent and unrealistic fear that is cued by the presence or thought of a specific object. A recent study (Kiejna et al., 2015) examining the lifetime prevalence of different disorders showed that specific phobia occurred in 3.4% of Polish adults. Based on the Hungarian version of the Diagnostic Interview Schedule (DIS) authors (Szádóczky, Fazekas, Füredi, & Papp, 1996; Szádóczky, Papp, Vitrai, & Füredi, 2000)reported a 6.3% prevalence. Other previous studies estimated the lifetime prevalence of specific phobias from 3.8% to 4.2% in a large sample of Korean adults(Cho et al., 2007; Park et al., 2013), 8.7% of Israeli young adults (Iancu et al., 2007), 9.4% - 12.5% in the United States (Kessler et al., 2005; Stinson et al., 2007). In the 5th

edition of the Diagnostic and Statistical Manual of Mental Disorders specific phobia had been differentiated into five subtypes: animal phobias, blood–injection–injury phobias, natural environment phobias, situational phobias, and other phobias (American Psychiatric Association, 2013).

Animal phobia (zoophobia) has been found to have the highest prevalence of the five subtypes of specific phobias (Becker et al., 2007; Oosterink, De Jongh, & Hoogstraten, 2009; Witthauer et al., 2016). Fredrikson et al. (Fredrikson, Annas, Fischer, & Wik, 1996) found that 5.2% of Swedish adults have a phobic fear of snakes or spiders. A recent study (Ajdacic-Gross et al., 2016) showed that the prevalence of pure animal phobia is 3.5%. They also pointed out that animal phobias were preponderant among females – 5.2% compared to 1.5% in males. Thus far, to our best knowledge there has been only two Hungarian surveys (Zsido, 2017; Zsido, Arato, Inhof, Janszky, & Darnai, 2018) targeting the prevalence of this subtype of special phobia. Similar pattern was found compared to the previously mentioned international studies: 9.5% of the respondents reached the clinical cut-off point for spider phobia, and 4.24% reached the cut-off point for snake phobia based on previous studies with diagnosed phobic participants. It seems plausible to claim that this is a universal phenomenon, as the prevalence is nearly the same across all countries worldwide, and it is independent of the number of species – poisonous or not – that populates the given country. This is also a feature of the other, evolutionary relevant phobias and fears, such as fear of heights, strangers, and wide-open spaces (Coelho & Purkis, 2009).

Human adults know that numerous objects and animals could mean potential threat and, thus, better be avoided. A large body of past research (Blanchette, 2006; Brosch & Sharma, 2005; Gomes, Silva, Silva, & Soares, 2017; Lipp, Derakshan, Waters, & Logies, 2004; LoBue & Rakison, 2013; Purkis & Lipp, 2007; Thrasher & LoBue, 2016; Zsido, Bernath, Labadi, & Deak, 2018) showed that there are distinct cues that we quickly learn to fear of, detect them automatically, and respond faster to them. These stimuli can be broken down into two main categories: ones that have an evolutionary history and those that are highlighted during the course of ontogenesis. It has been shown (see e.g.,Öhman & Mineka, 2001; Seligman, 1971; Tooby & Cosmides, 1990) that stimuli with evolutionary relevance have an advantage, and therefore, fear acquisition occurs more rapidly and possibly after the very first exposure. For other stimuli, it seems that the

three-way model of Rachman (1977) could describe the connection. The model suggests that fear can be acquired via three general pathways: (1) direct learning through association, and there are two indirect, (2) social learning pathways through observation and (3) verbally transmitted information (see also Mobbs et al., 2015).

The three models of fear acquisition

General learning model

The very first model describing the possible pathway of fear acquisition is a typical domain-general model. Fear acquisition occurs throughout different mechanisms (e.g. habituation, associative learning) that has to do with several sensory modalities coming from different inputs, and wide range of knowledge areas. The idea originates from way before 1970's and is in connection with the widely shared image, that fear can only be learned through direct conditioning – similar to what was demonstrated in the case of Little Albert (Watson & Rayner, 1920). Later, Rachman (1977) claimed that fear could be learned via three domain-general learning pathways: (1) direct learning with classical conditioning, and indirect learning through (2) observation, and (3) information from verbal communication. This theory has been supported by a large body of research, and also serves as the basis to several new theories (see e.g.Field & Purkis, 2011). The observation of traumatic events also supports the notion that permanent fear can be formed by simple conditioning. For instance, posttraumatic stress disorder is widely seen as an evidence to Rachman's model; if we think about the symptoms of PTSD as behavioural response developed as a consequence of a traumatic event. Even clinical studies showed that even one encounter with a highly negative event could cause intense fear of that specific event. For instance, Dollinger and colleagues (Dollinger, O'Donnell, & Staley, 1984) surveyed two groups of people: those who were present at a football game that has been interrupted due to lightning striking into the field and those watching it on TV . They found that those present at the game feared more, generalised this fear, and reported sleeping issues and somatic problems more often compared to the control group.

Non-associative model

The previously described learning model might not be efficient enough from an evolutionary perspective, if only one encounter with the threatening stimuli could be lethal. According to the evolutionary theory one has to immediately recognise potential threats in order to survive. If one can only learn fear based on general learning strategies, then many would not live long enough to reproduce (Bolles, 1970). Supporters of this

idea do accept the model proposed by Rachman, however, with an additional fourth pathway, that is specific to evolutionary recurrent threats. In case of such stimuli fear develops very early (i.e. innate), and, therefore, no previous experience is needed: "*Non-associative models assert that most members of a species will show fear to a set of biologically relevant stimuli from early encounters (…) without any relevant associative learning experiences.*" (Poulton & Menzies, 2002, pp 127-128). For this addition, however, domain-specific processes are needed that facilitate fear acquisition. These mechanisms are sensitive to a specific input sign of a given domain of knowledge. Moreover, as Poulton and Menzies (2002) emphasised, several terms has to be fulfilled during birth or shortly after.

This model has been met with criticism during the past decades. The main reason behind this is the fact that evidence supporting non-associate learning is based on retrospective reports. These are thought to be highly biased by the actual mental state (e.g. phobia) of the narrator, not speaking of the extent of how accurate the memory is. Furthermore, the vast majority of the studies supporting non-associative learning, only tries to control for the effects of direct conditioning and leave other indirect effects out of account (Muris, Merckelbach, de Jong, & Ollendick, 2002).

Prepared learning model

The third, and most recent model could be considered as merging the previous two – the general learning and the non-associative learning models. Supporters of the prepared learning model claim that fear acquisition always occur via one of the three pathways described by Rachman (1977). However, the highlighted role of evolutionary relevant recurrent cues by the non-associative model is affirmed. It is assumed that fear from these stimuli is learned faster (Seligman, 1971). According to the general learning model connecting any two stimuli occurs in the same manner and pace, some previous research showed that learning is privileged for certain combinations of stimuli, i.e. these associations are formed easier and quicker. For instance, it has been shown (Garcia & Koelling, 1966) that rats associated gastric sickness with ingestion of liquid or food much quicker than with lights or noises.

The rapid association between evolutionary relevant threatening stimuli and fear is similarly described by the prepared learning model. In this model fear acquisition can

be considered as a dimension, where the two, previously mentioned models serve as two end points. Learning for some advantaged stimuli occur instantaneously; while several trials are needed for other stimuli. Again, similarly to the non-associative models, these advantaged stimuli have evolutionary relevance (Öhman & Mineka, 2001). This offers one explanation why many of such stimuli appears as the object of clinical phobias; due to the advantaged and innate pathway, the risk of developing an association that is too strong and long-lasting is higher (see e.g. Öhman & Mineka, 2001; Seligman, 1971).

It is of high importance for such a model to be supported by subhuman and infant studies as well. Susan Mineka started her experiments in the 1980's (see e.g. Cook, Mineka, Wolkenstein, & Laitsch, 1985; Mineka, Keir, & Price, 1980) to explore fear acquisition. One of her questions was how rhesus monkeys (*macaca mulatta*) born and raised in the lab learn to fear different objects. Interestingly, she found that these monkeys neither show fear reaction for the evolutionary relevant and threatening snake nor did they for the evolutionary relevant but non-threatening flower. Then, they were presented short videos of a wild monkey from their species get frightened by a snake, or a flower. The lab-raised monkeys then showed fear response to the snake, but not for the flower. DeLoache and LoBue (2009) have arrived at a similar conclusion in their experiment with human infants. In their first study, there was no difference between the spontaneous reaction of 9-10 months old babies when watching short films of various animals including snakes and other, non-threatening ones. In contrast, in their second study 7-18 months old babies attended clips of snakes longer when hearing a fearful adult voice, compared to when hearing a happy voice. These results support the prepared learning model, i.e. some stimuli highlighted during the course of evolution is learned to associate with fear quicker than other cues; even if they are evolutionary relevant as well.

Fear and threat detection

It has long been posited that humans possess a "fear module" that underlies the rapid detection of potential threats to help survival (Öhman & Mineka, 2001). Öhman defines this module in the sense as Fodor (1983) described them. According to Fodor, modules are information-processing units, that are domain specific, innate, working fast and automatically, encapsulated and impenetrable for previous knowledge. Öhman and Mineka (2001) have proposed, that the processing of evolutionary old threatening stimuli is very similar at several points. The processing of these stimuli is also fast, automatic and subconscious. It requires specific cues as an input, that are negative, threatening and relevant in survival. It is encapsulated, because the evolved fear reaction cannot be modified by conscious control. The processing of fearful cues is linked mainly to the amygdala (Coelho & Purkis, 2009; LeDoux, 2000; Pessoa & Ungerleider, 2005; Vuilleumier, Armony, Driver, & Dolan, 2001).

What is the special stimulus this module is the most sensitive to? Öhman and colleagues (Öhman, Flykt, & Esteves, 2001) showed that there is an attentional processing advantage to fear-relevant stimuli (spiders, snakes) compared to non-fearful stimuli (mushrooms, flowers). Participants detected snakes and spiders faster among mushrooms and flowers in a visual search task than mushrooms and flowers among snakes and spiders. Moreover, Öhman et al. (2001) suggested that the procession of these negative stimuli is automatic. There was no difference whether they had to be found in a 2x2 or a 3x3 matrix, in spite of the fact there were five more distractors to scan in the latter case. Still, questions arose: Is it possible to collapse spiders and snakes into one category? Are they equal in terms of fearfulness?

Soares and colleagues (Soares, Lindström, Esteves, & Öhman, 2014) tested the difference between spiders and snakes through detection in peripheral vision, the distracting effects of non-target stimuli, independence of snake detection, and perceptual load, i.e. the number of stimuli presented at once. The screen was divided into a 6x6 grid. The perceptual load was manipulated; there were four set sizes (3, 6, 12, 18 pictures presented in total). Participants saw different numbers of distractors (fruits) and one target stimulus (spider or snake), and the rectangles not used were left blank. The location of the target varied across the foveal, parafoveal, and peripheral areas. Results showed that

the search efficiency remained the same for snakes across eccentricities; however, for spiders it deteriorated at the parafoveal and peripheral locations. Detection accuracy indicated that snakes were more efficiently detected than spiders. Moreover, when they used spiders and snakes as task-irrelevant distractors, only snakes could produce a significant interference with the task. Results were similar when the authors investigated low and high perceptual load situations; only snakes could cause a significant interference in the high load condition. This study supports the theory that snakes are a specific fearful stimulus with phylogenetic origin; one that has an adaptive advantage when it comes to visual processing.

Öhman and colleagues (Öhman, Soares, Juth, Lindström, & Esteves, 2012) reviewed a series of experiments published earlier from their laboratory. They also concluded that if they compare snakes and spiders, instead of collapsing them into the same category, snakes do have an advantage over spiders; they are detected faster and regardless of the perceptual load (number of distractors presented). In the light of these studies, we suggest that snakes can be used as fear-relevant stimuli as the best representative of the evolutionary old category. Hence, in our experiments snakes often represented the evolutionary relevant category.

As previous studies (Coelho & Purkis, 2009; Davey, 1995; Mobbs et al., 2015; Rakison & Derringer, 2008) underscore encoding general features during the course of evolution for threatening cues might be more likely than maintaining a specific fear module (Öhman & Mineka, 2001, 2003) for each stimulus. Especially when considering the costs of several specific units compared to a general one. Nonetheless, this seems to be only plausible for stimuli with evolutionary relevance. The results of a more recent study (LoBue, 2014) support this theory. LoBue showed that solely based on low-level visual features children still detect "snake-like" objects – namely, curvilinear shapes – faster than other, highly similar – rectilinear – ones (see also Wolfe et al., 1992). Coelho and Purkis (2009) calls for a similar investigation in order to test the possibility of using a similar general feature encoding system to efficiently detect modern threats too. We compared the detection of visually similar modern threatening and non-threatening stimuli in a population of preschool children to investigate this question (see Study 1 Experiment 3).

Modern fearful stimuli

The gun stands out from modern threats similar to how a snake excels among evolutionary fearsome stimuli. Loftus and colleagues (Loftus, Loftus, & Messo, 1987) were among the first to investigate a modern threatening stimulus: the gun. They observed that participants were sensitive to a picture of a gun, it not only captured participants' attention automatically but also caused them to recall other details less accurately. There are only a few researches to consider other types of weapons. Loftus and colleagues mentioned knives as another potential weapon type; however, they only used guns as stimuli in their experiments. More than 10 years later, a study (Pickel, 1998) examined the "*weapon focus theory*" (Loftus et al., 1987) with guns, scissors, knives, and screwdrivers as potential weapons. Pickel was able to replicate the results: participants were sensitive to guns, but not to knives or other modern fear-relevant stimuli. Even Öhman and Mineka (2001) supported the idea that guns belong to a very specific type of modern stimuli. They suggest that for most people growing up in industrialised environment, guns are strongly associated with danger and, of course, potentially death, a perspective reinforced in movies and news. In addition, guns are lethal from a distance, which makes them even more threatening. Öhman and Mineka (2001) argue that in some special cases, modern fear-relevant stimuli, such as a pointed gun, can be processed as fast as stimuli with phylogenetic history, such as snakes. It has been shown (Mineka, 1992)that under ordinary circumstances, participants did not show significant covariation bias for knives and shock, i.e. they did not overestimate random contingencies between knives and the aversive consequence of shock. In contrast, Flykt (1999) reported a significant covariation bias for guns and shock.

According to the above-mentioned studies and results, we suggest that the specific fearful stimulus of the modern or non-evolutionary category is the gun, because it has an acquired advantage during visual processing. If people have a special sensitivity to fearful cues and they have a fear module that is innate, is it possible that their module is responsible for detecting modern threats as well? To answer this question, a previous experiment (Brosch & Sharma, 2005) exposed participants to threatening and neutral stimuli during a visual search task similar to the VST. They used both evolutionary old (snake, spider, flower, and mushroom) and relatively modern (gun, syringe, mug, cell phone) stimuli. Importantly, in contrast with the results of previous work by Öhman and

colleagues (e.g. Öhman et al., 2001) their results showed a general advantage for fear-relevant stimuli – they found no difference between snakes and guns. Another study (Blanchette, 2006) also repeated the experiments of Öhman et al. (2001). In addition to snakes and spiders, Blanchette added guns and syringes as modern threatening stimuli. Participants detected the target stimulus faster when it was threatening than when it was not. Furthermore, Blanchette reported a slight advantage to modern fear-relevant stimuli – participants found guns faster than snakes and spiders. A more recent study (Brown, El-Deredy, & Blanchette, 2010) found a similar pattern in an event-related potential study: Both evolutionary old and new fearsome stimuli increased the P1 amplitude, but the effect was slightly stronger for non-evolutionary threats. In addition, Fox and colleagues (Fox et al., 2007) exposed participants to phylogenetic (snake) and ontogenetic (gun) stimuli against neutral ones (flower, toaster) and found that threatening stimuli were faster and more efficiently identified than neutral ones. However, they found no difference in the response between the two types of threatening stimuli.

Thus, the question is what possibly can be behind these antimonic results, and which are the factors that should be taken into account in future research to give the final answer on whether threating stimuli with evolutionary origin possess an advantage over modern threatening stimuli.

Role of the context

The context of the fearsome targets that are presented was also found to be relevant. Some of the aforementioned studies (Blanchette, 2006; Brosch & Sharma, 2005; Brown et al., 2010) used both evolutionary old and modern stimuli as distractors (i.e. context), however, they decided not to use this factor during the data analyses. Thus, the question is whether the context has an effect on the visual search or not. For example, can an evolutionary old stimulus, like the snake, be found just as fast among evolutionary old distractors – e.g. flowers – than among modern ones – e.g. cell phones; or will there be a difference?

Young and colleagues (Young, Brown, & Ambady, 2012) used a priming paradigm to investigate this question. Participants were primed with pictures of either a natural or urban environment, then an evolutionary or non-evolutionary fearful stimulus was presented very briefly with a backward mask, and then they responded to a spatial-cueing task. Results showed that finding the ontogenetically or phylogenetically relevant stimulus faster depends on the context. When primed with a human-made environment, participants responded to modern fearful stimuli faster than the ones with evolutionary history, and vice versa. Experiments using functional magnetic resonance imaging (fMRI) data lend further support for this. Cao and colleagues (Cao et al., 2014), using fMRI, examined the activation of the amygdala in cases of phylogenetic and ontogenetic stimuli in both human and non-human environments. Their results indicated that the activation of the amygdala is greater for animal-like stimuli with phylogenetic history (for example, snakes) when these stimuli appeared in a non-human environment. In contrast, if they were embedded in a human-made environment, the evoked response to lifeless frightening stimuli (for example, guns) was stronger.

It seems that the context primes our visual system to detect the congruent cues to the specific scene faster. Thus, we are able to find a snake faster among flower distractors than among cell phones, because snake and flower are both evolutionary old stimuli, and cell phones are modern. We propose that not only does the context matter, but also the position the threatening stimulus is presented in (see also Quinlan, Yue, & Cohen, 2017). A threat facing towards the participant might be considered more dangerous than the one

seemingly moving away or not noticing the participant. Can this distinction also have an effect on the performance?

STUDY 1 – THE CLASSICAL VISUAL SEARCH TASK

Introduction

Arousing effect of the stimulus

The arousing effect of the emotionally charged stimuli is an important factor which was pointed out earlier: "*the quality of an emotion depends on the proportion of pleasure-displeasure and arousal (or activation-deactivation) that is experienced*" (Reisenzein, 1994, p. 527). Some recent studies (Lundqvist, Bruce, & Öhman, 2015; Lundqvist, Juth, & Öhman, 2014; Pessoa, 2013) underscore that arousal has a distinctive role in the procession of emotional stimuli. Lundqvist and colleagues showed that the salience of arousal level is more influential than valence with regression analyses. However, they only used faces in their studies (see also Csukly et al., 2013).

One of the aforementioned studies (Young et al., 2012) touched on this question as well, but they did not control for arousal. They chose these pictures from the International Affective Picture System (Lang, Bradley, & Cuthbert, 1997) database and provided the slide number of the pictures used. Moreover, they mentioned that some of the snake pictures they used were directly facing the respondents and some were not. We claim that there is a major distinction between these two types of pictures According to the given slide numbers by Young and colleagues and further review of the IAPS database, we have concluded that highly arousing snakes and guns tend to face the viewer directly, while less arousing ones are shown in side-view or top-view. Thus, it seems that they indeed collapsed stimuli with mixed arousal into the same category.

Similarly, another study (Fox et al., 2007) also mention that during the presentation of the stimuli, three out of five of the negative stimuli faced the participant. Crucially, this study was the first to compare the detection of evolutionary relevant (snakes) and modern (guns) cues using a VST. Yet Fox and colleagues did not include the arousal level of the stimuli in further analyses. Hence, we claim that using mixed arousal might be a possible reason for the fact that they did not find a difference between

the evolutionary old and new pictures. Hence, the novelty of our first study is the comparison between medium and high arousal levels.

The possible effects of previous experience

The effect of the arousal level of the emotionally charged stimuli may have different effects on people with relevant previous experiences. Firefighters, for instance, often perform multiple and both physically and mentally demanding tasks during firefighting operations in hostile environments while conditions are unknown and unpredictable. These cognitive demands are including, but not limited to for instance assessing emergency scenes, executing critical decisions, and situational awareness of their surroundings. Thus, the objective behind this experiment and the recruitment of a special group was to test whether people with special training, and previous life experiences would differ from the young adults (University students) when it comes to detecting stimuli that are considered as highly dangerous.

Previous research has shown that firemen are capable of functioning on the normal level, i.e. their performance do not deteriorate, or even better under stress, e.g. in very hot and hostile environments (Hemmatjo, Motamedzade, Aliabadi, Kalatpour, & Farhadian, 2017; Williams-Bell, McLellan, & Murphy, 2016). For instance, Hemmatjo and colleagues (2017) recruited firemen to conduct simulated firefighting activities (e.g. hose pulling, ladder handling and climbing its stairs, passing through narrow routes, search and rescue operation, and passing through escape tunnel) in a special indoor unit. Such an indoor unit is called the smoke-diving room, which is an indoor environment with dark and nested rooms, various obstacles, narrow routes; and used for exercising firefighting activities. Here, temperature, humidity can be adjusted and smoke can be produced. Hemmatjo and colleagues (2017) measured vigilance, i.e. reaction time and accuracy of responding with a continuous performance test. Subject has to detect a priori defined targets for a sustained period of time, with ten pictures displayed at a time for 200 ms and 20% target frequency. First, subjects performed the previously instructed firefighting activates, then entered the control room, where they completed the vigilance task immediately. The results demonstrated that firemen showed faster reaction time relative to baseline throughout the exercise condition.

In contrast, another study (Robinson, Leach, Owen-Lynch, & Sünram-Lea, 2013) assessed the changes in cognitive performance (visual attention, declarative and working memory) of volunteers with no firefighting experience in a simulated firefighting emergency. Participants underwent a three-day long basic firefighter training, with a simulated fire emergency on the last day. Their cognitive performance was measured immediately after completing the emergency task and after a 20-minute delay. Robinson and colleagues observed differences in cognitive performance after the highly threatening situation. They found impairments in visual declarative memory immediately after the task and working memory after a 20-min delay.

Other findings (Leach & Ansell, 2008) also supports the idea that people without relevant training have to face elevated risk of 'freezing' – or cognitive paralysis – in an emergency situation. In their experiment, Leach and Ansell (2008) recruited members of the Royal Air Force (aircrew) and a control group who were not undergoing survival training. The sample consisted of young adults (mean age 24.95 years, S.D. = 2.35) and mostly males (89.3%). The aircrew underwent a classroom training, and then, completed a practical field phase, which was a simulation of an 'aircraft down' survival incident. This means that they were deployed into a mixed woodland and moorland open field during the winter in north of England, often facing with sub-zero temperatures, wet, windy, and snowy weather. Here, they had to perform various survival tasks, for instance shelter building, preparing signal fires, etc. The Test of Everyday Attention were assessed, measuring selective attention, attentional switching, multitasking with auditory-verbal task loading, and sustained attention. Data were obtained on three occasions: during classroom phase, during first deploy into the field, and three to four days after completing the experiment. According to the results the experimental (aircrew) group showed significant impairment in selective and sustained attention compared to the control group. On the one hand, this demonstrates that even well-trained individuals with previous experiences could be a victim of dysfunction in controlled attention. On the other hand, the two samples were not matched in terms of experimental conditions, i.e. only trained aircrew members completed the demanding survival task and control group members did not. Thus, comparison between their results cannot be used for drawing in depth conclusions.

Another special group: Children

Fear is one of the basic emotions, as it has a crucial role to this date in survival. Human adults know that numerous objects and animals could mean potential threat and, thus, better be avoided. A large body of past research (Blanchette, 2006; Brosch & Sharma, 2005; Gomes et al., 2017; LoBue & Rakison, 2013; Purkis & Lipp, 2007; Thrasher & LoBue, 2016; Waters & Lipp, 2008; Zsido, Bernath, et al., 2018) showed that there are distinct cues that we quickly learn to fear of, detect them automatically, and respond faster to them. These stimuli can be broken down into two main categories: ones that have an evolutionary history and those that are highlighted during the course of ontogenesis. It has been shown (see e.g., Seligman, 1971; Tooby & Cosmides, 1990; Öhman, & Mineka, 2001) that stimuli with evolutionary relevance have an advantage, and therefore, fear acquisition occurs more rapidly and possibly after the very first exposure. For other stimuli, it seems that the three-way model of Rachman (1977) could describe the connection. The model suggests that fear can be acquired via three general pathways, where the first is direct learning through association, and there are two indirect, social learning pathways through observation and verbally transmitted information (see also Mobbs et al., 2015).

The advantage of evolutionary relevant cues has been supported by a vast body of literature (Öhman et al., 2001; Purkis & Lipp, 2007; Shibasaki & Kawai, 2009; Soares, Esteves, & Flykt, 2009; Tipples, Young, Quinlan, Broks, & Ellis, 2002). Moreover, this advantage was also demonstrated in children supporting the notion that it is innate. One of first research to do so had been conducted by Waters, Lipp, and Spence (2004). Using a dot-probe paradigm they showed that children had a stronger attentional bias towards threatening than non-threatening cues. Later, LoBue and DeLoache (2008) introduced the classic visual search task (VST) designed by Öhman and colleagues (see. e.g. Öhman, Flykt, & Esteves, 2001; Öhman, & Mineka, 2001) in testing fear advantage in children. The adult version of VST consists of nine pictures in total arranged in a 3x3 array (see Figure 1 for the layout). For target present trials, eight pictures serve as distractors, or *background* en masse, and one image from a different category as the *target*. To avoid false responses, target absent trials are needed with nine pictures of the same category. However, this doubles the overall number of trials presented and is not efficient to use

for testing young children. Hence, LoBue and DeLoache (2008) created and validated a touchscreen version of the VST and showed that preschool children possess an attentional bias and visual search advantage for snakes, in spite of the fact that only a few children reportedly feared snakes. The same pattern was demonstrated for spiders as well (LoBue, 2010a).

As previous studies (Coelho & Purkis, 2009; Davey, 1995; Mobbs et al., 2015; Rakison & Derringer, 2008) underscore encoding general features during the course of evolution for threatening cues might be more likely than maintaining a specific fear module (Öhman & Mineka, 2001, 2003) for each stimulus. Especially when considering the costs of several specific units compared to a general one. Nonetheless, this seems to be only plausible for stimuli with evolutionary relevance. The results of a recent paper by LoBue (2014) support this theory. LoBue showed that solely based on low-level visual features children still detect "snake-like" objects – namely, curvilinear shapes – faster than other, highly similar – rectilinear – ones (see also Wolfe et al., 1992). Coelho and Purkis (2009) calls for a similar investigation of stimuli encoded during ontogenetic learning.

To this date, there is only a few previous research (Blanchette, 2006; LoBue, 2010b) to explore the rapid detection of modern threatening stimuli. Moreover, in particular, whether as young as preschool children are capable of using a similar mechanism as proposed for evolutionary relevant threatening stimuli. It seems reasonable to claim that rapid acquisition of modern threats could add to the probability of survival. Thus, an advantage similar to evolutionary ancient threatening stimuli appears plausible for some modern stimuli that children previously encountered and had a few negative experiences with. This idea is supported by the results of LoBue (2010b) who showed different modern threatening and non-threatening targets to children, in addition considering previous negative experiences, using the VST. LoBue found that children detected those targets faster which they had previous negative experience with (syringe), compared to neutral (pen) ones. However, they found threatening stimuli without negative encounter (knife) equally as fast as other neutral (spoon) cues.

Throughout Study 1 we used the classical VST paradigm. In the first experiment we investigated the effects of arousal on the detection of evolutionary relevant and

modern threatening stimuli in young adults. Then, in the second experiment we recruited firemen and repeated Experiment 1, allowing us to compare this specially trained population to those without such previous experience. The third experiment is the first one to date, to our knowledge, to directly compare evolutionary relevant and modern threatening stimuli in preschool children. Here, we sought to investigate the differences in the underlying mechanism of threat detection.

Experiment 1 – The role of modern threatening cues

Aims and hypotheses

We claim that beside evolutionary old stimuli, modern threatening cues must be considered, while arousal should have a highlighted role in this comparison. The overall impression from past research (Blanchette, 2006; Brown et al., 2010; Öhman & Mineka, 2001; Purkis & Lipp, 2007) is that it is not evident whether evolutionary relevance means there is an advantage in visual processing and responding. It is still a question whether evolutionary old threatening stimuli have an advantage over modern threatening ones. In our view, it is possible that arousal state causes the conflicting and inconsistent results. The present study, and the experiments within, is the first to compare modern and evolutionary relevant stimuli in a visual search task where the effects of the context and the level of arousal are also considered. For Experiment 1, our hypothesis is that arousal does have a crucial role in the evaluation of a threatening cue, and higher levels of it would mean faster detection.

Method

The basic paradigm adopted in this study is the well-established visual search task (Fox et al., 2007; Öhman et al., 2001). In their studies four or nine pictures are presented at the same time in a matrix array, and participants have to determine whether the previously specified target was present or absent.

However, the present paradigm differs from the classical VST in some regards. For instance, in these previous studies, they directly compared the detection of fear-relevant (snakes and guns) stimuli, however, they did not control for the arousal level of the stimuli. An important feature of our experimental design is that two arousal categories were introduced (medium and high), allowing us to investigate the specificity of the fear module.

Participants

Fifty-three university students (21 men and 32 women, mean age 21.4 years, ranging from 19 to 23 years) volunteered in the experiment. The sample size for this

experiment was determined by computing estimated statistical power (β > .8), based on the results of prior experiments on fear advantage using the odd-one-out visual search task (Blanchette, 2006; Fox et al., 2007). All participants were right-handed with normal or corrected-to-normal vision. None of them had a history of neurological diseases or mental disorders, as noted through self-report. Participants were rewarded with course credit. Data from three participants were excluded because of a failure to follow instructions. Our research was approved by the Hungarian United Ethical Review Committee for Research in Psychology (EPKEB) and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki), and informed consent was obtained for experimentation with human subjects.

Experimental stimuli

The experimental stimuli consisted of target and distractor pictures. The target pictures were threatening, while the distractors were neutral. Sixteen threatening target pictures [1] (See *Footnote 1 with the exact numbers of IAPS pictures used*) (snakes and guns) were taken from the International Affective Picture System database (Lang et al., 1997) based on the Hungarian standards (Deák, Csenki, & Révész, 2010). Previous studies (e.g. Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Olofsson, Nordin, Sequeira, & Polich, 2008) have shown that various physiological changes (e.g. EMG, skin conductance, heart rate, and EEG) reflect participants' reports of greater affective arousal. We chose this database, based on previous experiences and because it enabled us to control the properties of the emotional stimuli we present.

The level of valence was controlled and arousal was manipulated. A pilot study was conducted on an independent sample of 36 undergraduates to validate the valence and arousal ratings of the selected pictures. We used four categories: Medium arousal snakes, high arousal snakes, medium arousal guns and high arousal guns, see Table 2 for mean valence and arousal ratings. The medium and high level arousal categories differed

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[1] The IAPS identification numbers of images used: medium arousal snakes: 1026, 1080, 1090, 1110; high arousal snakes: 1050, 1051, 1114, 1120; medium arousal guns: 6190, 6200, 6241, 6610; high arousal guns: 2811, 6230, 6250, 6260.

both in the level of arousal and valence (ts>2, p<0.05). The pictures of snakes and guns did not differ in valence, nor in the level of arousal (ts<1, p>0.1).

Table 2 – Valence and arousal ratings of the pictures used.

| Target type	Arousal category	Valence	Arousal
Snake	High	2.9	7.01
	Medium	3.94	5.44
Gun	High	2.99	6.80
	Medium	4.17	5.23

In order to avoid the confounding effects of low level visual features we analysed the target stimuli based on visual features: colour brightness, contrast, luminance, and spatial frequency. These features were calculated using a MATLAB program (MATLAB 6.1, The MathWorks Inc., Natick, MA, 2000). The colour brightness value was the mean value of each channel in a colour image. The mean contrast level of each picture was calculated with root mean square contrast. The mean luminance values of each picture were computed by transferring a colour picture from RGB space to YUV space and then calculating the mean value of the Y component(Bex & Makous, 2002). Spatial frequencies were accessed by creating a frequency domain array for both the X- and Y-axes of each image, and then using Fourier transformation to obtain the peak values in the spectrum in both directions. There were no significant main effects or interactions for any of the low-level visual features (all Fs < 1, p > 0.1).

Neutral distractors (flowers and cell phones) were collected from the Internet. Both ancient and modern distractors were used to match the targets in evolutionary age and to address the contextual effect (i.e. the stimuli is presented in a congruent or incongruent context). To ensure that the neutral distractors were similar in valence and arousal, a pilot study was carried out with 47 undergraduate students who saw the pictures in random order and rated them on two 9-point Likert-type scales: valence and arousal.

There was no significant difference between the type of the distractor on these scales (all ts < 1, p > 0.05).

The pictures were presented in two set sizes – either nine or four pictures appeared – similarly to previous studies using VST. If there were nine pictures, they appeared in a 3x3 matrix; one target among eight distractors. In the case of smaller set size, there were 2x2 pictures; one in each corner, and one target among three distractors. Each individual picture (target and distractors) was rescaled to 200x200 pixels, and the visual angle of the stimulus was 5° by 5°. The size of each matrix was 600x600 pixels (visual angle: 15° by 15°), the background was black and individual pictures were separated with a 2-pts wide black boarder (see Figure 1). Thus, in the different matrix sizes, the stimuli were presented at different eccentricities, which is similar to how it was handled in previous studies using the same paradigm (Blanchette, 2006; Brown et al., 2010; Fox et al., 2007; Öhman et al., 2001; Soares et al., 2014).

The targets were presented in every possible location; in the smaller set size this meant four, and in the bigger set size, nine possible places. We used four types of targets (medium-arousal snake, high-arousal snake, medium-arousal gun, and high-arousal gun) and two types of distractors (flowers or cell phones). That is, for the smaller set size, 4 (location) x 4 (type of target) x 2 (type of distractor), and for the bigger set size, 9 (location) x 4 (type of target) x 2 (type of distractor). Thus, we had 104 stimuli where there was a target present; half of them with congruent and half with incongruent contexts. To avoid habituation and automatic responses, participants also saw 104 target-absent pictures, where there were only distractors without a target, resulting in 208 stimuli altogether.
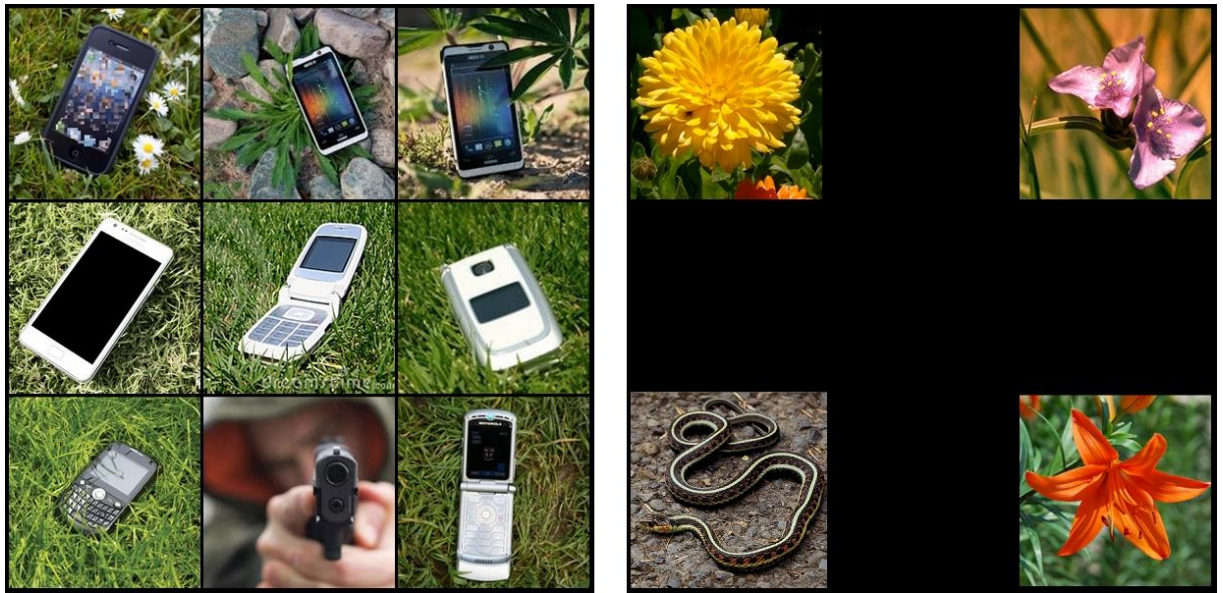
Figure 1 - Examples of the stimuli used in the present research. The bigger (3x3) set size on the left shows the target stimulus is a gun with high arousal level displayed among cell phone distractors. The smaller (2x2) set size on the right depicts a medium arousal level snake among flower distractors. Please note that IAPS pictures were replaced due to copyright issues.

Procedure

Participants completed the experiment individually. Each participant was seated at a distance of 60 centimetres from the monitor. The stimuli were presented on a 17-inch TFT colour monitor, with a visible area of 15.6 inches and a resolution of 1366x768, refresh rate of 60 Hz, and 24-bit colour format. A stimuli set was presented using DMASTR software (DMDX) developed at Monash University and at the University of Arizona by K. I. Forster and J. C. Forster.

Participants were instructed to detect the presence or absence of a target (snake, gun), among distractors (cell phones, flowers). A white fixation cross ($0.25°$ by $0.25°$), was displayed in the centre of the screen for 500 ms to indicate the onset of a trial, followed immediately by a stimulus display. The participants responded with pressing button "A" if the pictures they saw were all from the same category (i.e. nine flowers) or press button "L" if there was an odd-one among them (i.e. a snake among eight flowers). They always responded to targets with their dominant (right in all cases) index finger.

First, they saw 16 practice trials that we excluded from the data processing. Then the randomised experimental stimuli were presented, and reaction times were measured.

Results

The statistical analyses were performed using the JASP Statistics Program (Version 0.7 for Windows). We checked for errors and excluded the outliers, which were greater than ± 3 standard deviations of the group mean (< 2% of all the collected data). The missing data were replaced by the mean of the given variable.

The reaction time (RT) responses were analysed with a repeated-measures analysis of variance (*r*ANOVA) with factors as the type of distractors (flower or cell phone), set size (2x2 or 3x3), arousal (medium or high) and evolutionary age (snake or gun) as within-participants factor.

The two types of threatening targets differed ($F(1,52)=24.2$, $p<0.01$, $\eta_p^2 = .32$). Participants found non-evolutionary targets faster than evolutionary ones. Significant interaction was found between evolutionary age and arousal ($F(1,52)=6.8$, $p<0.05$, $\eta_p^2 = .12$). Interestingly, the two types of stimuli did not differ when presented at a medium arousal level; however, in the case of a high arousal level, they did. Participants found the modern threatening stimuli faster than the evolutionary old threatening ones. See Figure 2A for the RT differences between targets and Figure 2B for the interaction between the type of the target and arousal.

The two types of distractor images also differed ($F(1,52)=49.7$, $p<0.01$, $\eta_p^2= .49$), with lower RT for flowers than for cell phones. Significant interaction was found between set size and type of distractor ($F(1,52)=6$, $p<0.05$, $\eta_p^2 = .1$); in the case of the modern distractor, the RT was faster for the bigger set size, while in the case of the evolutionary distractor, the set size did not have an effect on the RT. See Figure 2C for RT differences between the two types of distractors and Figure 2D for the interaction between distractor types and set sizes. Set size and arousal did not show a main effect ($p>0.05$).
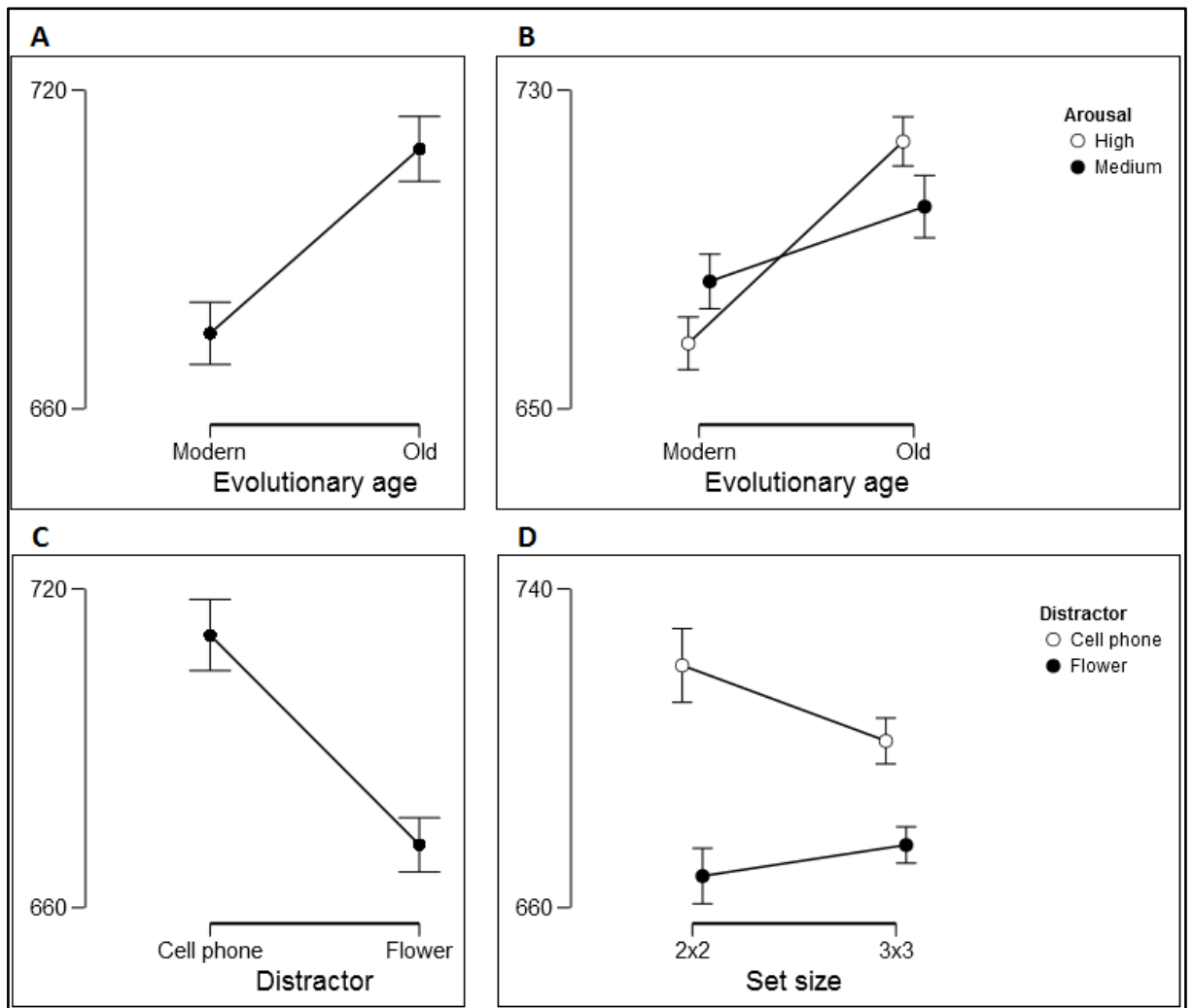
Figure 2 – (A) The main effect of evolutionary age. Lower RT was found for the modern threat – gun – than for evolutionary old threat – snake. (B) Significant interaction found between the type of the threat – modern vs. old – and level of arousal – medium and high. (C) The main effect of distractors. Lower RT for the evolutionary old flower than for the non-evolutionary cell phones. (D) Significant interaction between the type of the distractor – cell phone and flower – and set size – 2x2 and 3x3. Standard errors are displayed on all diagrams.

Discussion

Past research (Lipp & OV, 2006; Mineka & Öhman, 2002; Öhman & Mineka, 2003)has suggested that humans possess a "fear module" that underlies the rapid detection of potential threats to help survival. There is a dispute whether evolutionary fearsome stimuli have an advantage over modern threats in this process. Recent evidence highlights the importance of controlling for the context (Cao et al., 2014; Young et al., 2012) in which these cues are presented and the arousal (Lundqvist et al., 2014; Schimmack & Derryberry, 2005) level they have.

The aim of this study was to investigate the differences and similarities of evolutionary old and modern threatening stimuli, taking arousal into account, while also controlling for the context in which they appeared– both modern and evolutionary ancient. We examined this with a visual search task similar to the ones used in former experiments (e.g. Öhman et al., 2001; Blanchette, 2006; Soares et al., 2014). Participants saw images and they had to indicate whether there was an odd-one (snake or gun) between the distractors (background: flowers or cell phones), and their reaction times were measured. Our results showed that a modern non-threatening stimulus (cell phone) distracted attention more than did an evolutionary ancient one (flower), and modern fearsome cues (guns) capture attention faster than evolutionary old ones (snakes). The interactions indicate that the set size and arousal both have an influence in this.

We found that participants detected modern threatening pictures faster than ancient ones. This finding may be the behavioural manifestation of the stronger P1 amplitude increment for evolutionary modern over old stimuli that was shown by Brown et al. (2010). They concluded that there was no difference between evolutionary old and modern cues; it must be highlighted that they used knifes and syringes as modern fearsome stimuli, although they are not the best representatives of the category. In the theoretical background of our study, we investigated past research and proposed that the best representative of the modern threatening category is the gun. In line with the suggestion of Öhman & Mineka (2001) that guns are a specific category of modern stimuli that is strongly associated with danger and death, and they are lethal from a distance, thus giving people less time to react. Thus, we conclude that these facts, along

with growing up in industrialised environment, can result in faster response time to the best representative of modern threats over evolutionary fearsome stimuli.

In line with our hypothesis that arousal plays an important role in the procession of threatening stimuli, we found an interaction between the main effect of evolutionary age and arousal. In the case of medium arousal pictures (ones that faced sideways to the viewer), evolutionary relevance did not matter and that participants responded equally fast to old (snake) and modern (gun) threatening cues. However, when presented with high arousal stimuli (i.e. threat facing the viewer directly), the two types of fearsome stimuli differed and respondents found the modern cue faster than the evolutionarily relevant one.

If we recall the words of Öhman and Mineka (2001), the core difference is that guns are lethal from a distance, while snakes are only threats when they are close. Therefore, the adaptive response to a gun is to flee immediately, because running makes us harder to hit. It is irrelevant whether the gun is pointing somewhere else or directly at us. On the other hand, snakes are only lethal from a shorter distance, making the adaptive response different. If it is not bothered by us or is located far away, the best choice for a response is to escape, carefully, not raising its attention. However, if it is already close and staring at us, the best thing we can do is not to move, only to freeze and hope it will move away. Physiological results also support this idea (see Kreibig, 2010 for review), and, for example, it was shown (Dimberg, 1986) that evolutionary fearsome stimuli (snakes, spiders) evoked heartrate deceleration and larger skin conductance response magnitudes. Campbell and colleagues (Campbell, Wood, & McBride, 1997) wrote in detail about the evolutionary origins of automatic responses to threatening stimuli, highlighting parasympathetic activation, and freezing. This is called fear bradycardia (slow heart rate), and is an adaptive response to predators and fearful, evolutionary relevant stimuli, when they are about to attack.

The main effect of the context, i.e. targets were found faster among cell phones than flowers, is not surprising, given the previous research (Young et al., 2012). However, Cao et al. (2014) showed that participants tend to find the target faster in congruent setups – i.e. evolutionary old target in a natural context. In our case, it did not matter whether participants had to find a modern or ancient threat; they always found the target faster in

the case of ancient distractors. This can be interpreted that evolutionary modern stimuli (cell phones) distract attention more than evolutionary modern ones, even though flowers are more colourful and diverse. There is one key difference between the previous experiments (Young et al., 2012; Cao et al., 2014) and ours: the context was represented in two different ways. They used pictures of human-made and natural scenarios as priming images, while we used a classic setting, where distractors are the context. This means that they primed their participants with a superordinate category (human-made and evolutionary old), and thus they showed this priming effect. In the present study, however, the target was presented in the context, thus giving the experiment more ecological validity. Considering our modern world, we suggest that cell phones are more relevant to people and thus more distracting in an attentional task than flowers.

The interaction between this main effect of the distractors and set size indicates that the case of the context is not so simple. The perceptual load had no effect in the case of evolutionary ancient distractors (flowers), but it did have an effect in the case of modern ones (cell phones). Reaction times decreased when the perceptual load increased, but participants were still slower to detect the target among cell phones, compared to flower distractors. This means that the visual search task was processed automatically when evolutionary ancient stimuli were present. However, this is not automatic in the case of modern threats. We suggest that flowers are not as relevant of a stimulus to people nowadays as are phones, thus distracting less attentional capacity and allowing an automated visual search. In contrast, the visual search was not automatic for modern distractors and we propose that participants used different methods to find the target in small and large display sizes. It took more time to find the target in smaller displays because the four pictures were presented in the corners of the visual field with no image right next to them, thus participants had to look at them one by one, covering a fairly large area. On the other hand, a large display meant that pictures filled the visual area, and thus the target popped out more, because the images next to it were different. This resulted in faster reaction time in the larger display compared to smaller display size, but since the process was not automatic, the detection of the target was still slower than in the case of ancient distractors and automatic processing.

In sum, Experiment 1 indicates that there is a new perspective in the phylogenetic – ontogenetic dispute: the level of arousal. We compared the best representatives of

evolutionary (snake) and non-evolutionary (gun) threats, while controlling for the level of arousal, evolutionary relevance of distractors, and the display size. Results show a slight advantage to modern fearsome stimuli over evolutionary ones. The level of arousal had a significant effect on the detection of these stimuli, participants responded in different ways to medium and highly arousing cues. Of course, the fact that we used only one representative of the evolutionary relevant and irrelevant categories is a limitation; in the future it would be necessary to explore this effect with more stimuli from the respective categories. Future research should also pay attention to the distractors and display sizes, because the modern neutral stimuli distracted attention more, and when they were presented more dispersedly, participants were slower to find the target.

Conclusions

The aim of this study was to investigate whether there is an evolutionary age effect in the case of threatening stimuli when controlled for the arousal level (medium, high) of the pictures and the context and background (modern, ancient). It was successfully demonstrated that the two types of target stimuli cannot be merged into one category; people react to them in a different way. Arousal is also a key factor, as we saw it is important whether participants see the threat directly pointing at them, causing a highly arousing emotional state. In the case of evolutionary stimuli, it evoked different responses: flight in the case of the medium arousal versus freeze in the case of highly arousing snake.

Experiment 2 – Testing the reactions of specially trained firemen to threat

Aims and hypotheses

In the present experiment, our goal is twofold: First, to test how a group of firemen with special previous training would perform in the classic visual search task. Second, to compare the results between this group to a control group of young adults without any previous training. To our best knowledge, this is the first study to assess firemen and controls on the same visual search task. According to previous research (Hemmatjo et al., 2017) our hypotheses are that firemen would have similar results to students, i.e. they would find modern threatening cues faster than evolutionary relevant ones. Moreover, we predict that they would be faster overall on the same task when compared to students.

Method

Participants

Twenty-two firemen (between the age of 25 to 45, all of them are males) participated in the experiment during the Healthcare Day of the Baranya Country Organisation for Rescue Services, which was a mandatory program for the participants. Data from two participants were excluded because of failure to follow instruction. All participants were right-handed with normal or corrected-to-normal vision. None of them had a history of neurological diseases or mental disorders, as noted through self-report.

Experimental stimuli

The exact same stimuli set was used as described in Experiment 1.

Procedure

We tried to match the procedure as close as possible to the previously described experiment. However, we had to relocate the necessary equipment to conduct the experiment to the headquarter of the Baranya Country Organisation for Rescue Services. Here, participants completed the experiment in individual workstations while others were filling out questionnaires in the same room. Each participant was seated at a distance of approximately 60 centimetres from the monitor of the laptop. Two Dell Inspiron 15 laptops were used with identical hardware setup and the monitor properties were also matched. The stimuli were presented on the 15.6-inch (visible area) colour monitor of the laptops and a resolution of 1366x768, refresh rate of 60 Hz, and 24-bit colour format. A stimuli set was presented using the same DMASTR software (DMDX) developed at Monash University and at the University of Arizona by K. I. Forster and J. C. Forster.

Participants were asked to detect the presence or absence of a target (snake, gun), among distractors (cell phones, flowers). First, they saw the white fixation cross in the centre of the screen for 500 ms, followed immediately by a stimulus display. The participants responded with either pressing button "A" – if the pictures presented belonged to the same category (i.e. nine flowers) – or pressing button "L" – if there was an odd-one among them (i.e. a snake among eight flowers). Participants always responded to target-present trials with their dominant index finger; and used the subdominant index finger for target-absent trials. Similarly to the previous experiment participants started with 16 trial exemplars. These were excluded from further data processing. Then the randomised experimental stimuli were presented, and reaction times were measured.

Results

The statistical analysis was performed using the JASP Statistics Program (Version 0.7 for Windows). We checked for input errors and excluded the outliers, which were greater than ±3 standard deviations (< 2% of all the collected data). Wrong answers were considered as system missing. After this, mean reaction time (RT) were calculated for each category.

The RT responses were analysed with a repeated-measures analysis of variance (ANOVA) for multiple factors. These factors were: the set size (2x2 or 3x3), the type of distractors (flower or cell phone), the evolutionary age of the target (snake or gun), and arousal level of the target (medium or high).

The two types of threatening targets differed ($F(1,21)=8.68$, $p<.01$, $\eta_p^2 = .29$). Participants found non-evolutionary targets faster than evolutionary ones. The type of the distractor also had a significant effect ($F(1,21)=44.02$, $p<.01$, $\eta_p^2 = .68$), which means that targets could be found faster among flowers compared to cell phones. In addition, respondents were able to detect the targets faster in smaller than bigger set size ($F(1,21)=42.01$, $p<.01$, $\eta_p^2 = .67$). The level of arousal did not matter ($p>.05$).

The analysis also yielded a two-way and a three-way interaction. The first one was found between the set size and the type of distractors ($F(1,21)=14.28$, $p<.01$, $\eta p2 = .41$) indicating that when targets had to be found among modern distractors (cell phones), the set size did not matter, participants were equally faster in the 2x2 and 3x3 settings. Conversely, they were faster to find the target in the smaller setting compared to the bigger one among evolutionary older distractors (flowers).

The three-way interaction was found between the set size (see Figure 3), the type of the distractor, and the type of the target ($F(1,21)=9.07$, $p<.01$, $\eta_p^2 = .30$), meaning that the previous effect varies with the type of the target. Further analysis revealed that only the type of distractor has a main effect when the target was a snake ($F(1,21)=24.12$, $p<.01$, $\eta_p^2 = .54$). In the 3x3 set size, there was no difference between the two types of distractors. However, in the 2x2 setting snake was found faster among flowers than among phones. We also analysed the cases when the target was a gun. In this setting, we found significant effect for both set sizes ($F(1,21)=12.36$, $p<.01$, $\eta_p^2 = .37$) and the type of the distractor ($F(1,21)=24.59$, $p<.01$, $\eta_p^2 = .54$). This indicates that the gun was found faster in a 2x2 matrix compared to the bigger one, and participants were also faster to find it among flowers than cell phones.
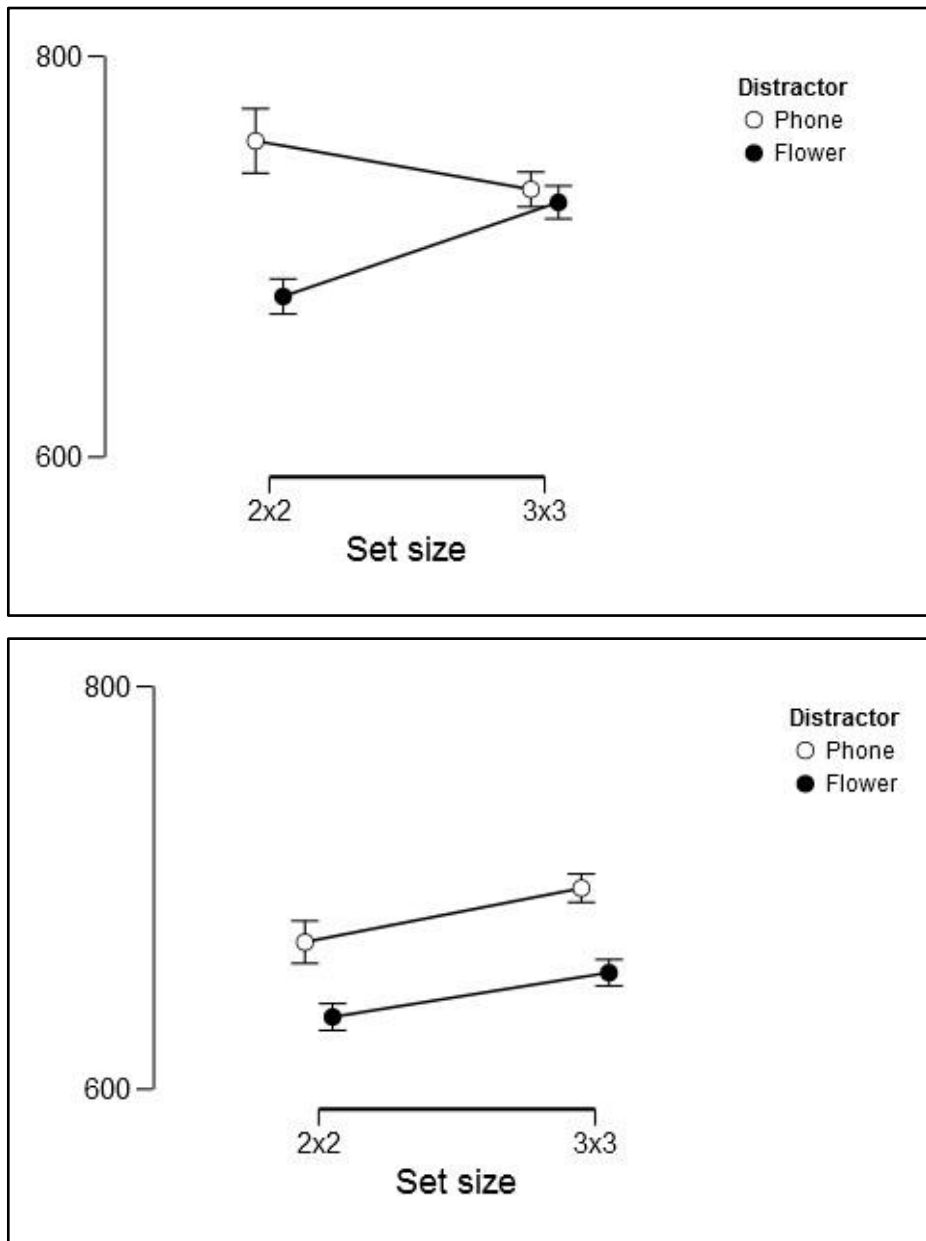
Figure 3 – On the upper graph, the interaction between set size (2x2 and 3x3) and distractor type (cell-phone and flower) when snakes served as targets. Lower RT was found for the evolutionary relevant threat – snake – when it was shown among flowers than among phones. On the lower graph, the same interaction when the target was a gun. The modern threatening stimulus was found faster in smaller matrices compared to the bigger ones, moreover, it was also easier to detect among flowers than cell phones. Standard errors are displayed on the diagrams.

Comparison of the two samples

To assess group differences, the datasets containing the results of University students and firemen were merged. The RT responses were analysed with a mixed analysis of variance for the following within subject factors: the set size (2x2 or 3x3), the type of distractors (flower or cell phone), the evolutionary age of the target (snake or gun), and arousal level of the target (medium or high). The grouping variable was entered as the between subject factor. Our main goal here was to identify the differences in the pattern of the reactions of the two groups. The main effect of the group was not significant, therefore, results regarding between subject factors will not be reported. We will focus on the results of interactions and discuss the possible implications more in details.

We found two two-way interactions. The first one is a tendency between the type of target and group ($F(1,73)=3.53$, $p=.06$, $\eta_p^2 = .03$). The group of firemen found guns faster than the group of students, however, students were able to detect snakes more quickly compared to firemen. See Figure 4 for the interaction. Groups also differed in the reaction to the two set sizes – as it is seen from the set size X group significant interaction ($F(1,73)=5.34$, $p<.05$, $\eta_p^2 = .07$). The performance of students was not affected by the number of pictures present, i.e. 2x2 or 3x3; however, interestingly, the performance of firemen did change. They were faster to find the target in smaller matrices; compared to students, and the bigger set size. Moreover, they were slower to find the target in bigger matrices, again, compared to students and the small set size. The other interactions and the within subject factor was not significant ($p>.1$).
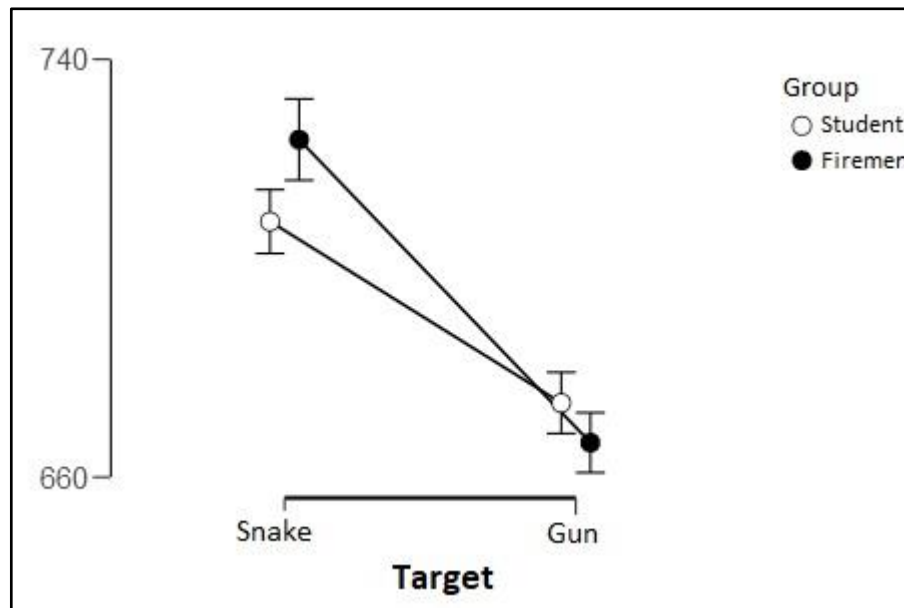
Figure 4 – Interaction between the target type (snake and gun) and the two groups (students and firemen). Interestingly, when participants had to find a snake as the target, University students were faster. However, when the target was a gun, lower RT was found for firemen. Both groups found guns quicker compared to snakes. Standard errors are displayed on the diagrams.

Discussion

In this study, we compared the detection of modern and evolutionary relevant stimuli in a well-established visual search task, namely the odd-one-out paradigm. The novelty of Experiment 2 was the participants involved, a group of firemen with relevant training and previous experiences of how to cope with highly dangerous situation. After testing them, we also merged the data with our previous dataset on young adults performing the same task and ran further analyses to compare the two groups. According to our results, firefighters found the modern threat (i.e. gun) faster than the evolutionary relevant (i.e. snake). The type of distractor and set size also had a significant main effect such that participants were faster to find the target when it was presented among evolutionary relevant distractors (i.e. flowers) compared to modern ones (i.e. cell-phones), and that the RT was found lower for smaller (2x2) compared to bigger (3x3) set sizes. Moreover, these results seem to be related to the origin of the target such that evolutionary relevant target was found faster among congruent (evolutionary relevant) distractors compared to incongruent (modern) ones in the smaller matrices. In contrast,

subjects were able to detect modern threatening target faster among incongruent (evolutionary relevant) distractors compared to congruent (modern) ones in both matrix sizes.

Taken this together, it seems plausible to claim that people having a dangerous profession found modern threatening cues faster, even if they have not received previous training involving weapons. Although, mainly as a consequence of the age gap, many of the firefighters reported that they have been recruited as enlisted men (mandatory service in the army) as young adults. Moreover, the significant interactions are highly interesting and surprising in the sense that processing of threatening stimuli are considered as automatic (Öhman et al., 2001; Öhman & Mineka, 2001), which means that they could be found equally as fast regardless of the number of distractors around them. One possible explanation of this result would be that a non-automatic process happens right after the automatic process. That is, subjects automatically detect the threatening target, and then 'double-check' the visual field once again to make sure they identified the target correctly. As it is important not to forget that in 50% of the cases there were no target present. Subjective reports after completing the task seems to support this. The majority of the participants wanted to know how accurate they were, and they tried to compete with their peers with their results. Further studies should take these motivational and subjective variables into account as well, even though this might be hard to control for in such an experiment.

After adding the young adults' data to the database of firemen, we conducted further analyses to reveal group differences and within X between subject factor interactions. We did find two interactions: One between group and the type of target, the other, interestingly, between group and set size. The first interaction, although was only found to be marginally significant, showed that firefighters found the modern targets faster than young adults; at the same time, students were faster to find evolutionary threatening targets faster than firemen. Regarding the set size interaction, it seems that firemen found targets faster than young adults in small matrices, while in bigger matrices firemen were faster to detect the targets compared to young adults. Moreover, it is also important to point out that the performance of young adults was not affected by the number of distractors present.

When drawing the interference, the fact should not be neglected that the interaction between group and type of target was only found to be marginally significant. Taken the effect size into account as well, one might argue that this would have been a Type I error, as the effect size is rather low. On the other hand, if we take group sizes into account as well, this might very well be a Type II error in the sense that controls (n = 53) were more than twice as many as firemen (n = 22). This imbalance and the relatively small size of the special group can be considered as a weak point of the present study. Nonetheless, this interaction, if proven to be valid, would suggest that firefighters are more prone to the threats of the modern world, or at least to guns. Therefore, further investigation on this is needed in the future to answer this question.

The interaction found between the set size and groups might help us to understand the main effect of the set size in firemen. If we take the results of the young adults as a hypothetic baseline, we might argue, that firemen engage in a trade-off between speed and accuracy. In the easier task, when the number of distractor is smaller, they are answering very rapidly, because the chance of missing a target is lower (again, note that 50% of the trials was target-absent). However, when it comes to more distractors, and, at least as they think, the chance of a wrong answer is higher, they double-check the visual field and the presence of the target again, resulting in longer RT.

As any experiment, the present one has some limitations as well. We think it is important to draw attention to the lack of exact age values in the special sample. They were, on average 10 years older than the controls, however, knowing the exact values would add the understanding of the results. For instance, knowing that RT increases with age (Der & Deary, 2006; Fozard, Vercruyssen, Reynolds, Hancock, & Quilter, 1994; Weiss, 1965), it is possible that we miss such a crucial result that firefighters react as quickly as young adults, even by growing older; which would show that not finding a group difference is indeed what makes this group special. Moreover, further research tapping into the differences of firefighters and young adults should also control for the possible confounding effects of motivation (Weiss, 1965). Nonetheless, it is also a question to be answered, whether the present task would be threatening enough to discriminate between the two groups.

Despite these shortcomings, the present study is valuable as this is the first one to compare a group of specially trained people with average young adults. According to our results, the two groups did differ in the detection of threatening stimuli, and possibly using different strategies to scan the visual field for potential threats. However, we would like to underscore that this is only the first step toward describing these differences and, therefore, more studies should include special groups (e.g. police officers, sensation seekers, etc) to the analyses. Young adults from the university may be a somewhat representative sample of average population when it comes to visual threat detection, nevertheless, by recruiting people with previous experiences in surviving a highly threatening and demanding situation might be the next step towards helping average people cope with such situations.

Experiment 3 – The underlying mechanisms of detecting threatening cues with different origins

Aims and hypotheses

To this date, there is no research using the classical VST in order directly compare evolutionary old and modern threatening stimuli that are both familiar to children in a sense that they reportedly had encounters with them. The aim of our research is to fill this gap. Based on the literature review, it appears that the advantage for evolutionary cues is driven by general features, such as perceptual properties of the threats (Coelho & Purkis, 2009; Davey, 1995). On the contrary, we predict that for modern stimuli the detection is based on a sufficient amount of similarities with the exemplar (Nosofsky & Johansen, 2000; Osherson & Smith, 1981) of a given category. Our first hypothesis was that both types of threatening cues are found equally as quickly, and faster than non-threatening cues. Furthermore, we had a second, more exploratory hypothesis that the visual similarity between threatening and non-threatening targets may contribute to the understanding of the underlying mechanisms for detecting threatening cues such that different strategies might be used for evolutionary relevant and modern exemplars.

Method

The paradigm used in this paper is similar to what previous studies (LoBue, 2010a, 2010b; LoBue & DeLoache, 2008) developed to test the attentional bias towards threatening stimuli in children. Here, participants see nine pictures at a time in a 3x3 block arrangement. One of the pictures, the *target,* is different from the others. Henceforth, pictures other than the target that were included in the visual search task will be referred to as *background* images.

However, our paradigm includes some changes and novelties compared to those used in previous studies. We directly compared modern and evolutionary relevant threatening and non-threatening targets among neutral distractor images (both modern and ancient) that never served as targets, to avoid any confusion. Thus, a 2x2x2 design was used with type of background (i.e., evolutionary and modern), origin of target (i.e.,

evolutionary and modern), and threat level of target (i.e., threatening vs. neutral) as fixed factors.

Images within respective target categories (evolutionary relevant, modern) were similar in shape and pose; and all pictures used were averaged for low-level visual features. This allows us to test the threat advantage hypothesis in a population of children, and rules out variables that were previously proven to be confusing (Quinlan, 2013; Quinlan et al., 2017); for instance, distracter picture only serving as a background, and not a target.

Participants

Sixty-eight (33 girls, 35 boys) preschool children participated in our experiment in exchange for small gifts (i.e. stickers or erasers). Their mean age was 5.5 years (S.D. = 0.6). All of them were right-handed with normal or corrected-to-normal vision, as reported by their parents. We also asked some control questions about their handedness (i.e. "Which hand do you use to hold your spoon when eating?"). Testing was carried out during a previously set one-week interval with the contribution of an institute that oversees several kindergartens in the region. Data from six children were excluded because of failure to follow the instruction, and one child did not want to proceed after the trial phase. Our research was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki), an informed consent was obtained from parents, and oral consent from children.

Stimuli

The stimuli consisted of targets and background images. All of the pictures were taken from the internet. There were four types of targets based on the level of threat (fearful and neutral) and the evolutionary age (modern and old). We sourced nine exemplars of each target category. Spiders were used as evolutionary threats, and ladybirds as a neutral control; the modern threatening cues were pictures of syringes, and pens were used as a neutral control. When sourcing the images, steps were taken to attempt to control and match the pose of the respective threatening cues with their neutral

counterparts. Ratings of the threat of images were assessed using a visual analogue scale (transformed to scores 0–100, higher scores mean higher perceived threat level) by our participants after completing the visual search task. The threatening targets (evolutionary relevant $M = 69.12$, $SD = 46.54$; modern $M = 66.18$, $SD = 47.66$) were rated as more threatening than the non-threatening ones (evolutionary relevant $M = 11.77$, $SD = 32.46$; modern $M = 10.29$, $SD = 30.61$; $F(1,67) = 133.35$, $p < 0.01$), the modern and ancient threatening and non-threatening groups did not differ from each other, and there was no interaction between type and origin of the stimulus (Fs < 1, ps > 0.1). All participants reported that they are familiar with the targets, i.e., they have previously encountered them on more than one occasion. In each case this was also confirmed by one of their parents.

Different targets and backgrounds were used to avoid possible confusion in children between the tasks. We used two types of backgrounds, pictures of bushes serving as evolutionary relevant and mugs as modern ones. There were 16 exemplars of both categories.

After collecting the images, we used the Spectrum, Histogram, and Intensity Normalization and Equalization (SHINE) toolbox (Willenbockel et al., 2010) written with MATLAB to control the low-level visual features (luminance, contrast, spatial frequency). The matching steps were applied to the whole images. All the images (threatening, non-threatening targets, and backgrounds) were loaded in the program and converted to grayscale, then, the low-level properties were equated among them.

First, the luminance and contrast values were matched using exact histogram matching across images. The image histogram is a graphical representation of the tonal distribution in a digital image that plots the number of pixels for each tonal value. For each image, a histogram is extracted, then, the average histogram is calculated and applied to the original images.

Then, the sfMatch function equates the rotational average of the Fourier amplitude spectrum (i.e., the average energy at each spatial frequency) of the histogram matched images. The structural similarity (SSIM) indexes between the images were also optimised, for maximising perceptual image quality (using 3 iterations). Therefore, after

passing through this process, every image had the same luminance, contrast, and spatial frequency levels.

Then, the 3x3 sets were created in a block arrangement (measuring 22.45° x 22.45° in total), with eight background images (measuring 7.57° x 7.57° each) of the same category, and one target image (same size as background pictures). Images were separated with a 2pts wide white border. All four targets were presented in each of the nine possible locations; among both types of background images. Thus, the stimuli set consisted of 72 matrices. See Figure 5 for exemplars of the final stimuli set.
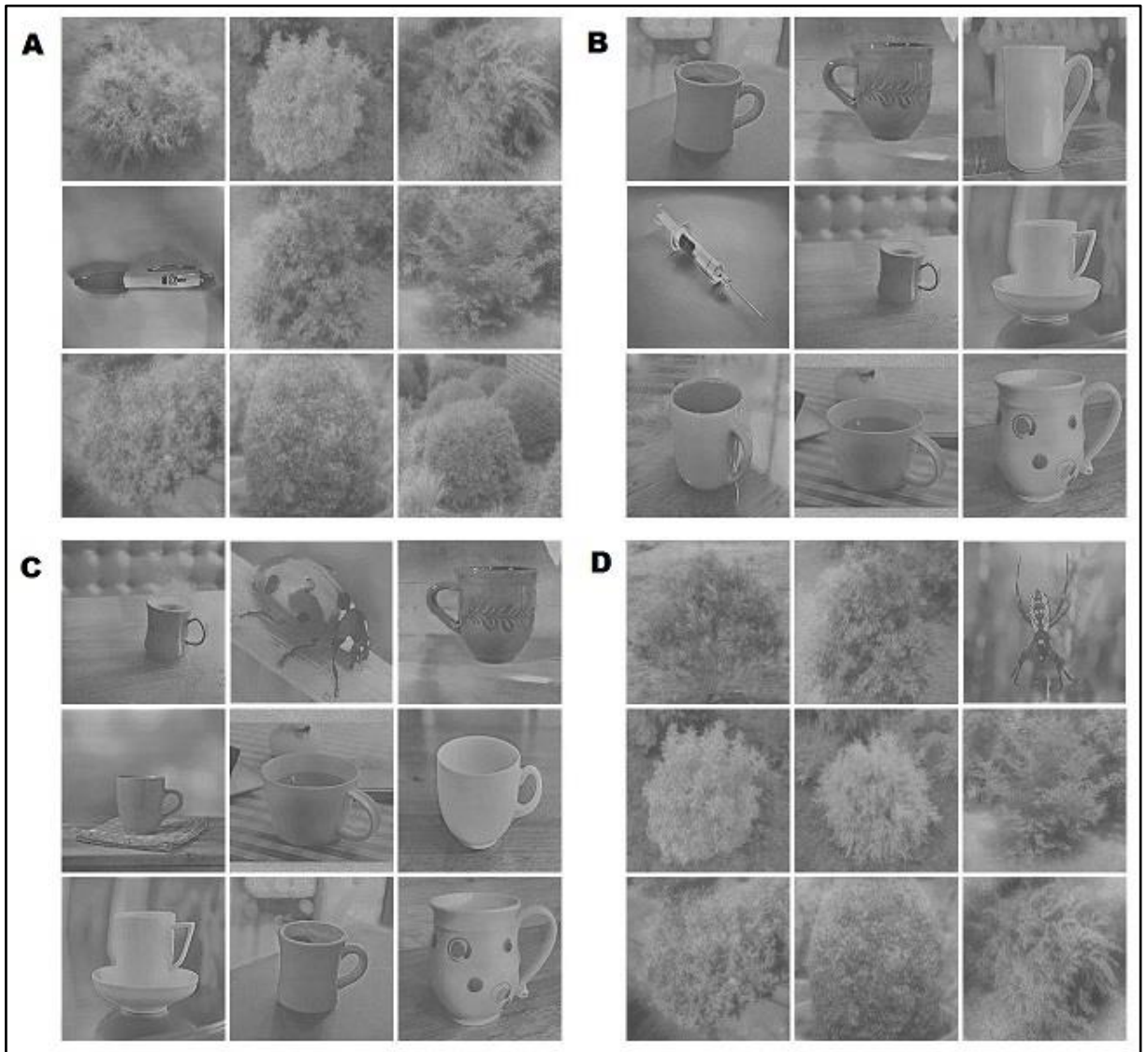
Figure 5 – Exemplars of the final stimuli set. These are four of the possible eight arrangements: **A**/ modern neutral target among evolutionary background, **B**/ modern threatening target among modern distractors, **C**/ evolutionary neutral target among modern distractors, and **D**/ evolutionary target among evolutionary distractors.

Procedure

Each participant was tested individually in a quiet room of the kindergarten. First, they were taught to use the touch screen monitor. Then, the experimenter helped the child to create a drawing of their own right hand on a sheet of paper. They were asked to place the right hand on this paper between trials. After this, children were seated approximately 40 cm in front of a 17-inch LCD Touchscreen colour monitor with a visible area of 15 inches and a resolution of 1366x768, refresh rate of 60 Hz, 24-bit colour format. The stimuli set was presented using PsychoPy Software version 1.83 for Windows (Peirce, 2007).

First, they completed five warm-up matrices, starting with two exemplars where there were only two images present and they had to press the picture showing a flower. Then, there were three exemplars displaying four pictures at a time, and children had to select the pen or the ladybird. After that, they saw four 3x3 test trial matrices, one with each target; these were not included in further analyses. If the experimenter saw that they understood the task, and the children also gave their oral consent to continue, the experiment was started. Respondents completed the experiment in two sessions with a short break in between. The instruction was to find the picture that is different from the others; the targets were named before the stimuli presentation started. Children placed their right hands on the paper in front of them, the experimenter started the stimulus by hitting a button on the keyboard, and then, they had to indicate the location of the target by pressing it on the touchscreen monitor. Upon completing both tasks, they could choose the little gift for their efforts.

Results

Reaction times were averaged over trials yielding eight variables based on three factors: type of background (i.e., evolutionary and modern), origin of target (i.e., evolutionary and modern), and threat level of target (i.e., threatening vs. neutral). These were then entered in a three-way repeated measures ANOVA as fixed factors. Please note that the results have been corrected for multiple comparisons using the Benjamini–Hochberg procedure.

The analysis revealed statistically significant main effects of threat level ($F(1,66)$ = 41.68, $p < 0.01$, $\eta_p^2 = .39$) such that participants found threatening targets faster. The main effect of background was also significant ($F(1,66) = 400.244$, $p < 0.01$, $\eta_p^2 = .86$), indicating that the targets were detected more quickly on the evolutionary relevant background. In sum, the main effect of threat level revealed that children found threatening images (M = 1.90 sec, SD = 0.20) faster than they found non-threatening images (M = 2.01 sec, SD = 0.26), and were systematically faster when evolutionary old pictures served as background (M = 1.81 sec, SD = 0.21), compared to modern (M = 2.11 sec, SD = 0.26) ones.

In addition, the threat level x origin of target image ($F(1,66) = 70.86$, $p<0.01$, η_p^2 = .52), threat level x background ($F(1,66) = 26.83$, $p<0.01$, $\eta_p^2 = .29$), and origin of target x background ($F(1,66) = 25.29$, $p<0.01$, $\eta_p^2 = .28$) interactions also reached statistical significance. The three-way interaction was also significant ($F(1,66) = 28.63$, $p<0.01$, $\eta_p^2 = .30$). We used paired samples t-tests to follow up the results of the two-way interactions.

Interestingly, the interaction between threat level and origin of the target showed that participants found modern neutral targets (M = 2.10 sec, SD = 0.36) slower compared to modern threatening (M = 1.87 sec, SD = 0.24, $t(67)$ = 9.24, $p<0.01$, *Cohen's d* = 1.12), evolutionary neutral (M = 1.92 sec, SD = 0.23, $t(67)$ = 5.12, $p<0.01$, *Cohen's d* = 0.62), and evolutionary threatening (M = 1.93 sec, SD = 0.23, $t(67)$ = 4.26, $p<0.01$, *Cohen's d* = 0.52) ones. See Figure 2 for the interaction. Furthermore, the test for evolutionary relevant vs. modern threatening stimuli ($t(67)$ = 2.13, $p<0.05$, *Cohen's d* = 0.26) was found significant, however, this did not survive the correction for multiple comparisons. Also, the effect size was small.
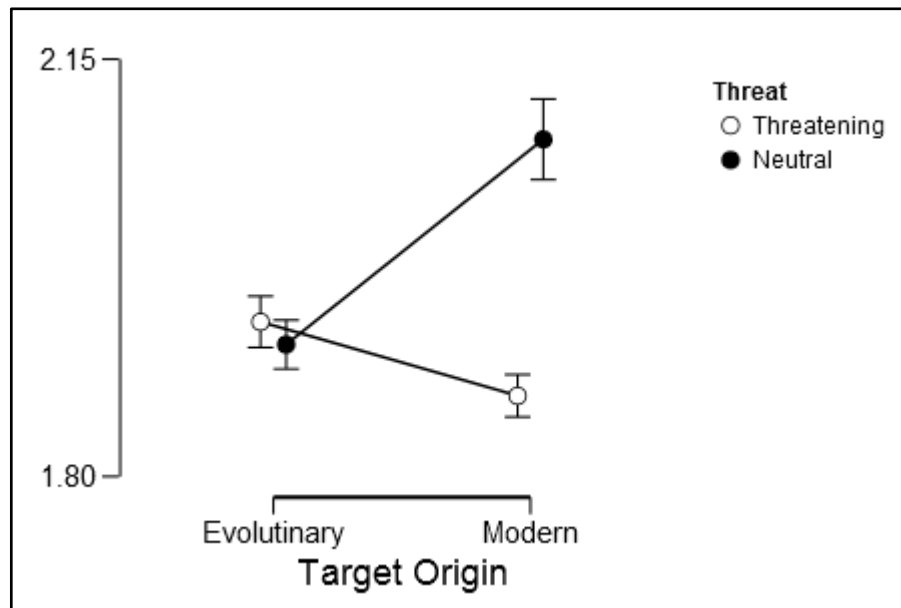
Figure 6 – The significant interaction between the threat level (threatening and neutral) and origin (evolutionary or modern) of the Target. The evolutionary stimuli were spider and ladybug, while modern ones were syringe and pen. Standard errors are shown.

The threat x background interaction was also followed up with paired sample t-tests (again, controlled for multiple comparisons). Participants found the threatening cues ($M = 2.02$ sec, $SD = 0.25$) significantly more quickly than the non-threatening ones ($M = 2.20$ sec, $SD = 0.31$; $t(67) = 6.78$, $p < 0.01$, *Cohen's d* $= 0.82$) on modern backgrounds. While the same difference for threatening ($M = 1.79$ sec, $SD = 0.19$) and non-threatening ($M = 1.82$ sec, $SD = 0.24$) stimuli on evolutionary background was only marginally significant ($t(67) = 1.76$, $p < 0.05$, *Cohen's d* $= 0.21$) with a rather small effect size. This suggests that the effect of threat level, i.e., finding threatening stimuli faster compared to neutral stimuli, is more robust when the background consists of modern cues.

The two follow-up ANOVAs on the three-way interaction revealed that the two-way interaction found between threat level and origin of target is significant on both evolutionary relevant ($F(1,66) = 11.07$, $p < 0.01$, $\eta_p^2 = .14$) and modern ($F(1,66) = 74.60$, $p < 0.01$, $\eta_p^2 = .53$) backgrounds. However, there are two differences: all four categories of target were found significantly more quickly on an evolutionary relevant background compared to modern background. Table 3 shows the mean scores and standard deviations

for all types of targets on both types of backgrounds; and results of paired samples t-tests regarding the differences when a target is present on a modern and an evolutionary background.

Table 3 – Mean scores and standard deviations (displayed in seconds) for the four types of targets (evolutionary relevant and modern x threatening and non-threatening) on two different types of background (evolutionary relevant and modern). Paired samples t-tests show the differences when a target is present on a modern and an evolutionary background.

Target	Background	N	Mean	SD	Statistics
Evolutionary threatening	Modern	68	2.044	0.289	$t(67) = 7.81$, p < 0.01, *Cohen's d = 0.95*
	Evolutionary	68	1.823	0.230	
Evolutionary non-threatening	Modern	68	2.038	0.257	$t(67) = 8.95$, p < 0.01, *Cohen's d = 1.09*
	Evolutionary	68	1.800	0.254	
Modern threatening	Modern	68	1.986	0.272	$t(67) = 10.47$, p < 0.01, *Cohen's d = 1.28*
	Evolutionary	68	1.756	0.220	
Modern non-threatening	Modern	68	2.358	0.448	$t(67) = 15.19$, p < 0.01, *Cohen's d = 1.84*
	Evolutionary	68	1.840	0.315	

Moreover, the main effects of target origin ($F(1,66) = 15.36$, $p<0.01$, $\eta_p2 = .19$) and threat level ($F(1,66) = 46.00$, $p<0.01$, $\eta_p^2 = .41$) were only found significant when targets were presented on a modern background. In contrast, the two-way threat level x target origin interaction, when targets were presented on an evolutionary relevant background, was caused by modern threatening targets being found faster compared to modern non-threatening ones ($t(67) = 3.21$, $p < 0.01$, *Cohen's d = 0.39*).

Discussion

We investigated whether the perception and detection of evolutionary relevant and modern threatening cues are equally quick, while controlling for several important variables such as background – *context* –, shape of the target, and low-level visual features. We have found that children spot the threatening targets more quickly compared to the neutral ones. Furthermore, if we compare these results to those of the evolutionary relevant stimuli, the children found the threatening cues equally as quickly. Therefore, we claim that as young as preschool children detect threatening cues faster, regardless of the evolutionary origin of the cues, if they have previous negative experience with them. Hence, we support the findings of previous research (Blanchette, 2006; LoBue, 2010b) that arrived at the conclusion that threat-relevancy matters the most.

Nonetheless, the picture is not at all that clear, since we also found several interactions. The three-way interaction between the threat level of target and background type showed us that the context in which the targets are presented matters such that participants found the targets faster when the targets were positioned among evolutionary relevant distractors compared to modern ones – regardless of target origin and threat level. This might be the consequence of the distractors used. The recognition of natural scenes and images (e.g., bushes) is automatic (Csathó, van der Linden, & Gács, 2015), and thus, requires less effort compared to the recognition of modern (e.g., cups) images. Hence, we suggest that the automatic detection of the background might made the task as easy as detecting a cue without any distractors, thereby resulting in nearly similar reaction times for all the categories used.

The question of whether there are stimuli that have an advantage in attentional processing has been a topic of wide scientific interest during the past decades (Brosch & Sharma, 2005; Gomes et al., 2017; Öhman, 1986). An increasing number of studies suggest that threatening cues with evolutionary relevance are processed quickly and draw attention automatically (Öhman, Flykt, & Esteves, 2001; Purkis & Lipp, 2007, Shibasaki & Kawai, 2009). It was also shown that there are some modern threatening objects that can elicit the same response (Blanchette, 2006; LoBue, 2010b; Zsido et al., 2017). In previous work, LoBue (2014) showed that threatening evolutionary relevant stimuli are processed based on their shapes (see also Rakison & Derringer, 2008; Wolfe et al., 1992).

This supports a general feature detection theory (Coelho & Purkis, 2009; Davey, 1995). In contrast, the mechanism behind the perception of threatening but modern cues remains under-researched which calls for a similar investigation of stimuli encoded during ontogenetic learning.

Therefore, we included evolutionary relevant and modern non-threatening targets that are highly similar in shape to the threatening cues. Based on the reviewed literature, if children detect the visually similar non-threatening and threatening targets equally as quickly, that may suggest that the detection is driven by general features (e.g., shapes, shadows, being followed, stared at, etc., see Coelho & Purkis, 2009; Davey, 1995), and therefore the visually similar non-threatening object evokes a similar response to the threatening object. This was the case for evolutionary relevant targets, which might suggest that throughout the course of evolution the trade-off between unnecessary alarm and the cost of fewer missed warnings proved to be cost-effective.

In contrast, if children detect the non-threatening targets more slowly than threatening ones, that might imply that the underlying mechanism of threat detection is based on a sufficient amount of similarities with the exemplar (Nosofsky & Johansen, 2000; Osherson & Smith, 1981) of a given category. That is, the visual similarity between threatening and non-threatening cues is irrelevant or might slightly slow down the response. We saw this pattern for modern cues which may suggest that fear acquisition (Rachman, 1977) and detection works differently for modern cues.

Some limitations of this study will be noted. First, the number of exemplars used per category may limit the generalisation of our findings. The design we used was based on previous studies. In addition, using more stimuli might lead to worse performance in children at this age which might lead to confounded results. Despite this limitation, given the sample size, our results are robust and could open new questions. Indeed, it would be interesting for further studies to include different exemplars. Similarly, the number and type (e.g., non-threatening animals and objects) of distractors used could be extended. Moreover, our suggestion on the differences between detecting evolutionary relevant and modern threatening cues is somewhat speculative as it is based on the visual similarity of the pictures used. Only a comparison of visually similar and different targets could prove this argumentation valid.

These limitations notwithstanding, in sum, the current study aimed to investigate the evolutionary constraints on the detection of evolutionary relevant and modern threatening stimuli in preschool children. Our results suggest a threat superiority effect, such that threatening cues are found faster than non-threatening ones. However, evolutionary age comes into play: a general feature-based detection describes the detection of stimuli with evolutionary relevance regardless of the threat level. On the other hand, results suggest a specific feature-based detection for modern cues, and, therefore, fast detection only applies to threatening stimuli. Overall, these findings contribute to a growing body of evidence on the fast detection of threatening stimuli and they describe the differences between evolutionary old and modern cues in the acquisition of fear.

General Discussion

The goal of the first study was to show that beside evolutionary old stimuli, modern threatening cues must be considered; moreover, that arousal should have a highlighted role in this comparison. The present study was the first to compare ontogenetic and phylogenetic stimuli in a visual search task where the effects of the context and the level of arousal are also considered. We conducted three experiments, using different samples – young adults as control, a group with special background, and preschool children. Our hypothesis was that arousal does have a crucial role in the evaluation of a threatening cue, and higher levels of it would mean faster detection. In the first experiment, the results suggest that arousal indeed is a very important factor. Thus, future research should avoid mixing them to avoid possibly confounding results. Indeed, it we had not had these two categories, we would know little about the striking interaction between arousal level and target origin. Which we consider the main finding of the first experiment. The interaction shows that when the targets are moderately arousing, they act similarly in a sense that respondents detect them equally as fast. In contrast, however, high arousal cues of the same categories do differ, as participants tend to find the modern threat faster compared to evolutionary relevant ones.

Interestingly, we could not replicate this interaction in the second experiment, where we recruited firemen to test how they would react to these threats. They did find the modern threats faster, similarly to University students, however, there was no arousal effect. We claim that this might be due to their previous experiences and the training they received (Hemmatjo et al., 2017; Williams-Bell et al., 2016). Thus, they are better at regulating arousal, or they would need more elevated levels of arousal to produce different results. The significant interactions when directly comparing the two datasets, i.e. between group and target type, and group and set size, support the importance of previous training and experiences, and, at the same time the relevance of motivational factors, such as being highly accurate and competitive.

The third experiment is somewhat different, as we decided to use different targets, and, in the meantime also acquired a method to control for low level visual features. An important step that should be applied to the stimuli set used in Experiment 1 and 2, because that might help us to draw clearer conclusions. Nonetheless, here, we tested

preschool children. This sample came with some restrictions, e.g. we were not allowed to use highly arousing threatening images. The results cannot be perfectly compared given that here we used different exemplars of both modern (syringe instead of gun) and evolutionary relevant (spider instead of snake) stimuli. Here, we also matched the threatening and neutral targets of the same origin, which we consider a strength of the study. Our results show that children found visually similar threatening and non-threatening targets equally as quick. Which is in line with the results of previous research (LoBue, 2010a; LoBue, 2014; Rakison & Derringer, 2008). We claim that these results provide additional support to a general feature detection (Coelho & Purkis, 2009), at least for evolutionary relevant cues. The results of Exp. 3 support the notion that people are indeed more prone detecting threatening cues, or stimuli that have similar characteristics to some other threat.

In sum, we claim that the three experiments presented here take us closer to the understanding of how threat detection, fear acquisition occurs and what is the unique role of each factor that are present. Preschool children are seemed to be visually prepared to detect well-known – i.e. had previous experience with – threats quickly, and this might be generalised to further stimuli that one considers threatening but have no previous experience with (e.g. gun for students). Moreover, with the inclusion of a special sample of firemen we could also investigated individual differences that should be also considered and mapped by future research. To date, we do not know whether biological predisposition or careful training could account for the differences better. That is people become firemen because they could tolerate stress and high arousal more, or people who became firemen learned to cope with stress better.

STUDY 2 – PROPOSING A NOVEL PARADIGM TO INVESTIGATE THE DETECTION OF THREAT-RELEVANT CUES

Introduction

To this date, a large body of research has investigated whether there is an automatic attentional processing that gives advantage to threatening stimuli compared to non-threatening ones, using various paradigms. One of the first to study this question was Öhman (1986), who conducted his first experiments using Pavlovian conditioning paradigm. For instance, Öhman and Soares (1998) exposed participants to masked threatening (i.e. snakes and spiders) and non-threatening (i.e. flowers and mushrooms) pictures as conditioned stimuli, and mild electric shock as unconditioned stimulus. Then, participants were shown the stimuli set, while their skin conductance were measured. They demonstrated unconscious conditioning (i.e. elevated SCR) only to threatening stimuli. However, further research from other laboratories using similar methodology failed to reproduce the same results (Menzies & Clarke, 1995; see Poulton & Menzies, 2002 for review), thus, this paradigm became widely considered less reliable.

Hence, Öhman, Flykt, and Esteves (2001) proposed a new methodology that uses an odd-one-out visual search task (VST). In this paradigm, participants are exposed to different numbers of pictures (typically 4 or 9) which are presented on a screen arranged in matrices (2x2 or 3x3 respectively). In half of the cases the pictures belong to the same category (e.g. flowers), in the other half, one picture differs from the others (e.g. a snake appeared among eight flowers). Participants have to decide whether all the pictures belong to the same category or there is a discrepant one. Their reactions were measured by pressing different keys. In the past decade, this paradigm became widely used in experiments with both adults and children participants.

The advantage in visual processing for threatening stimuli has first been shown using this paradigm by Öhman et al. (2001), who later also coined the term *fear-module* (Öhman et al., 2001; Öhman & Mineka, 2003). They used pictures of evolutionary

66

relevant cues, snakes and spiders as threatening and mushrooms and flowers as non-threatening stimuli. According to their results, participants responded to threatening stimuli faster than non-threatening ones. Plenty of research (Gao et al., 2017; Isbister & White, 2004; see Öhamn & Mineka, 2003 for review) showed that these animals – especially snakes (Gomes et al., 2017) – had been present as human species evolved, and posed as a real threat to our species. This suggests that fast and accurate detection of potentially lethal animals might have been under positive selection in the evolutionary past. The aforementioned studies used only evolutionary relevant cues Therefore, in the recent years, this theory was met with criticism because of the difficulty to generalize the findings to other types of threatening cues (e.g. modern).

Consequently, an alternative theory was proposed, namely, the *relevance superiority effect* (Fox et al., 2007; Sander et al., 2003, 2005; Subra et al., 2017). The relevance superiority effect suggests that people perceive fear-relevant stimuli faster than neutral ones regardless of the evolutionary relevance. Brosch and Sharma (2005) conducted an experiment similar to the VST used by Öhman et al. (2001). However, they compared modern stimuli (e.g. gun, toaster) to evolutionary old ones (e.g. snake, flower). They concluded that in the case of fear-relevant stimuli – regardless of it being evolutionarily relevant or modern – participants recognized it faster compared to neutral ones. That is, the fear relevance of the cue seems to be more important than its evolutionary relevance (see e.g. H. Gao & Jia, 2017; March, Gaertner, & Olson, 2017). Fox and colleagues (2007) suggested a similar conclusion based on a study, in which they found no difference in response to modern and evolutionary old fear-relevant stimuli. Nonetheless, the aforementioned studies used a small number of exemplars per stimulus category.

Nearly a decade after the first research using the VST proposed by Öhman et al (2001), LoBue and DeLoache (2008) introduced a change in the methodology. Instead of registering the different key press responses, they used a touch-screen monitor to collect data from their participants. They claimed that responding with touch-screen monitor simplifies the task and responding itself; it takes out the use of a keyboard that can lead to several issues. More importantly, there is no need to use stimuli that do not contain a target picture, which was commonly used in previous experiments to reduce the possibility of response learning. The lack of target absent trials opened up the possibility

to increase the repetitions of stimuli presentation or use more exemplars per stimulus category. It was also shown (LoBue & Matthews, 2014) that the pattern of results is the same across the two types of responses, i.e. key press and touch-screen Thus, we think further research should utilize touch-screen-based response collecting.

Nonetheless, the VST has been challenged (Quinlan, 2013; Quinlan et al., 2017; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005; Subra et al., 2017). After surveying a large body of literature Quinlan (2013) argued that it is unclear whether distractors or targets caused the results, i.e. the results are due to a faster detection of the target, or a faster rejection of the background (see also Rinck et al., 2005). Furthermore, it was also shown (Subra et al., 2017) that since respondents need to process all the simultaneously presented pictures and select one of them, this task does not quite resemble the originally intended process of attention capturing. Finally, there is growing evidence (Cave & Batty, 2006; Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes, 2011; Quinlan, 2013) suggesting that controlling for potential perceptual confounds such as luminance, contrast and spatial frequency is crucial in studies dealing with visual search tasks.

A new approach emerged when studies started to use eye tracking devices. For instance, Humphrey and colleagues (2012) created digital photographs depicting real life scenes (e.g., street, bedroom) containing a target that could be emotionally charged (i.e. positive or negative) or neutral. Participants completed recall and recognition memory tests after seeing all the pictures; eye-movements were also recorded. Results showed that respondents recognised negative targets more accurately and recalled them in greater detail than positive and neutral ones. According to eye-movement data, participants spent more time fixating on negative targets than positive or neutral ones. Thus, Humphrey et al. (2012) concluded that negative emotional stimuli did have an advantage in attentional processing. Nonetheless, it is important to point out that the content of the negative target ranged from those provoking disgust to those depicting fear-relevant animals or object (e.g., snakes, knives). In our view, the methodology Humphrey et al. (2012) used provides a sound alternative to the VST and can be adapted into behavioural testing.

The overarching goal of our study was to introduce a novel paradigm that incorporates the aforementioned flaws (i.e. using both evolutionary relevant and modern cues with more exemplars per stimulus category) and methodological innovations (i.e.

higher ecological validity, utilizing touch-screen monitors), and thus, could serve as an alternative to the VST. We sought to test whether evolutionary threatening cues have an advantage over neutral and modern threatening ones, or threatening cues regardless of evolutionary relevance have an advantage over neutral ones. Maybe there is no threat advantage at all as some previous research (e.g. Quinlan, 2013; Quinlan, Yue, & Cohen, 2017, Yue & Quinlan, 2015) suggest. The first experiment presented here is a pilot study to test the paradigm. In the second experiment, we used the most often included best representative (see e.g. Öhman et al., 2001; Fox et al., 2007; LoBue & DeLoache, 2008) of the modern (gun) and evolutionary relevant (snake) threatening categories and compared them with neutral cues. Then, in the third experiment, we broaden these categories and included several more exemplars (i.e. knife, syringe, and spider, scorpion, respectively). We hypothesised that all threatening targets will be detected faster compared to neutral ones regardless of their evolutionary relevance.

Experiment 1 – Pilot study

Aims and hypotheses

First, we wanted to test our proposed paradigm, thus Experiment 1 is a pilot study to explore the weak and strong points of the method and to allow us to make necessary changes for further testing.

Methods

Participants

Fifty-five participants (20 male, 35 female) were recruited from students of the University of Pécs, with a mean age of 22.6 (S.D. = 2.01). All participants were right-handed with normal or corrected-to-normal vision. None of them had a history of neurological diseases or mental disorders, as noted through self-report. Data from one participants was excluded because of a failure to follow instructions. Our research was approved by the Hungarian United Ethical Review Committee for Research in Psychology (EPKEB) and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki), and informed consent was obtained for experimentation with human subjects.

Materials

All images (both background and target) were collected from the Internet. We sought for neutrally valanced backgrounds that could be either evolutionary relevant (e.g. forest, natural scenes) and modern (e.g. street, factory) images depicting real-life scenes. Then, all pictures were resized to 800x600 pixels. After this, we also made some adjustments regarding their basic visual features (namely luminance, contrast, and colour intensity) to avoid the possible confounding effects. After creating a large set of pictures, we conducted an online pilot study with 40 University students to assess valence, arousal and threat ratings of all the images. Respondents had to rate the pictures on 9-point Likert-type scales regarding valence (1 – very negative, 9 – very positive), arousal (1 – not

arousing at all, 9 – very arousing), and perceived threat (1 – not threatening, 9 – very threatening). Table 4 shows the mean valence, arousal and threat ratings for the 16 neutral pictures selected.

Table 4 – Mean valence, arousal, and threat ratings and standard deviations of the background images

	Valence	**Arousal**	**Threat**
Backgrounds image	7.29 (1.26)	2.64 (0.94)	2.54 (0.62)

The selection of target pictures went similarly. First, we collected a big database of images depicting a snake, a spider, a knife, or a gun, and then, resized them to 45x45 pixels. The same low-level visual feature filtering procedure was applied to them as for the background images. The same 40 students rated the targets (after completing the rating of the background pictures), and we selected the targets used in the experiment based on these ratings. See Table 5 for mean values and standard deviations; please note that respondents rated all gun pictures more threatening than other images, therefore, this will be considered when interpreting the results. The other images did not differ from each other on the three scales (ts<1; p>0.1), moreover, the evolutionary relevant (average of snake and spider) and modern category (average of knife and gun) were not statistically different on the three scales.

Table 5 – Mean valence, arousal, and threat ratings and standard deviations of the four types of targets used

	Valence	**Arousal**	**Threat**
Snake	3.7 (1.9)	5.4 (2.0)	5.6 (2.4)
Spider	4.0 (1.7)	5.3 (1.9)	5.3 (2.2)
Knife	4.0 (1.5)	5.2 (1.9)	5.7 (2.0)
Gun	2.9 (1.7)	6.4 (1.7)	7.0 (1.8)

After selecting the both background and target pictures, the final set was assembled. Each target was presented on each background image four times, once in every possible location. The locations were set by diving each background into four quartiles (the four corner of each picture), and then, pictures were placed within these quartiles by keeping the credibility of the scenes as high as possible. Thus, for instance, we placed a snake on a fallen trunk, and not just flying in the air. See Figure 7 for exemplars of the final stimuli set. Therefore, the final stimuli set consisted of 2 types of backgrounds (evolutionary relevant and modern), 4 types of targets (snake, spider, knife, gun), and 4 positions presented two times, i.e. a total of 64 images.

Figure 7. – Examples of stimuli used. Evolutionary relevant (A) and modern (B) backgrounds, with evolutionary relevant (snake) and modern (gun) threatening targets – respectively. The red circle only appears here, as a visual guide to the reader.

Apparatus

The stimuli were presented on a 17-inch LG Flatron T1710 touch-screen colour monitor, with a resolution of 800x600, 5:4 aspect ratio, refresh rate of 60 Hz, and colour depth of 16,7M. PsychoPy Software version 1.83 for Windows (Peirce, 2007) was used to present the stimuli.

Procedure

Participants were tested in individual work stations. They were seated at a distance of approximately 60 centimetres from the monitor. They were provided both written and oral task instructions. Then, they were shown the target stimuli used in the experiment. They were asked to respond by touching the screen and try to be as quick and accurate as possible. After responding, they had to replace their hands on a paper in front of them on the table. Every trial began with a central fixation cross, that was present for 500 ms.

First, a set of 8 practice trials were given to teach respondents how to use the touch-screen monitor and to get familiar with the pictures they were going to see. All of them learned the task quickly. We excluded the practice trials from the data analysis. Then, the randomised experimental stimuli were presented to them. Reaction times and the coordinates of the responses were recorded.

Results

First, we excluded inaccurate responses. We did this using an outlier flagging procedure with a two-standard deviation criterion on the raw data of coordinates. Reaction time data were deleted in these cases (<1%) and were considered as system missing during further analyses. None of the measurements deviated from the normal distribution, neither the assumption of variances nor sphericity were violated. The statistical analyses were performed using the JASP Statistics Program (Version 0.7.5 for Windows).

We used a 2x2 ANOVA to analyse the dataset: Background (Evolutionary relevant and modern) and Type of Stimuli (Evolutionary relevant and modern) were the main variables. The type of the stimuli yielded a significant effect ($F(1,54)=73.25$, $p<.01$, $\eta^2=.58$). The main effect of the background was not significant ($p>.05$) and the two main effects did not interact ($p>.05$).

Participants found modern threatening targets faster than evolutionary old ones, irrespective of the background (see Fig. 8a). The evolutionary relevant target category had two types of stimuli: spider and snake. To analyse whether they act differently in the two contexts, we used a 2x2 ANOVA: Background (evolutionary relevant and modern) and Type of Evolutionary relevant target (spider and snake) were the two main factors. The analysis yielded a significant interaction between the two main effects ($F(1,54)=47.26$, $p<.01$, $\eta^2=.47$), while the two main effects were not significant (both ps $>.05$). As Figure 8b indicates, participants found spiders faster in modern context – compared to snakes in modern context and spiders in evolutionary context; while they were faster to respond to snakes in an evolutionary background when compared to snakes in a modern setting or to spiders in an evolutionary one.

The modern threat-relevant target category also had two subtypes: knife and gun. We used a 2x2 ANOVA to analyse whether they act the same way in different contexts. The two factors were Background (evolutionary relevant and modern) and Type of Modern target (knife and gun). The Type of target factor had a significant effect on the detection ($F(1,54)=7.56$, $p<.01$, $\eta^2=.12$), indicating the participants were faster to find gun targets than knives in general. However, the interaction between the two factors (background and type of target) was also found to be significant ($F(1,54)=44.84$, $p<.01$, $\eta^2=.45$). The Background did not have a significant effect ($p >.05$). As Figure 8c shows participants found knives faster in evolutionary relevant context than in a modern one, or when compared to guns in an evolutionary setting. However, they were faster to detect gun targets in modern backgrounds than in evolutionary old ones and when compared to knives in modern context.
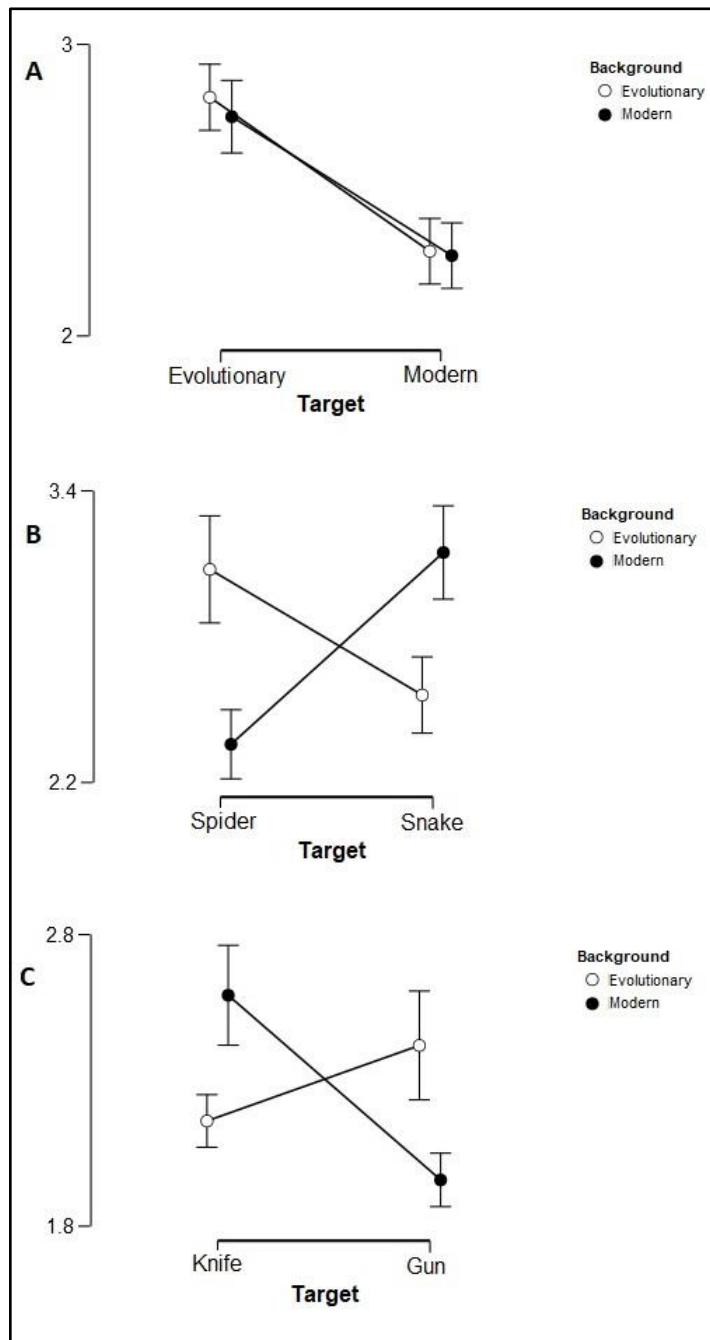
Figure 8 – The main effect of threat (A), participants found modern threatening images with lower RT irrespective of the background. The interaction between the type of evolutionary threatening target and background (B). Respondents were faster to find spider in modern, while the snake in evolutionary relevant environments, compared to evolutionary relevant and modern respectively. The interaction between the type of modern threatening target and background (C). Participants found knives faster on evolutionary relevant backgrounds compared to modern ones. In contrast, the detection of guns was faster on modern backgrounds compared to evolutionary relevant ones. Standard error bars are shown on each graph.

Discussion

Our results suggest that people tend to find modern threatening targets faster than evolutionary relevant ones. However, the context plays an important role. We claim that the interaction between the background and the subtype of the stimuli can be interpreted as a priming effect that can change how people look at different cues. One might argue that both knives and guns are irrelevant in an evolutionary setting because they are modern threatening targets.

However, we believe that the evolutionary relevant context, for instance, a forest, activates different representations of the different subtypes of targets than the modern context, for example, a street. Subtypes (spider, snake, knife, gun) that are widely used in previous experiments (Blanchette, 2006; Fox et al., 2007; Öhman et al., 2001). Knives too had a major impact on the evolution of humans and served as an important tool both in survival and warfare. In contrast, guns are less relevant in such a setting, but if we take an industrialised context, it gets more emphasis, just like Öhman and Mineka (2001) suggested.

Parallel to this comparison it seems that spiders as fear-relevant cues have more significance in a modern context than in an evolutionary one to people growing up in modern, urban areas. More so it is also possible that spiders evoke fear due to disgust, which can be considered as a different mechanism compared to snakes evoking fear directly due to their poisonous and lethal features. Just like spiders becoming more of common occurrence in our industrialised environment, people growing up like in them hardly ever see a snake in their natural habitats. Snakes are, however, still of high priority in a sense that in evolutionary context people detect them faster than spiders. The confound and mixed, sometimes even contradictory results, as Quinlan (2013) pointed out, in our view, could possibly originate from the previously discussed interaction between the context and different subtypes of target stimuli. In conclusion, we suggest a relevance superiority effect over the evolutionary fear module.

Considering the methodology, we can conclude that it is capable of measuring visual search and threat detection, and it seems to serve as a sound alternative to the classical visual search task previous experiments used. There are, of course, methodological flaws that need to be highlighted. A more strict procedure is needed to

control for the valence, arousal, and threat levels of collected raw pictures (background images and targets). Moreover, subjects' ratings on the backgrounds were rather positive, which might be a result of no reference; i.e. they did not see positive and negative images, and, hence the bias towards positive valence. In addition, the possible locations of targets could also confound the results, because the distance of these locations from the fixation cross was not controlled for either. Previous research suggest that threatening images might be detected even faster when presented in a peripheral position (Soares et al., 2014), thus, in our forthcoming experiments we worked towards controlling this as well.

Despite these shortcomings, we think that the new paradigm presented here could be used in further testing of threat detection with the necessary changes and correcting for the flaws that were shown in this pilot study. The results of these studies may add to the better understanding of threat detection, and to either support one of the previously described theories or show a way to merge them and create a new one.

Experiment 2 – Comparing the best representatives of modern and evolutionary relevant threatening stimuli

Aims and hypotheses

Again, the main goal of the present study was to test whether evolutionary threatening cues have an advantage over neutral and modern threatening ones, or threatening cues have an advantage over neutral ones regardless of the origin. Maybe none of this is true and as Quinlan (2013) suggests there is no threat advantage at all. In Experiment 2, we use the best representative (see e.g. Öhman et al., 2001; Fox et al., 2007; LoBue & DeLoache, 2008) of the modern (gun) and evolutionary relevant (snake) threatening categories and compare them with neutral cues. We hypothesised that threatening targets are found faster compared to neutral ones regardless of evolutionary relevance.

Methods

Participants

Thirty-four participants (16 men, 18 women) were recruited from students of University of Pécs, with a mean age of 21.3 (S.D. = 1.78). The sample size for this experiment was determined by computing estimated statistical power ($\beta > .8$), based on the results of prior experiments on fear advantage (Blanchette, 2006; Fox et al., 2007; Öhman et al., 2001). All participants were right-handed with normal or corrected-to-normal vision. Data from one respondent were excluded because of failure to follow instruction. Our research was approved by the Hungarian United Ethical Review Committee for Research in Psychology (EPKEB) and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Informed consent was obtained from all participants.

Materials

A set of pictures depicting real-life scenes (background images), and target objects were collected from the internet. Each target was added to the backgrounds with digital

editing. Eight neutral background pictures of the same size (800 x 600 pixels) were collected from the Internet. Half of these pictures depicted natural scenes (e.g. forest, riverside), the other half depicted modern ones (e.g. street, factory). We, then, collected four types of target pictures: evolutionary relevant threatening (snake) and non-threatening (cat), and modern threatening (gun) and non-threatening (pen). Each category included three different pictures of the object. All targets had the same size (50x50 pixels, i.e. visual angle 1.26°x1.26°). None of the background pictures contained any similar objects, and neither humans nor animals were present on them.

To avoid the possibly confounding effects of uncontrolled variance in low-level visual properties, we used the Spectrum, Histogram, and Intensity Normalisation and Equalisation (SHINE) toolbox for MATLAB (Willenbockel et al., 2010) to ensure that our background pictures were equivalent with respect to luminance, contrast, and spatial frequency. As a result, all the images used were grayscale.

The target pictures were placed on the background images with equal distribution regarding their position and different types of objects. To avoid the possible bias that different targets placed on different places of the backgrounds would result in an unequal contrast of the targets, each target was then cut out (60x60 pixel squares) of the background and entered together in the SHINE toolbox to achieve equal luminance, contrast and spatial frequency values. These images were then placed back on the backgrounds. The 10-pixel difference between the cut-out squares and the actual size of the targets allowed us to apply a gradually fading filter to mask the visual differences between the replaced images and the background.

Images were presented on one of 16 possible locations of the screen (see Figure 9 for the layout). The image locations were distributed on two circles - and inner and an outer circle. The inner circle had a diameter of 400 pixels (10.08°), and the middle of the target pictures was placed on this with a distance of 157.08 pixels (3.97°). The diameter of the outer circle was 945 pixels (23.54°), to maximise the area covered. The distance between the targets on each side was 156.03 pixels (3.94°). Finally, we created the stimuli set that consisted of 16 (possible locations) X 8 (backgrounds images), i.e. 128 images. See Figure 10 for exemplars of the final stimuli set.
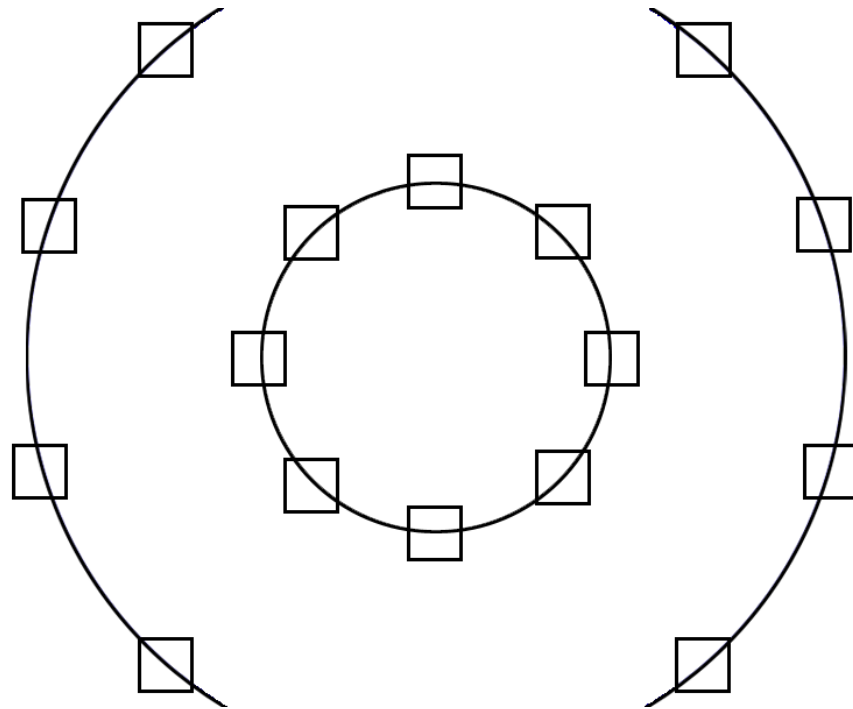
Figure 9 – The 16 possible locations of the targets: 8 on the inner and 8 on the outer circle.

Image complexity was also calculated for all the final pictures, to control for the possible confounding effects of variance in visual complexity. The method we used is based on the assumption that average complexity increases as a function of log JPG file size(Donderi & McFadden, 2005; Forsythe, Nadal, Sheehy, Cela-Conde, & Sawey, 2011). The pictures used in this experiment did not differ on this measure ($F < 1$, $p > .1$).
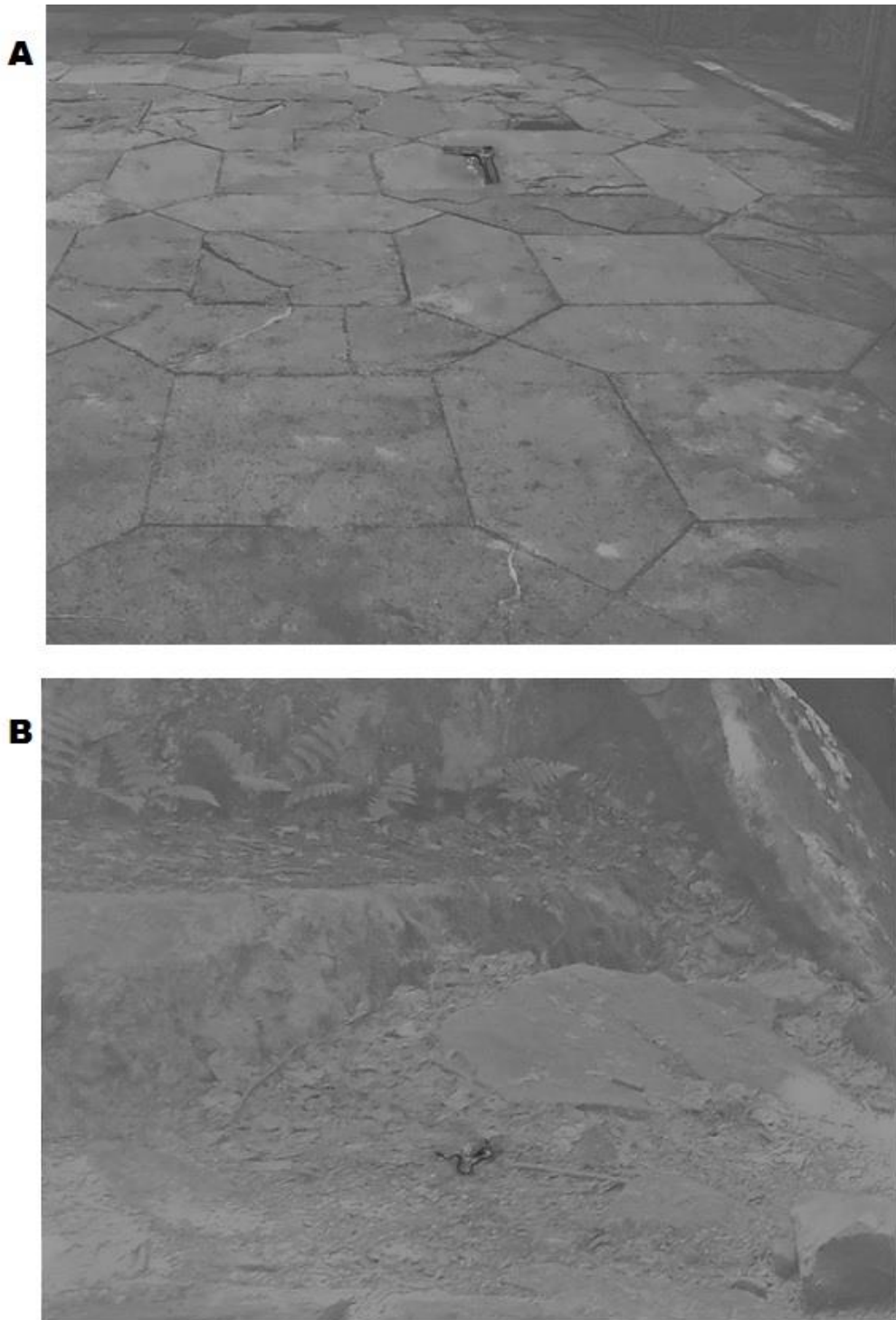
Figure 10 – Examples of stimuli used. From top to bottom: Modern target on modern background, and evolutionary relevant target on evolutionary background.

Apparatus

The stimuli were presented on a 17-inch LG Flatron T1710 touch-screen colour monitor, with a resolution of 800x600, 5:4 aspect ratio, refresh rate of 60 Hz, and colour depth of 16,7M. PsychoPy Software version 1.83 for Windows (Peirce, 2007) was used to present the stimuli.

Procedure

They were seated at a distance of approximately 60 centimetres from the monitor. They were provided both with written and verbal task instructions. Then, they were shown the target stimuli used in the experiment. They were asked to respond by touching the target on the screen and try to be as quick and accurate as possible. After responding, they had to replace their hands on a paper in front of them on the table. Every trial began with a central fixation cross presented for 500 ms.

First, a set of 16 practice trials were given to teach respondents how to use the touch-screen monitor and to get familiar with the pictures they were going to see. All of them learned the task quickly. We excluded the practice trials from the data analysis. Then, the randomised experimental stimuli were presented to them. Reaction times and the coordinates of the responses were recorded.

Results

First, we searched for inaccurate responses. We did this using an outlier flagging procedure with a two-standard deviation criterion on the raw data of coordinates. Reaction time data were deleted in these cases ($<1\%$) and were considered as system missing during further analyses. None of the measurements deviated from the normal distribution, neither the assumption of variances nor sphericity were violated. The statistical analyses were performed using the JASP Statistics Program (Version 0.7.5 for Windows).

We used a 2x2x2x2 ANOVA to analyse the dataset with the background (evolutionary relevant vs. modern), origin of stimuli (evolutionary relevant vs. modern), type of stimuli (threatening vs. neutral), and position (inner vs outer circle) being the fixed factors. See Table 6 for means reaction times and standard deviations for all categories.

**Table 6** – Mean response times and standard deviations in seconds for each category

Type of stimuli	Origin of stimuli	Background	Position	Mean	SD
Threatening	Evolutionary	Evolutionary	Outer	1.437	0.184
			Inner	1.341	0.128
		Modern	Outer	1.457	0.141
			Inner	1.341	0.125
	Modern	Evolutionary	Outer	1.465	0.177
			Inner	1.325	0.107
		Modern	Outer	1.466	0.156
			Inner	1.341	0.117
Neutral	Evolutionary	Evolutionary	Outer	1.451	0.153
			Inner	1.475	0.289
		Modern	Outer	1.446	0.154
			Inner	1.340	0.105
	Modern	Evolutionary	Outer	1.457	0.189
			Inner	1.345	0.125
		Modern	Outer	1.529	0.187
			Inner	1.353	0.125

The type of the stimuli yielded a significant effect ($F(1,33)=8.57$, $p<.01$, $\eta^2=.21$). Participants were faster to find threat-relevant stimuli (snake and gun) than neutral ones (cat and pen) – see Figure 11. The position of the target was also significant ($F(1,33)=57.93$, $p<.01$, $\eta^2=.64$) such that targets on the inner circle were found faster than when they were presented on the outer one.

We found a background X target origin interaction ($F_{(1,33)}=8.65$, $p<.01$, $\eta^2=.21$), evolutionary relevant compared to modern targets were found faster on modern background and vice versa. Interestingly, both the target origin X position ($F_{(1,33)}=19.04$, $p<.01$, $\eta^2=.37$) and the background X position ($F_{(1,33)}=7.83$, $p<.01$, $\eta^2=.19$) interactions were significant. Participants found modern targets faster than evolutionary relevant on the inner circle, and vice versa on the outer one. Moreover, they found targets on the inner circle faster if they were present on a modern background, compared to evolutionary relevant; and vice versa on the outer circle.

The analysis also revealed three three-way interactions between target type X target origin X background ($F_{(1,33)}=9.61$, $p<.01$, $\eta^2=.23$), target type X target origin X position ($F_{(1,33)}=4.88$, $p<.01$, $\eta^2=.13$), and target type X background X position ($F_{(1,33)}=7.27$, $p<.01$, $\eta^2=.18$). Interestingly, these interactions revealed that neutral targets were accountable for all three two-way interactions described previously.

The first interaction revealed that respondents found the evolutionary relevant neutral target faster than modern ones on modern backgrounds and vice versa on evolutionary backgrounds. However, this effect was not present regarding threatening targets, as they were found equally fast irrespective of the type of the background. Neutral modern targets were found faster in the inner circle compared to the outer one; while this effect was not significant for the neutral evolutionary cues. Finally, neutral cues were found faster when placed on the inner circle compared to the outer one on modern background, while they were found equally fast when presented on evolutionary relevant background. Threatening targets were always found faster when present on the inner circle irrespective of target and background type.
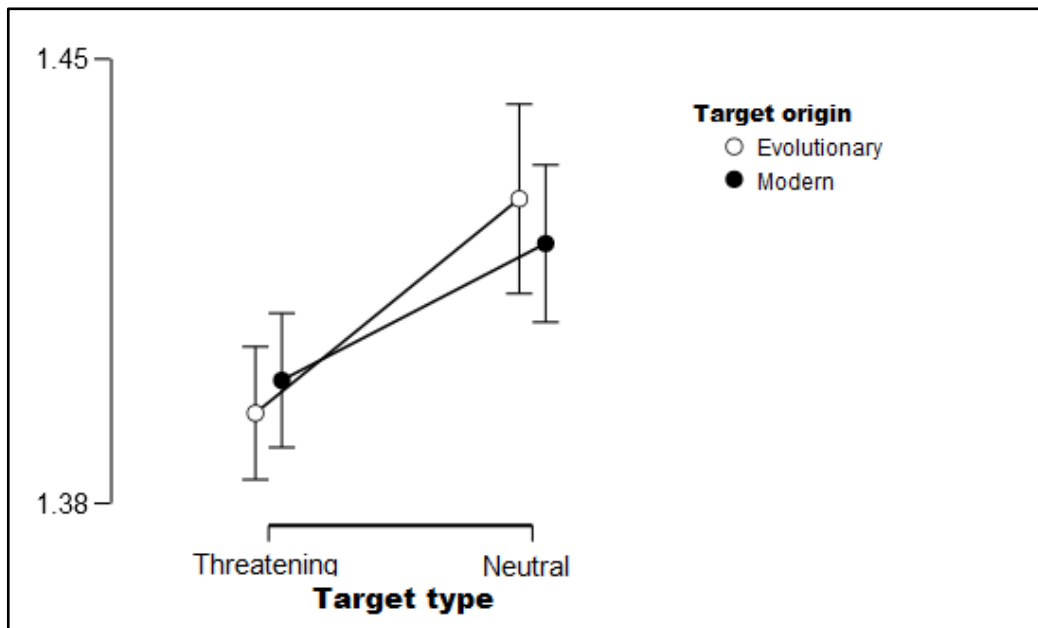
Figure 11 – Threatening targets (snake and gun) were found faster compared to neutral cues (cat and pen), irrespective of target origin (evolutionary relevant or modern). Error bars (95% confidence interval) are shown.

Discussion

Taken the best representative of the modern and evolutionary relevant threat categories and comparing them to neutral stimuli using a new behavioural paradigm. Our results show that the new method we proposed respondents tend to find threatening targets faster than neutral ones, regardless of their origin. Moreover, the significant effect of position underscores the importance of controlling for this variable, i.e. distance of targets from the fixation cross, in future experiments.

The interactions show that there are specific effects that are present for neutral stimuli but not for threatening ones. This might indicate that threatening cues are indeed preattentive in the sense that they are more resistant to the context they are presented in. It seems plausible to claim that there is a context effect (Young et al., 2012) for neutral cues, i.e. the target that is incongruent with the context is detected faster. Our results suggest that non-matching background and target origin highlights the target and makes it easier to find.

Taken these together, it seems that the confound and mixed results, as Quinlan (2013) pointed out, could possibly originate from the interaction between the context and different subtypes of target stimuli, i.e. congruent vs. incongruent. In conclusion, the results of our second experiment suggest a relevance superiority effect over the evolutionary fear module, i.e. threatening targets are found faster compared to neutral cues regardless of the evolutionary relevance.

Experiment 3 – Does fear have an advantage after all?

Aims and hypotheses

The overarching aim of Study 2 was to explore if threatening cues have an advantage over neutral at all (see Quinlan, 2013 for instance) is it regardless of the origin or evolutionary threatening targets are more highlighted than other cues.

The motivation behind conducting a third experiment was to test whether the main effect of threat shown in Experiment 2 is specific to the best representatives (i.e. snake and gun) widely used in former experiments or can be generalised to all threatening cues. Hence, in the present experiment, we broadened these categories and included several more objects.

Methods

Experiment 3 was similar to Experiment 2 in every aspect but one: there were more types of targets in both the evolutionary relevant and modern categories.

Participants

Thirty-three participants (15 men, 18 women) were recruited from students of University of Pécs, with a mean age of 22.1 (S.D. = 1.59), matching the sample size of Experiment 2. All participants were right-handed with normal or corrected-to-normal vision. Data from two respondents were excluded because of failure to follow instruction. Our research was approved by the Hungarian United Ethical Review Committee for Research in Psychology (EPKEB) and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Informed consent was obtained from all participants.

Materials

We collected 24 background images (800X600 pixels) in total (including the previously used 8 from Experiment 2), half of it depicting evolutionary relevant scenes (e.g. grassland, forest) and the other half modern ones (e.g. side-walk, terrace). Four types of target categories were used and pictures were sourced from the Internet: evolutionary relevant threatening (snake, sider, and scorpion) and non-threatening (cat, bird, and turtle), and modern threatening (gun, knife, and syringe) and non-threatening (pen, flashlight, and toaster). Three different exemplars were used for all types of the objects (e.g. three snakes, three guns, etc). All targets had the same size (50x50 pixels, i.e. visual angle 1.26°x1.26°). None of the background pictures contained any similar objects, and neither humans nor animals were present on them.

Preparation of the final image set was identical to that of Experiment 2. Background images went through the low-level feature averaging technique using SHINE toolbox (Willenbockel et al., 2010). Then, targets were converted into grayscale, placed on the background images using the outer and inner circle layout as seen on Figure 9. Afterwards, targets were cut out (60x60 pixels) and averaged on low-level visual features, and then placed back to the backgrounds. A filter was applied on the 10-pixel wide frame of the 50x50 pixel target to gradually fade the replace image back to the background. The final stimuli set consisted of 16 (possible locations) x 24 (number of background images), i.e. 384 pictures.

We, again, calculated image complexity for all the final pictures, with the same method used in Experiment 1 (Donderi & McFadden, 2005; Forsythe et al., 2011). The pictures used in this experiment was similar in visual complexity ($F < 1$, $p > .1$).

Apparatus

The same 17-inch LG Flatron T1710 touch-screen monitor was used as in Experiment 2 to present the stimuli, with a resolution of 800x600, 5:4 aspect ratio, refresh rate of 60 Hz, and colour depth of 16,7M. PsychoPy Software version 1.83 for Windows (Peirce, 2007) was used to present the stimuli.

Procedure

The procedure went the same as described at Experiment 2. Participants were tested individually, seated at a distance of approx. 60 centimetres from the monitor. After task instructions, they were shown the target stimuli used in the experiment. They were asked to respond by touching the screen and try to be as quick and accurate as possible. After responding, they had to place their hands on a paper in front of them on the table. Every trial began with a central fixation cross, that was present for 500 ms.

The experiment began with a set of16 practice trials, and the experimenter made sure respondents understood the usage of the touch-screen monitor and the task. Then, the randomised experimental stimuli were presented to the participants. Reaction times and the coordinates of the responses were recorded.

Results

First, inaccurate responses were identified using an outlier flagging procedure with a two-standard deviation criterion on the raw data of coordinates. Reaction time data were deleted in these cases (<1%) and were considered as system missing during further analyses. The three subtypes of each target category were averaged, thus resulting in the same 16 variables as seen in Experiment 2. None of these variables deviated from the normal distribution. Neither the assumption of variances nor sphericity were violated. The statistical analyses were performed using the JASP Statistics Program (Version 0.7.5 for Windows).

We had four factors, thus, a 2x2x2x2 ANOVA was used to analyse the dataset where: the background (evolutionary relevant vs. modern), origin of stimuli (evolutionary relevant vs. modern), type of stimuli (threatening vs. neutral), and position (inner vs outer circle) served as the fixed factors. See Table 7 for descriptive statistics of response times.

Table 7 – Mean response times and standard deviations in seconds for each category

Type of stimulus	Origin of stimulus	Background	Position	Mean	SD
Threatening	Evolutionary	Evolutionary	Inner	1.307	0.127
			Outer	1.409	0.202
		Modern	Inner	1.307	0.155
			Outer	1.463	0.227
	Modern	Evolutionary	Inner	1.323	0.158
			Outer	1.433	0.239
		Modern	Inner	1.314	0.168
			Outer	1.447	0.180
Neutral	Evolutionary	Evolutionary	Inner	1.350	0.308
			Outer	1.419	0.232
		Modern	Inner	1.319	0.187
			Outer	1.409	0.200
	Modern	Evolutionary	Inner	1.301	0.156
			Outer	1.426	0.236
		Modern	Inner	1.316	0.172
			Outer	1.469	0.224

Strikingly, only one main effect, the position was significant ($F(1,32)=121.59$, $p<.01$, $\eta^2=.79$). As expected, participants found targets faster on the inner position compared to when they appeared on the outer circle. We also found two significant two-way interactions between origin X position ($F(1,32)=10.67$, $p<.01$, $\eta^2=.25$), and background X position ($F(1,32)=11.45$, $p<.01$, $\eta^2=.26$). Modern targets were found slower on the outer circle compared to evolutionary ones; which effect was not present when targets appeared in the inner positions. Same was true for the other interaction: targets were found slower on modern backgrounds when present in outer positions compared to evolutionary backgrounds; while they were found equally fast in inner positions regardless of the type of background. The analysis also yielded two significant three-way interactions. The first, origin X position X type of target ($F(1,32)=7.12$, $p<.05$, $\eta^2=.18$) shows that the previously described effect regarding the origin X position

interaction is only true for neutral stimuli, and not for threatening cues. The other interaction is between background X origin background ($F(1,32)=6.53$, $p<.05$, $\eta^2=.17$) – see Figure 12. Interestingly, the origin X background interaction is different for the two types of stimuli (threatening and neutral). Evolutionary relevant threatening targets seem to have a slight advantage on evolutionary relevant backgrounds compared to when presented on modern backgrounds. While natural targets show a context effect, i.e. evolutionary relevant targets are found faster on modern backgrounds compared to evolutionary ones, and modern targets are found faster on evolutionary relevant backgrounds compared to modern ones.
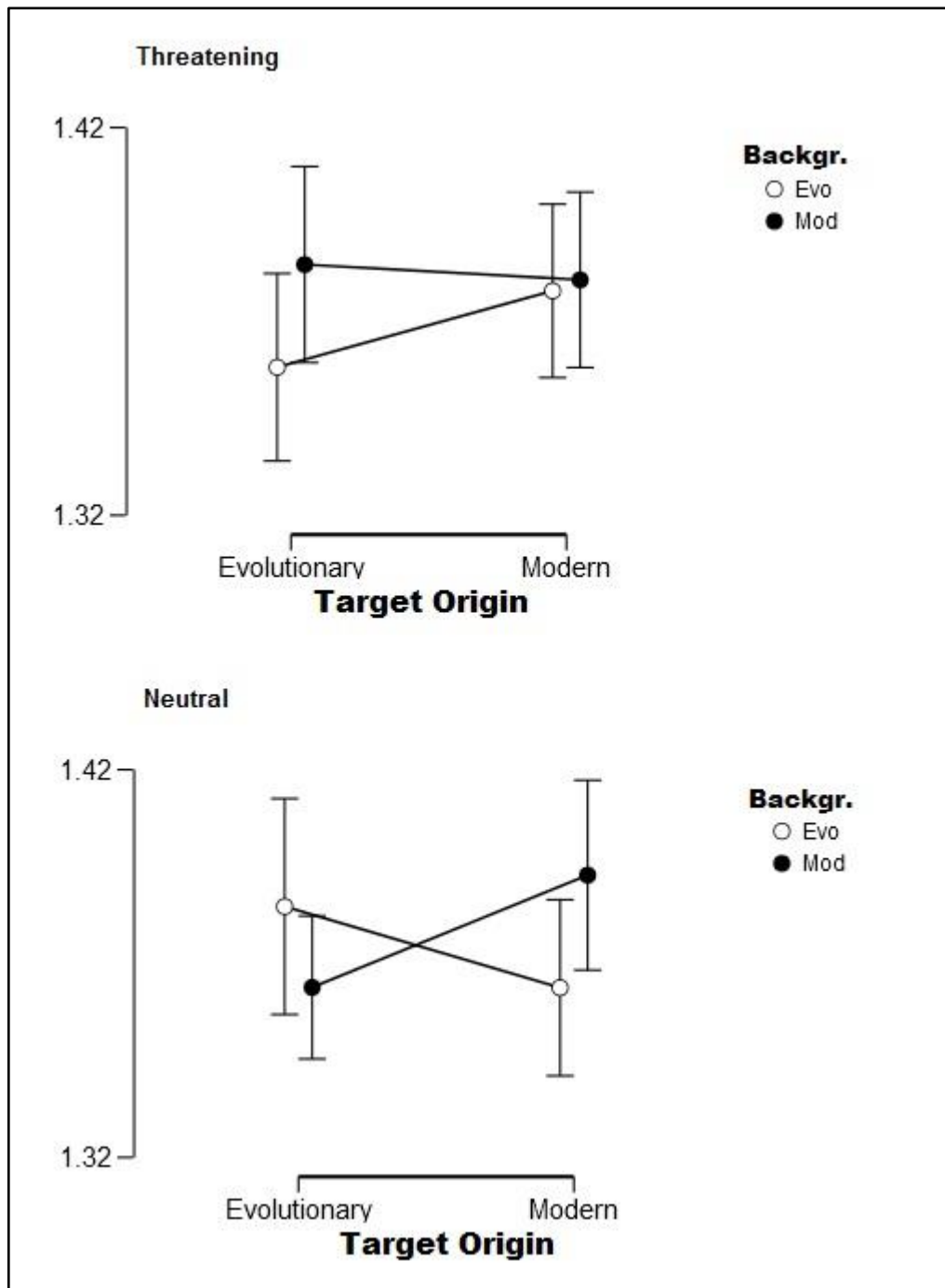
Figure 12 – Significant origin X background X target type interaction. On the top: origin X background interaction for threatening targets shows advantage for evolutionary relevant cues present on evolutionary background compared to when present on modern background. On the bottom: origin X background interaction for neutral targets show a context effect – targets are found faster when presented on different. Error bars (95% confidence interval) are shown.

Discussion

In the third experiment, we compared four categories: evolutionary relevant and modern threatening stimuli, and evolutionary relevant and modern neutral cues. More representative for each category were used compared to our second experiment in order to acquire a broader picture of the underlying mechanisms of threat detection. Interestingly, our results suggest that there is no difference in the detection of threatening and neutral cues, which is in accordance with the suggestion of some recent research (Quinlan, 2013; Quinlan et al., 2017; Yue & Quinlan, 2015).

The significant interactions indicate that the effect of context, i.e. the background they are presented on works differently for threatening compared to neural targets. For threatening ones, the congruent background seems to help finding the target, but this effect is specific only to evolutionary relevant cues and not for modern ones. Contrary, for neutral targets, the incongruent background highlights the target and makes it easier to detect, and this effect works the same for evolutionary relevant and modern settings. This particular result might contribute to understanding the effects of the context in which the stimuli appeared (see also Gronau & Shachar, 2014; Vogt, Lozo, Koster, & De Houwer, 2011; Young et al., 2012).

Regarding the position of the target, we found that neutral stimuli were found faster when presented on the periphery compared to when they appeared close to the middle of the screen. Threatening targets seem to be untouched by this effect. One possible explanation is that animate objects might have an advantage over inanimate ones in perceptual processing (see e.g. Sakaki, Niki, & Mather, 2012)). Furthermore, participants found targets on the outer compared to inner circle when they were presented on evolutionary relevant backgrounds, while they found targets faster on the inner compared to the outer circle on modern backgrounds. Previous results (Csathó, van der Linden, Hernádi, Buzás, & Kalmár, 2012) showed that the processing of evolutionary relevant natural scenes (similar to what we used as backgrounds) are preattentive. Thus, we suggest that the interaction is due to the difference in the effort needed to process the background image, such that automatic processing made it possible to find the targets equally as fast in two eccentricities. Therefore, we suggest that the position of the target stimuli should also be controlled in further studies.

General Discussion

Our goal was, beside the methodological innovation, to find clear evidence in the dispute over fear advantage. In three experiments, we test whether threatening targets have an advantage in visual detection, and if so, whether those with evolutionary relevance are highlighted in visual processing compared to modern cues. In Experiment 2, we used the best exemplars of the evolutionary relevant and modern categories, the snake and the gun, respectively. Our results suggest that there is an advantage for threatening cues over neutral ones, regardless of the evolutionary age. This supports the relevance superiority effect (see e.g. Fox et al., 2007; Subra et al., 2017).

In Experiment 3, we used 3-3 exemplars per category, to allow us to generalise the results of Experiment 2. Interestingly, however, we did not find a difference is visual search speed for threatening cues over neutral ones. This result by itself would suggest that there is no superiority effect for fear-relevant cues. Nonetheless, we claim that the results of the two experiments means that there are, indeed, specific threatening cues that have an advantage in visual search. Although this effect seems to be more specific, similar to the fear-module Öhman et al. (2001) suggested.

A particular strength of the experiments reported here is the exceptionally stringent controls used in the new paradigm. In most previous visual search studies, the low-level visual features were not equated, the target categories were not matched with all possible controls (e.g. only evolutionary or only modern categories used), moreover, they only used one or two exemplars (mainly snakes and guns). Our comparison of the detection of evolutionary relevant and modern, threatening and neutral targets provides strong evidence on the bias in the detection of some threating cues.

We argue that there is more than just threat-relevance. Some stimuli might be more strongly associated with threat and fear than others (Subra et al., 2017), thus, in a visual search task, the more advantaged stimuli are detected faster compared to other threatening and neutral ones. Nevertheless, in our view, the fact that the interactions we found were specific to neutral cues suggest that threat itself have an advantage in processing, and less sensitive to context, and other variables (see also Carretié et al., 2017).

Limitations of this study include the relatively small number of exemplars per target category (e.g. snakes, spiders, scorpions) used. This is a result of the relatively large number of categories, thus, the conclusions drawn from the results need further verification. Moreover, the repetitions we used could be further extended, however, the consequences of fatigue and the time-on-task effect should, then be taken into account (see e.g. Csathó, van der Linden, Hernádi, Buzás, & Kalmár, 2012; Lim et al., 2010). Lastly, in spite of our efforts to match the targets and backgrounds on low-level visual features, there are other variables that could cause confounding effects, for instance the position of targets, visual array and familiarity of the backgrounds.

Despite these shortcomings, people are particularly prone to the rapid visual detection of snakes and guns. These two specific threatening cues seem excel from others. This finding calls for a new theory that incorporates previous ones positing the existence of a bias to highly threatening cues that evolved during evolution or acquired through social connections during the ontogenesis.

STUDY 3 – COUNTING ON AROUSAL

Introduction

Evolution armed us with sharp senses to avoid danger, lethal threats and stimuli that we interpret as fearful. Several studies (Simola, Le Fevre, Torniainen, & Baccino, 2015; Van Strien, Franken, & Huijding, 2014; Yorzinski, Penkunas, Platt, & Coss, 2014; Yue & Quinlan, 2015) have shown that people still process threatening stimuli automatically and faster than other stimuli. For instance, they tend to find a snake or a spider amongst flowers and mushrooms faster than a flower or a mushroom amongst snakes or spiders (Öhman et al., 2001). Moreover, it seems that some threatening cues with evolutionary history have more advantage than others (Soares et al., 2014). Using a similar odd-one-out paradigm to Öhman et al. (2001) it was shown that participants found snakes faster than any other stimuli (Öhman et al., 2012; Soares, Esteves, Lundqvist, & Öhman, 2009). Respondents tend to identify snakes faster, and snakes were more distracting than a similarly evolutionarily ancient and frightening spider. This could be interpreted as evidence that the faster visual processing of snake stimuli is linked to their specific phylogenetic origin and is due to the adaptive benefits it conveyed during evolution.

It was also proposed that the temporal advantage in processing is not due to the evolutionary relevance of the threatening stimuli *per se*, but that it is fear relevance itself that is responsible. These studies (Brosch & Sharma, 2005; Brown et al., 2010; Fox et al., 2007; Young et al., 2012) underscore that when it comes to threatening stimuli – regardless of evolutionary age – how many distracting stimuli are present is less important and the fear relevance of the stimulus (i.e. negative valence) is a more important influence on visual processing than the evolutionary past. This suggests a *general processing advantage* for threatening over non-threatening stimuli. It is also well established (Öhman et al., 2012; Soares, Esteves, & Flykt, 2009; Soares et al., 2014) that threat-relevant targets amongst threat-irrelevant distractors are detected more quickly than threat-irrelevant targets amongst threat-relevant distractors. One can conclude, therefore, that it is harder to inhibit processing of negative, threat-relevant stimuli (Blanchette, 2006; Brosch &

Sharma, 2005; Fox et al., 2007; Lipp et al., 2004) and hence it might be harder to disengage attention from these stimuli.

However, there is more to an emotionally charged image than its valence. Behavioural research (Lundqvist et al., 2015, 2014) has shown that the extent to which stimuli affect the arousal system - their arousal level - is equally important (see Study 1). Arousal is a state of heightened physiological activation that creates a readiness for action and emotional arousal can be described as the degree of subjective activation an observer experiences when viewing a stimulus (Pessoa, 2013; Reisenzein, 1994). Another study (Schimmack & Derryberry, 2005) found that the greatest interference was produced by the most arousing, intense pictures, irrespective of their valence. In another experiment (Trick, Brandigampola, & Enns, 2012), it was shown that reaction times to highly arousing stimuli were shorter than those to less arousing stimuli, which suggests that arousal has an energising effect on the cognitive system, and hence might improve cognitive performance.

Nonetheless, the theory of arousal-biased competition (Mather & Sutherland, 2011) emphasises the role of arousal. It states that arousal enhances the contrast between a deviant stimulus and other stimuli, making the salient stimulus more salient while suppressing less salient stimuli further. Lundqvist and colleagues (Lundqvist et al., 2015, 2014) also underscored the importance of arousal, reviewing their previous experiments in the light of this. It should be noted that in their Lundqvist and colleagues always used faces as stimuli and hence one goal of our study was to revisit the phylogenetic-ontogenetic dispute.

There is a large body of research in this field based on the odd-one-out paradigm introduced by Öhman et al. (2001). This involves presenting several pictures simultaneously, arranged in matrices. For instance, nine pictures can be displayed simultaneously in a 3x3 array. Respondents have to indicate whether the array includes a target, i.e. a stimulus that is different from the others, the distractors. The distractors in a given array are always from a single category e.g. flowers. Over the past 15 years this paradigm has been used in numerous experiments designed to identify cues that are processed preferentially. Such cues include predatory cues (Lipp & OV, 2006; Purkis & Lipp, 2007), social threats (Lundqvist et al., 2014; Lundqvist et al., 2015), modern

threatening stimuli and fear-inducing stimuli generally (Brosch & Sharma, 2005; Brown et al., 2010; Fox et al., 2007; Young et al., 2012).

Nonetheless, the odd-one-out visual search paradigm has been challenged (Quinlan, 2013; Quinlan et al., 2017; Rinck et al., 2005; Subra et al., 2017). After surveying a large body of literature Quinlan (2013) argued that it is unclear whether distractors or targets caused the results, i.e. the results are due to a faster detection of the target, or a faster rejection of the background (see also Rinck et al., 2005). Furthermore, it was also shown (Subra et al., 2017) that since respondents need to process all the simultaneously presented pictures and select one of them, this task does not quite resemble the originally intended process of attention capturing. Finally, there is growing evidence (Cave & Batty, 2006; Notebaert et al., 2011; Quinlan, 2013) suggesting that controlling for potential perceptual confounds is crucial in studies dealing with visual search tasks.

Here, we present a new paradigm for investigating how emotional valence – threat in particular – and arousal modulate attentional processing. In the classical odd-one-out visual search task participants are exposed to stimuli of varying valence. Multiple emotional stimuli are presented simultaneously, most pictures are similar, but one differs with respect to both valence and category (Öhman et al., 2001; Öhman & Mineka, 2001; Öhman & Mineka, 2003; Mineka & Öhman, 2002). In our paradigm only one emotional picture is presented at a time. The main difference is that visual search performance is measured using a cognitive task that is superimposed on the emotional stimuli. Thus, the presentation time is also longer for each stimulus. In this way, we have separated the cognitive attentional task - the visual search - from the emotional stimuli. This allowed us to compare the attentional processing of stimulus categories of different valence and arousal level and, more importantly, threatening and non-threatening stimuli. Our proposed paradigm is similar of that used by Neisser and Becklen (Neisser & Becklen, 1975) in a sense that they too superimposed two different cues. However, we used static pictures instead of videos, moreover, in the background we presented emotionally charged stimuli, while they only used neutral ones.

Our over-arching goal was to create a better paradigm to hypothesis testing and to address the problems with the odd-one-out paradigm. In our first experiment, beyond

methodological innovation, we emphasised each emotional dimension – valence and arousal – in turn to determine which had a greater impact on cognitive processing. In the second experiment, we investigated the long-established issue of the relevance of the evolutionary history of stimuli, to determine whether phylogenetic age conveys a temporal advantage in visual information processing. Finally, in the third experiment, we validated our results by replicating them whilst controlling for variance in low-level visual features and using a touchscreen monitor.

Experiment 1 – Introducing a novel method to assess the effects of emotionally charged cues on cognitive performance

Aim and hypotheses

Our over-arching goal was to create a better paradigm to hypothesis testing and to address the problems with the odd-one-out paradigm. In our first experiment, beyond methodological innovation, we emphasised each emotional dimension – valence and arousal – in turn to determine which one had a greater impact on cognitive processing. Our hypothesis was that negative valence will have a bigger impact on visual search performance compared to neutral and positive valence.

Method

We designed a new visual search task with two components, a background picture and a number matrix in the foreground. The number matrices we used were all produced specifically for the research, using a specially written computer programme. Figure 13 shows an example of the final version of the stimulus assembly.
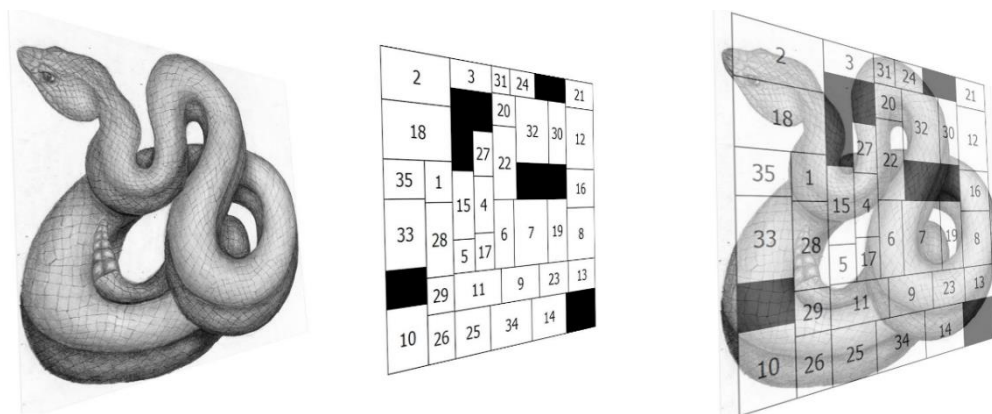
Figure 13 – Stimulus assembly. From left to right: an emotional picture, serving as background; an example of number matrices used for the visual search task; an example

of the final stimuli assembly used in this study. Please note that in this exemplar we replaced the IAPS picture due to copyright issues.

Participants

The sample comprised 117 volunteers – 79 men, 38 women who had not taken part in the pilot study. The participants were senior high school students or undergraduate students and their ages ranged from 18 to 26 years ($M = 22.23$, $SD = 2.42$). All participants reported normal or corrected-to-normal vision. Data from two participants were excluded because of failure to follow instructions.

Visual display

All pictures were taken from the International Affective Picture System database (IAPS) (Lang, Bradley, & Cuthbert, 1999). We chose this database, based on previous experiences and because it enabled us to control the properties of the emotional stimuli we present. These arousal level and valence of the pictures have been rated using nine-point scales. In the case of valence, the neutral point is 5 points and lower scores indicate negative valence. The medium level of arousal is also approx. 5 points and scores above 6 points are considered to indicate a highly arousing picture. The pictures were collected based on the Hungarian standard values (Deák et al., 2010)). The ratings were confirmed in an independent sample of 37 undergraduates. We used six categories: two neutral, two threatening (negative valence) and two with positive valence, see Table 8 for valence and arousal ratings. Statistical tests confirmed that the neutral, threatening and positive categories differed with respect to valence. The medium and high arousal categories differed from each other with respect to arousal (all ts > 2, $p < .05$), but not valence (all ts < 1, $p > .1$).

Table 8 – Valence and arousal ratings of the pictures used in Experiment 1

Category	Content	Valence	Arousal
Neutral	Highway	4.86	4.35
	Skyscraper	4.67	7.37
Negative	Snake	3.53	4.84
	Gun	1.6	8
Positive	Baby	8.22	4.51
	Erotic scene	7.63	7.33

The visual search task consisted of searching numbers in matrices created using a special matrix generator programme (download from *http://baratharon.web.elte.hu/nummatrix/*). The size of the matrices was 715x715 pixels (subtending a visual angle of 15.41°) and they all contained 35 white squares and between 3 and 6 black squares. The width and height of the squares varied from 70 to 230 pixels (visual angle of 1.51° to 4.98°). Both the matrices and squares had a 2-pt black border. All the white squares contained a number printed in black in 32-pt Tahoma font. The numbers ranged from 1 to 35 and each number appeared only once in a given matrix; the numbers were randomly distributed amongst the white squares. The black squares were randomly distributed amongst the white ones. The schematic arrangement of the stimuli is shown in Figure 13. To ensure that we only used matrices that produced similar search performance we carried out a pilot study with a sample of 33 undergraduate students. The students in the pilot study viewed the matrices without a background picture and their task was to count as far as they can in ascending order – they had 40 seconds for each matrix. A total of 30 matrices were used and we selected the ten with the most similar scores for use in our first experiment. These matrices did not differ from each other in terms of search performance ($F < 1$, $p > .1$). For Experiment 1 the matrices were

superimposed on the pictures, one matrix on one picture, with 50% transparency, so one could see both the picture and the numbers clearly, see Figure 13.

The stimulus pictures were all the same size. Visual search paradigms can be sensitive to potential low-level confounds, but analysis indicated that there were no differences between them with respect to colour brightness, contrast, spatial frequency or luminance (Fs < 1, p > .1).

There were four sets of stimuli. Two started with positive pictures, followed by neutral stimuli and then threatening stimuli; the other two started with threatening pictures, followed by neutral and then positive pictures. The order in which the pictures were presented also varied, each category either started with medium or high arousal stimulus. Pictures were presented with different matrices in each set. Each participant saw only one set.

Equipment and materials

The stimuli were presented on a 21-inch TFT colour monitor, with a visible area of 19.7 inches and a resolution of 1366x768, refresh rate of 60 Hz, and 24-bit colour format. Stimuli were presented using Microsoft PowerPoint. Responses were collected via spreadsheets.

Procedure

Participants arrived in the lab in groups although they always completed the experiment individually, at separate computer workstations. Participants were seated at approx. 70 cm from the monitor. They were informed via computer that they were participating in an experiment on visual attention and that they would complete tasks that would involve looking at pictures with numbers them. First two practice trials were given to teach participants the task. One matrix with scattered background (pixels of an image of a basket was mixed) and one with a neutral background image (the original version of the scattered picture: valence = 5.12, arousal = 2.33). After completing the practice trials, they were given an opportunity to ask questions. Participants controlled the pacing of the

trials by hitting the space bar to start a trial. They were instructed to search for the numbers in ascending sequence, starting with the number one, until they ran out of time. The stimulus assemblies were displayed for 40 seconds (the participants were not told this) and once this time had elapsed a black blank screen was displayed, and the participant was asked to write down the last number he or she had found.

Results

We checked for errors in the data and excluded the outliers (values more than 3 standard deviations from the mean; < 2.5% of all data). The missing data were replaced by the mean for that variable. Visual search performance was indexed by counting score (the number reached during the visual search).

We carried out MANOVA with counting score as the dependent variable and valence (three levels: negative; neutral; positive) and arousal (two levels: high; medium) as independent variables. There was no main effect of valence ($F(2,232) = 1.645$, $p > .05$) or arousal ($F(1,116) = 1.220$, $p > .05$) but, interestingly, there was a valence x arousal interaction ($F(2,232) = 4.573$, $p < .05$, $\eta_p^2 = .04$). Figure 14 shows this interaction.

To investigate this interaction further we carried out separate MANOVAs for the medium- and high-arousal stimuli. Strikingly, there was only a main effect of valence for medium-arousal stimuli ($F(2,232) = 4.918$, $p < .01$, $\eta_p^2 = .04$). Post hoc tests with Bonferroni correction revealed that performance was worse when the number matrices were presented against a negatively valenced background than when the background picture had a neutral or positive valence. Performance was similar with neutral and positive backgrounds. When the stimuli were highly arousing, visual search performance was not affected by their valence ($F(2,232) = 1.116$, $p > .05$).

Put together, at high arousal level, visual search performance is similar, irrespective of whether the background is a negatively valenced picture ($M = 17.86$, $SD = 4.67$), neutral picture ($M = 17.74$, $SD = 4.65$) or positive picture ($M = 17.21$, $SD = 5.39$). In contrast, at medium arousal level, performance was worse when the search was carried out with a negative picture in the background ($M = 16.50$, $SD = 4.99$) rather than a neutral

(M = 17.85, $SD.$ = 4.56) or positive picture (M = 17.62, SD = 5.57); performance was similar with neutral and positive backgrounds.
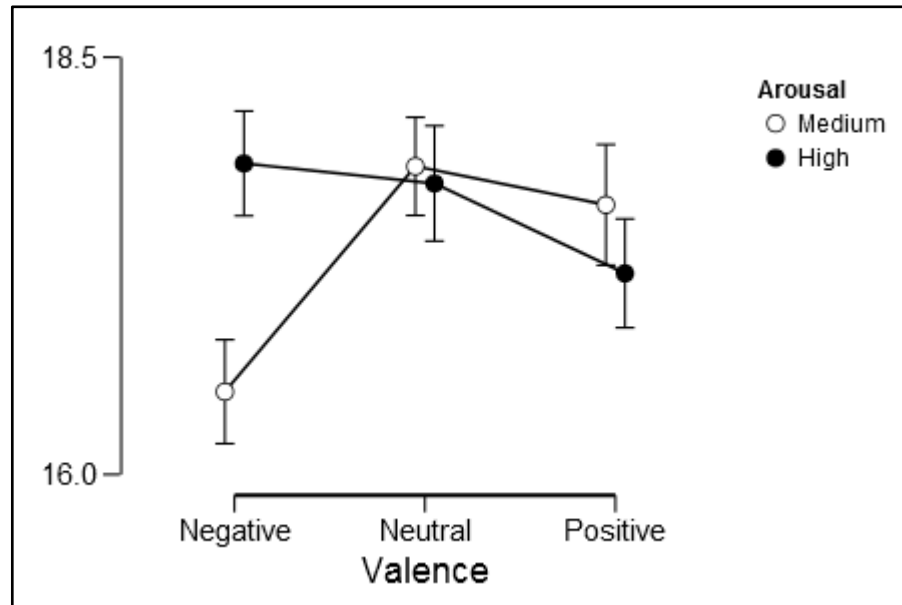
Figure 14 – The interaction between valence and arousal. Visual search performance decreased for medium level negative picture – a snake – compared to the other stimuli used; i.e. the high arousal negative picture – a gun –, both neutral, and positive ones. Standard errors are displayed on the diagram.

Discussion

We examined how threatening stimuli influenced visual search performance compared to neutral and positive emotional stimuli, taking their arousing properties into account. We used a new paradigm in which the cognitive task and the emotional picture were introduced to the visual field simultaneously and present throughout an entire trial. The cognitive task involved searching a number matrix and was superimposed on an image. Our results corroborate previous results (e.g. Lundquist et al., 2014; Öhman et al., 2001; Trick et al., 2012) suggesting that valence and arousal have different effects on search performance.

We claim that negative stimuli grab the attention and in our paradigm the negative background reduced performance on the cognitive visual search task because disengaging

attention depends on higher cognitive functions (Devue, Belopolsky, & Theeuwes, 2011). Arousal stimulates the cognitive system (Mather & Sutherland, 2011; Reisenzein, 1994; Trick et al., 2012) and hence that the difference between visual search performance with medium- and high-arousal threatening stimuli is due to the difference in induced arousal. It is important to note that arousal level had no effect on performance with neutral and positive backgrounds.

One could also argue, however, that being more alert to, and more attentive to negative, threatening stimuli was adaptive during the course of evolution, because it increased the chances of survival. If our ancestors detected threatening cues faster than neutral cues and paid more attention to them they would have had more opportunity to initiate an effective behavioural response e.g. fleeing. However, we found that a highly arousing negative stimulus - a modern, threatening stimulus - did not influence cognitive performance. This implies that the survival value of being good detecting snakes in our evolutionary past distinguishes them from other negative stimuli without a similar evolutionary significance, e.g. guns. Thus, the evolutionary significance of snakes means that their presence impairs search performance; indeed, our results suggest that the snake picture was the most distracting.

Nonetheless, we showed that our new paradigm can be used for future research and is a valid method for testing the effects of emotionally charged stimuli on visual search performance. We also demonstrated that it is very important to control the level of arousal, because it can influence the effect of negative valence on visual search performance. Our results raised the issue of whether differences between performance with the two negative pictures were due to differences in arousal or evolutionary origin, so we conducted a second experiment to address this question

Experiment 2 – The comparison of threating cues with different origins using the counting task

Aims and hypotheses

In the second experiment, we investigated the long-established issue of the relevance of the evolutionary history of stimuli, to determine whether phylogenetic age conveys a temporal advantage in visual information processing.

In Experiment 1 we showed that the paradigm we introduced is appropriate for measuring emotional effects on visual cognition. In Experiment 2 we investigated the specific questions of how evolutionary age and arousal level influence visual processing of threatening stimuli. The goal of Experiment 2 was to investigate whether the inconsistent results of previous research on the impact of threatening stimuli on visual search can be attributed to differences in arousal, by comparing visual search performance with ancient and modern threatening stimuli as backgrounds.

Method

Participants

Sixty-one university students – full-time and part-time –took part in our experiment voluntarily. None of them had participated in the pilot studies (IAPS picture rating; number matrix pilot study) or in Experiment 1. The participants (50 women; 11 men) ranged in age from 18 to 39 years ($M = 26.38$; $SD = 7.01$). All participants reported normal or corrected-to-normal vision. Data from 1 participant were excluded because of failure to follow instructions. Our research was approved by the EPKEB and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). All participants provided informed consent.

Visual display

As in Experiment 1, all pictures were taken from the IAPS (Lang et al., 1997). The Hungarian standards (Deák et al., 2010) did not include enough pictures of snakes and guns so after collecting these pictures based on content from the original database, we conducted a pilot study, asking 37 independent undergraduates to assess the valence and arousal level of the pictures. We then selected pictures with similar ratings for valence and arousal level, but different content.

We used five categories of background stimuli: non-threatening stimuli, with neutral valence and low arousal; two sets of moderately arousing, low-threat, negative stimuli (evolutionary relevant and modern exemplars); two highly arousing, highly threatening negative stimuli (snake; gun). Valence and arousal ratings for the stimuli are given in Table 9. The threatening pictures had similar valence (all ts < 1, p > .1). The medium- and high-level arousal pictures did differ in the level of arousal (all ts > 2, p < .05). The evolutionary relevant and modern groups did not differ with respect to arousal or valence.

The only distinction between the high- and medium-arousal stimuli was that the high arousal stimuli were depicted targeting the viewer – the guns were pointing at the viewer and the snake was striking at him or her. Fox et al. (2007) also noted this phenomenon too, but like Young et al. (2012) they used a mixture of medium and highly arousing pictures.

Table 9 – Mean valence and arousal ratings for stimuli used in Experiment 2

Category	Content	Valence	SD	Arousal	SD
No threat		4.97	0.14	2.09	0.46
Low threat	Snake	3.94	0.13	5.44	0.11
	Gun	4.17	0.63	5.23	0.59
High threat	Snake	2.9	0.14	7.01	0.24
	Gun	2.99	0.67	6.8	0.59

We used the same matrix generator programme as in Experiment 1 to create the matrices for this experiment. Ten matrices were selected using the method described for Experiment 1. A pilot study involving 33 undergraduates demonstrated that the matrices elicited similar visual search performance ($F < 1$, $p > .1$). The stimulus assemblies were created using the same procedure as in Experiment 1: a number matrix was set against an emotional picture with 50% transparency, see Figure 13. The pictures were all the same size and similar with respect to potential low-level confounds, namely colour brightness, contrast, spatial frequency and luminance (all Fs < 1, $p > .1$).

There were two sets of stimuli, both starting with the two neutral pictures. In the first set the neutral pictures were followed by the medium arousal pictures (snake, gun, snake, and gun) and then the high arousal pictures (snake, gun, snake, and gun). In the second set the neutral pictures were followed by the high-arousal pictures and then the medium-arousal ones. All participants saw only one stimulus set. Presentation order did not affect the behavioural data.

Equipment and materials

The stimuli were presented on 21-inch TFT colour monitor, with a visible area of 19.7 inches and a resolution of 1366x768, a refresh rate of 60 Hz and 24-bit colour depth.

Stimuli were presented using Microsoft PowerPoint. Responses were collected via spreadsheets.

Procedure

The procedure was same as in Experiment 1. Participants arrived in the laboratory in groups but were always tested individually, at separate computer workstations. Participants were seated approx. 1 meter from the monitor. Instructions were presented via computer. First, respondents completed two practice trials - these were the same as in Experiment 1; one had a scattered background and one a neutral background – data from which were not included in the analyses. After this they were given an opportunity to ask questions. Participants started a new trial by hitting the space bar. They were instructed to find the numbers in ascending order, starting with the number one. They were not told how long the stimuli would be visible (40 s). At the end of the stimulus presentation a blank, black screen was displayed and the participant was asked to write down the number he or she had reached in the search. The only change from Experiment 1 was to the pictures making up the backgrounds of the stimulus assemblies.

Results

We checked for errors in the data and excluded the outliers (values more than 3 *SD* from the mean; < 2.5% of all the collected data). The missing data were replaced by the mean for the relevant variable. Counting values were used as an indicator of visual search performance, i.e. as the dependent variable.

We carried out MANOVA with content (neutral; snakes; guns) and threat level (none; low; high) as independent variables.

As expected, based on the result of Experiment 1, there was a main effect of threat level ($F(2,120) = 6.41$; $p < .05$, $\eta_p^2 = .09$). Interestingly, there was no main effect of content and no interaction between threat level and content (Fs < 1, p > .1). Further analyses revealed that the low-threat pictures had a negative impact on search performance ($M =$

18.43, SD = 3.81) compared to neutral pictures (M = 19.74, SD = 2.81). However, search performance with high-threat pictures (M = 19.35, SD = 3.61) did not differ from performance with the other two categories of background stimuli. The main effect of threat level is illustrated in Figure 15.
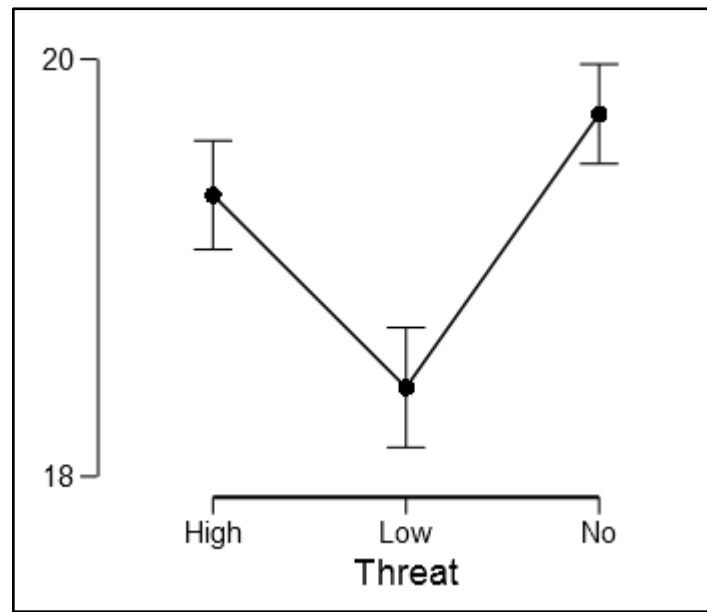
Figure 15 – The main effect of threat. Visual search performance was worse with low-threat pictures than no-threat pictures, but performance with the high-threat pictures was not different from performance with the other categories of background. Standard errors are displayed on the diagram.

Discussion

Our main goal was to compare evolutionarily ancient and modern threatening stimuli, whilst systematically varying their arousal level, represented in the case by threat level. Within each threat category the images of snakes and guns were rated similarly threatening and differed only with respect to arousal, as intended. Our results show that level of arousal did influence visual search performance; medium-arousal (low-threat) stimuli resulted in worse performance than less and more arousing background stimuli (no-threat and high-threat pictures, respectively).

An evolutionary framework such as that described by Öhman and colleagues (Öhman et al., 2001; Öhman & Mineka, 2001; Öhman et al., 2012) would predict search performance would be worse with background pictures of snakes than with pictures of guns, irrespective of their arousing properties. The evolutionary account assumes that snakes, because of their evolutionary significance, are given priority in visual processing, and grab and hold the attention better than other types of threatening stimulus.

In contrast, we argue that search performance is impaired when there is a threatening stimulus in the background, irrespective of its evolutionary history. Furthermore, we argue that the energising effect of arousal compensates for the negative impact of threat and that this energising effect is also independent of the evolutionary origin of the stimuli. In our view, this account is consistent with the results of Experiment 1.

Experiment 3 – Validating the counting task and previous results

Aims and hypotheses

Finally, in the third experiment, we validated our results by replicating them whilst controlling for variance in low-level visual features and using a touchscreen monitor.

In Experiment 2 we showed that although level of arousal influences visual search performance the evolutionary age of stimuli does not. In the last experiment, we sought to validate our results (i.e. confirm the accuracy of participants' self-reports of visual search performance) using a touchscreen monitor. Moreover, because concerns have been raised about the confounding effects of the low-level visual features of emotionally charged images (see Quinlan, 2013 for a review) we used low-level visual feature filtering, whilst also controlling for the complexity of the pictures used. Our first hypothesis was that evolutionarily old and modern threatening stimuli have similar effects on visual search performance. The second hypothesis was that arousal is the key determinant of visual search performance, and hence if not controlled can confound results.

Method

Questionnaire

As well as performing the visual search task in this experiment participants were asked to complete the Snake Questionnaire (SNAQ; Klorman, Weerts, Hastings, Melamed, & Lang, 1974)), a 29-item binary self-report measure of fear and phobia of snakes. The SNAQ consists of one scale, and has 9 negatively worded items. Respondents answer by indicating whether statements are true or false and the score is given by the sum of 'true' responses (range: 0 to 29). The Hungarian validation studies (Zsido, 2017; Zsido, Arato, et al., 2018) showed that the scale had excellent psychometric properties, with Cronbach's alpha = .93.

Participants

Forty-one university students (19 men; 22 women) took part in the experiment voluntarily. None of them had participated in the number matrix pilot study or in the earlier experiments. The mean age of the sample was 21.95 years (*SD* = 2.33). The participants completed the Hungarian version of the SNAQ. The median score was 8 (*M* = 7.78, SD = 6.19) and none scored above the threshold (23 points; Mats Fredrikson, 1983)) that indicates a clinical level of phobia. All participants were right-handed and reported normal or corrected-to-normal vision. Data from 2 participants were excluded because of failure to follow instructions. Our research was approved by the EPKEB and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). All participants provided informed consent.

Visual display

Pictures were taken from IAPS and the Nencki Affective Picture System (NAPS; Marchewka, Żurawski, Jednoróg, & Grabowska, 2014)), based on ratings of valence and arousal provided by the two databases. Moreover, after completing the visual search task the participants in this experiment rated the valence, arousal, and threat levels of the pictures using nine-point Likert scales. As expected, the arousal ratings were very similar to the threat level ratings.

There were six categories of background stimuli: three threat levels (none; low; high) and two types of content (animal; object). Each category consisted of four pictures. The neutral category comprised pictures of a cow, bird, fish and elephant. As in Experiments 1 and 2, snake and gun pictures were used for the low- and high-threat categories and once again the difference in threat level was derived from the perspective: in the high-threat pictures the gun or snake was positioned to target the viewer and in the low-threat pictures they were not. Pictures of different threat levels differed on all three scales (all *F*s > 3, *p* < .05). Different types of stimuli (animal and object) did not differ from each other within threat levels (all *t*s < 1, *p* > .1). Our participants' ratings of the stimuli are shown in Table 10.

Table 10 – Valence, arousal and threat ratings of the picture categories used. All ratings given using nine-point scales where 1 means very negative (valence), not arousing or not at all threatening and 9 means very positive (valence), very arousing or highly threatening.

Threat	Type	VAT	Mean	SD
High	Animal	Valence	2,158	1,4
		Arousal	6,947	1,173
		Threat	7,624	1,218
	Object	Valence	2,145	1,179
		Arousal	7,271	0,932
		Threat	8	0,885
Low	Animal	Valence	3,908	1,648
		Arousal	5,634	1,429
		Threat	5,816	1,869
	Object	Valence	3,566	1,669
		Arousal	6,276	0,984
		Threat	6,053	1,389
No	Animal	Valence	6,237	1,256
		Arousal	3,839	1,392
		Threat	1,395	0,522
	Object	Valence	5,655	1,257
		Arousal	3,461	1,768
		Threat	1,25	0,381

We again used the matrix generator programme to create the matrices for this experiment. Twelve matrices were selected using the method described previously. A pilot study involving 30 undergraduates showed that the stimuli produced similar levels of visual search performance ($F < 1$, $p > .1$). The stimulus assemblies were, once again, created using the method described in Experiment 1, see Figure 16.

To avoid the possible confounding effects of uncontrolled variance in low-level visual properties, we used the Spectrum, Histogram, and Intensity Normalisation and Equalisation (SHINE) toolbox (Willenbockel et al., 2010) written with MATLAB to adjust the images to ensure that they were equivalent with respect to these low-level properties. In all cases the matching procedure was applied to the entire picture. All the images (no-threat, low-threat and high-threat) were loaded into the programme and converted to greyscale then the low-level properties were adjusted so as to be similar in all images.

First, the luminance and contrast values were matched using exact histogram matching across images. The image histogram is a graphical representation of the distribution of tones in a digital image based on the number of pixels of each tonal value. A histogram is extracted from all images and then the average histogram is calculated and this distribution is applied to the original images. Next the sfMatch function equates the rotational average of the Fourier amplitude spectrum (i.e. the average energy at each spatial frequency) of the histogram-matched images. The structural similarity (SSIM) indices for the images were also optimised in order to maximise perceptual image quality (three iterations). After this process all the images had the same luminance, contrast and spatial frequency values.

We then calculated image complexity for all the pictures, to enable us to control for the possible confounding effects of variance in visual complexity. The method we used is based on the assumption that average complexity increases as a function of log JPG file size (Donderi & McFadden, 2005; Forsythe et al., 2011). The categories used in this experiment did not differ on this measure ($F < 1$, $p > .1$).

All participants saw two exemplars from each category, 12 pictures in total, presented in random order. The pictures and picture-matrix combinations varied between

participants; all pictures and matrices were presented with equal probability during the experiment.
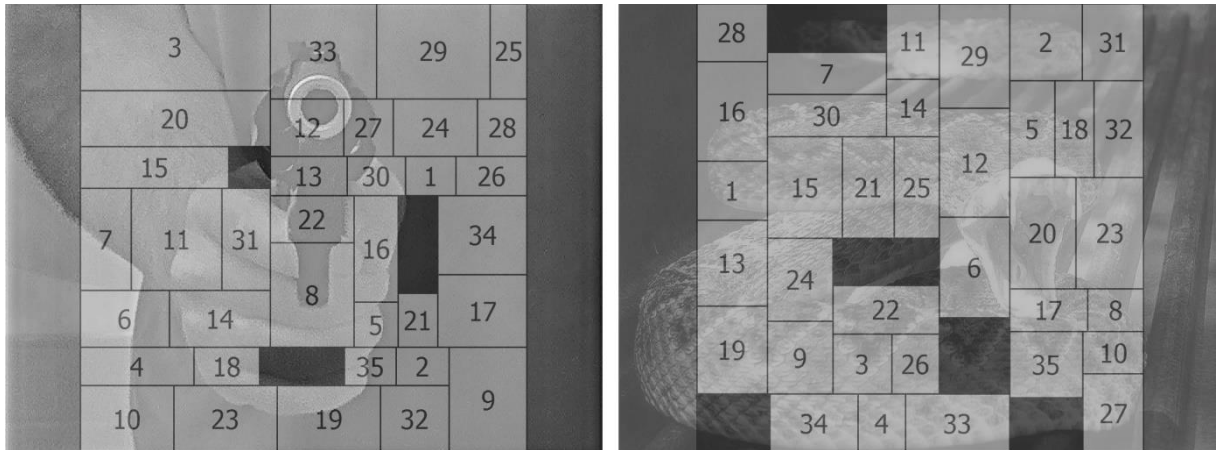
Figure 16 – Illustrative examples of the stimuli used in this study. From left to right: Hight-threat object and high-threat animal in the background. Please note that in this exemplar we replaced the IAPS and NAPS pictures due to copyright issues.

Equipment and materials

The stimuli were presented on a 17-inch LG Flatron T1710 touchscreen colour monitor, with a with a resolution of 1280x1024, 5:4 aspect ratio, refresh rate of 60 Hz, and colour depth of 16.7M. Responses were collected via spreadsheets. Stimuli were presented using PsychoPy Software version 1.83 for Windows (Peirce, 2007).

Procedure

The procedure was the same as in Experiment 1 and 2. Participants completed the experiment at individual computer workstations, seated approx. 60 cm from the monitor. Instructions were presented via computer. First participants completed two practice trials as in Experiments 1 and 2 - one with a scattered background; one with a neutral background – which were not included in the data analyses.

Participants used their right hand to respond. They were asked to place it in front of them on a piece of paper. They started each trial by hitting the space bar with their left hand. They were instructed to find the numbers in ascending order, starting with the number one. They had to indicate when they had found a number by touching it on the screen, then replacing their hand on the sheet of paper in front of them. Each stimulus was presented for 40 s, as in previous experiments. Once this period had elapsed, a black, blank screen was presented and the participant was instructed to write down the last number he or she had found.

Results

We examined the raw data and used the coordinates registered via the touchscreen monitor to validate the search results participants wrote down. In no instance did the reported number differ from that implied by the touchscreen data.

We used MANOVA to analyse the data, with content (object; animal) and threat level (none; low; high) as independent variables.

In confirmation of our previous results in Experiment 1 and 2 we once again observed a main effect of threat level ($F(2,80) = 5.54$, $p < .01$, $\eta_p^2 = .12$). There was no main effect of content and no interaction between content and threat level (Fs < 1, $p > .1$). Pairwise comparisons using the Bonferroni correction revealed that low-threat pictures elicited worse visual search performance ($M = 18.38$, $SD = 3.98$) than both high-threat ($M = 19.31$, $SD = 3.79$) and no-threat ($M = 19.31$, $SD = 3.79$) pictures, see Figure 17 for detailed results.
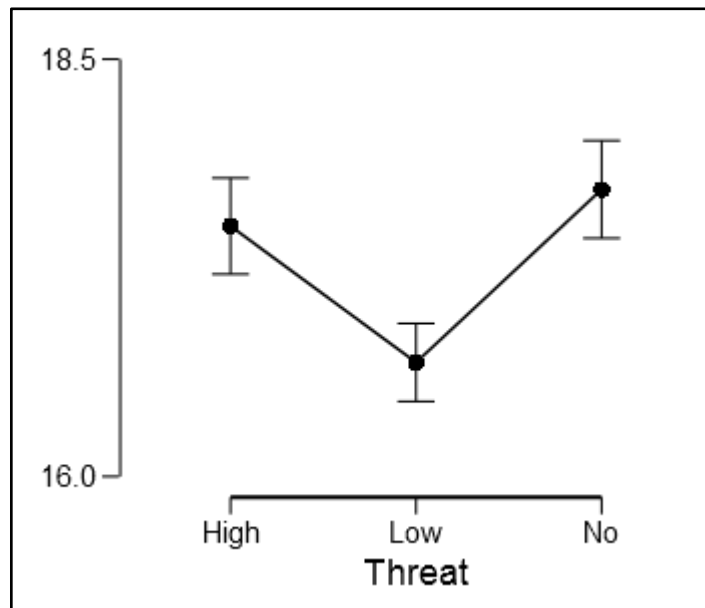
Figure 17 – The main effect of threat. Low-threat pictures were associated with worse visual search performance than no-threat and high-threat pictures, which were associated with similar levels of performance. Standard errors are displayed on the diagram.

The SNAQ scores did not have a significant covariation effect on the results ($F < 1$, $p > .1$). Interestingly, we also found no correlation between SNAQ score and search performance ($p > .1$).

Discussion

In the third experiment we sought to validate our new paradigm and our previous results, which were based on self-reported visual search performance. We also matched the stimuli with respect to visual complexity and low-level visual properties - contrast, luminance, and spatial frequency - that were considered potential confounders in order to produce a clearer picture. We tested two hypotheses. The first was that evolutionarily old and modern threatening stimuli have similar effects on visual search performance and the second was that arousal is the key determinant of visual search performance, and hence if not controlled can confound results.

Our results replicated those of Experiments 1 and 2. It seems that threatening stimuli do have an effect on perception and attention; they draw attention away from a task. Furthermore, at least in a sample of healthy adults, the evolutionary age of the threatening stimulus does not matter; images of both old and new threats were similarly effective in distracting attention from the visual search task. We thus emphasise the importance of the other distractor stimulus variable, namely, arousal level. Arousal also influences visual search performance: a higher level of arousal compensates for the decrement in performance produced by negatively valenced distractors. We claim that negative, threatening background images are more effective in distracting attention from the separate cognitive task than non-threatening background images. Hence presentation of low-threat, medium arousal cues impaired visual search performance. However, as the threat level of distractor stimuli increases, arousal increases and this speed up the cognitive system, so that participants search more quickly when the background consists of a high-threat image and perform as well as when the background consists of a non-threatening image.

General Discussion

We have presented a new visual search paradigm that could prove a good alternative to the classical odd-one-out task. First, we showed that our method is capable of measuring the impact of emotions on cognitive processing; focusing on threatening cues. After this, our main aim was to elucidate the factors driving attentional processing of threatening, negative pictures. Does evolutionary history matter the most, as previous research suggests, or are other factors also important?

We conducted three experiments to address these issues. In Experiment 1 we used positive, neutral and negative stimuli, combined with two levels of arousal, medium and high. We found that visual search performance was worse in the context of negatively valenced background images that elicited medium arousal than with images from other categories. This result demonstrates the importance of including arousal as a dependent variable in analyses of emotionally charged pictures.

Our second experiment was designed to find out what caused the difference in performance observed in Experiment 1, was it the content of the picture – i.e. its evolutionary relevance – or the level of arousal? In Experiment 2 we used medium- and high-arousal versions of images of snakes, and guns, comparing their effect on visual search performance with that of non-threatening images, and so we labelled the image categories no threat, low threat and high threat. Visual search performance was worse with low-threat pictures than no-threat pictures, but performance with high-threat pictures was not different from performance with other categories of background image.

Experiment 3 had several objectives. First, we sought to validate the paradigm by verifying the accuracy of the self-report results and show that - despite being based on self-reporting - the task is reliable and suitable for use in future research. Second, we wanted to eliminate potential confounding effects of variance in low-level visual features, such as contrast, luminance and spatial frequency. We achieved this by modifying the stimulus pictures so that they were matched for these variables. Third, we aimed to determine whether the impact of images of snakes on visual search performance was influenced by level of fear of snakes in a non-phobic sample. Fourth, we hoped to replicate our previous results. We confirmed the results of Experiment 2 and found no covariation effect of non-phobic fear of snakes.

We argue that all threats are evaluated by the same underlying system and agree with those who have suggested that evaluations are partly innate and partly learned during ontogenesis (see, for instance, Davey & Dixon, 1996; Mallan, Lipp, & Cochrane, 2013). During the course of life, we learn to treat threatening objects with no evolutionary significance as potentially dangerous objects, whereas fear of snakes is an evolutionary legacy, but as adults we evaluate them in the same way. Our experiments provide support for this notion as they demonstrate that images of modern threats have the same effect on visual search performance as images of ancient threats.

Fear-relevance drives information processing: threatening stimuli have a general attentional advantage over non-threatening stimuli, as others have noted (Brosch & Sharma, 2005; Brown et al., 2010; Fox et al., 2007). The interaction we observed in our first experiment is consistent with this. Search performance was lower in the presence of negative stimuli, because processing of negative stimuli required more cognitive capacity than neutral and positive and hence reduced the attention devoted to the task. Negative stimuli attracted attention, thus leaving less capacity for the cognitive task and reducing visual search performance. However, the decrement in search performance was only observed in the case of threatening images that elicited medium arousal. We suggest that higher arousal compensated for the negative impact of negative stimuli on search performance. In other words, valence alone cannot account for the influence of emotional stimuli on cognitive processes.

We tested this hypothesis in our second experiment, using evolutionarily ancient or modern negative stimuli in medium- and high-arousal versions. Our results showed that the differences in visual search performance observed in Experiment 1 were due to differences in arousal rather than the evolutionary age of the stimuli. In line with previous results (Soares et al., 2009; Soares et al., 2014; Öhman et al., 2012) we found that negative stimuli did capture attention and thus, in our paradigm, distracted participants from the visual search task. However, we claim that increased arousal can compensate for the detrimental effect of negative valence. This is in line with other studies (Mather & Sutherland, 2011; Lundqvist et al., 2014; Lundqvist et al., 2015) underscoring the importance of the arousal generated by a stimulus. Experiment 2 supported the idea that arousal, as well as affective valence, has an effect on cognitive performance.

Our last experiment confirmed the results of the previous two. We matched the stimuli with respect to low-level visual features, obtained arousal and valence ratings for the pictures from our participants, assessed their level of snake phobia and used a touchscreen monitor to verify their self-reported search performance. In our view the results of Experiment 3 suggest that low-level visual features, in particular colour, might not have as much influence on attention as the emotional properties of images. Furthermore, it appears that the visual search task we developed can be used without a touchscreen monitor and that it is acceptable to rely on self-reports of visual search performance in this context.

In summary, we conclude that neither valence nor arousal is sufficient to account for the effects of emotionally charged stimuli on cognitive performance; both must be taken into account. In three experiments, we showed that arousal has a distinctive role in this effect, and therefore, cannot be neglected when designing visual search experiments. Physiological processes have to be taken into account. Negative stimuli can have an energising, triggering effect that can contribute to differences in behavioural responses. Highly arousing events can have a direct impact on response preparedness, most likely through activation of the autonomic nervous system. More work is needed in the future to address this issue.

FINAL CONCLUSIONS

The main topic of the present dissertation, namely the relationship of negative emotion, fear and visual search in particular, has seen numerous research since the New Look, throughout the forming of the Emotion Lab at Karolinska Institutet by Öhman around the 1980's, until today. There is still, however, a debate on how threat affects visual search performance, is there an advantage in visual processing for evolutionary relevant cues (Öhman & Mineka, 2003; Öhman et al., 2012) or maybe the ones acquired the ontogenesis prevail (Brown et al., 2010; Subra et al., 2017); and there are even some (Quinlan, 2013; Quinlan et al., 2017) who claim there is no effect at all. There are robust results supporting the notion that our visual system is sensitive to detecting threatening cues that has been present during the course of human evolution because it was adaptive, as it helped survival (Öhman et al., 2001). Furthermore, previous research (Soares et al., 2014) concluded that some of these evolutionary relevant threatening cue, namely the snake, is even more highlighted compared to other evolutionary relevant threats. The research on phobias (Seligman, 1971) also supported this, as it was shown that the prevalence of developing a phobia specific to ancient stimuli is much higher compared to modern ones. Therefore, it seems plausible to claim that there is a fear module (Öhman & Mineka, 2001; 2003) that processes such stimuli automatically. In contrast, Loftus et al. (1987) described the weapon focus theory, which showed that a gun is a highlighted cue; thus, one could argue that there is a weapon module as well. Nonetheless, from a cognitive point of view, the existence of a specific module for all the possible threats seems rather uneconomical. Therefore, Coelho and colleagues (Coelho & Purkis, 2009; Coelho et al., 2010) suggest a general feature detection system that was evolved to increase the chance of survival; this system would allow for some plasticity, i.e. the general feature detection of evolutionary relevant stimuli are innate, however, the same system could encode new features, and, thus, help survival in the modern age. The new phobia categories of DSM-V (e.g. injection phobia, flight phobia, etc.) also point in this direction.

During the course of three studies, and nine experiments in total, we introduced methodological innovations such that new paradigms, taking into possibly confounding

factors (e.g. arousal level) and low-level visual feature controlling processes. Using various paradigms also allow us to draw conclusions that are not affected by methodological issues and specificities, and, thus are more generalizable. See Table 11 for an overview of the main results.

Table 11 – An overview of the results of experiments presented in the dissertation

Study nr.	Experiment nr.	Paradigm	Short description
Study 1	Experiment 1	Classical visual search task	Modern threatening cues are found faster compared to evolutionary relevant ones only at high arousal level
	Experiment 2		Firemen did not differ from young adults despite age differences
	Experiment 3		Detection of evolutionary relevant threatening stimulus is based on general features, while the detection of modern one is based on specific features.
Study 2	Experiment 1	New visual search task	Pilot study - Introducing a novel paradigm
	Experiment 2		The best representatives of evolutionary and modern threatening stimuli are found equally faster than neutral targets
	Experiment 3		Threat superiority effect is specific to some advantaged stimuli
Study 3	Experiment 1	Number matrices	Negative valence at medium arousal level decreased search performance
	Experiment 2		Negative arousal decreases search performance while higher levels of arousal compensates for this effect
	Experiment 3		Repeated the results of Experiment 2 using touch-screen monitor

In the first study, the classical visual search task (Öhman et al., 2001) was used, however, with some additional changes to improve the validity and to explore the cause of previous mixed effects. We showed that the existence of a threat detection module or

system is plausible, although according to our results modern threats have an advantage over evolutionary relevant ones. In addition, the experiment with pre-schoolers showed that if there is a general feature detection system, it is highly specific to the features of modern threats, since the visually highly similar threat and neutral objects were detected equally as fast, while the modern threat was faster to be found compared to its neutral counterpart.

The second study started with the introduction and testing of a new visual search paradigm, that is, in our view provides an ecologically more valid method of hypothesis testing. First, our results showed that the method could be used in such experiments and offers a great alternative to the classical visual search task. The results of the second and third experiment add to the understanding of threat detection and shed some light on the possible background of the debate on the visual detection of threatening cues. In the first experiment, using the two best exemplars of the evolutionary relevant and modern threat categories – snake and gun, respectively –, our results suggest that the modern threatening cue has an advantage over all other stimuli, while the evolutionary relevant threat is still found faster compared to neutral targets. Conversely, in the second experiment, when there were three different objects in each of the previous categories, we failed to replicate this effect. This could mean, on the one hand, that there are, indeed, specific stimuli that are even more highlighted, similarly as Soares and colleagues (2014) suggested regarding evolutionary relevant threatening cues. On the other hand, there are other possible explanations, for instance, that the advantaged nature of threatening cues could only be captured under specific circumstances in the laboratory. These circumstances could include but are not limited to the number of targets used, the time of the task, and other motivational factors. Due to the extended number of possible targets the working memory might heavily influence, and, thus, confound the results. Especially with the individual differences of change in motivation, e.g. experiencing complete boredom vs an interesting competition. Furthermore, as we pointed out, testing more targets requires larger stimuli sets, that could lead to fatigue of the visual system (Csathó et al., 2012). In contrast, if let us say there is a break included, that might also confound results. Thus, the final answer is yet to be found.

The third study is another alternative to the classical visual search task, and at the same time takes on a different perspective than the paradigm in Study 2. The number

matrices might be a technique to solve at least one of the questions of the previous study – the influence of the working memory. Our overarching goal was to, similarly to experiment one of study one, give evidence on the importance of taking arousal level of the stimuli used into account when conducting an experiment on the effects of threatening stimuli. Indeed, as we demonstrated in the first experiment, one gets to different conclusions with and without regard to the arousal level. If one does not control for the arousal one might conclude that evolutionary relevant stimuli distract attention more, thus resulting in lower performance, therefore the evolutionary relevant threats have an advantage over any other stimuli. Conversely, if one has actual arousal values on the threatening stimuli used in the experiment, the conclusion may be that threatening pictures distract attention more, however, the increase in arousal level compensates for this. Indeed, the results of experiment two support this latter idea, and provides further evidence on the fact that arousal has a crucial role in visual search. Here, experiment three was conducted to validate the results, which are in experiment one and two are based on self-report performance, and thus are less reliable.

In sum, the primary goal, an ambitious one indeed, of the present work was to solve a well-aged puzzle n threat detection. It was shown that the origin of the stimuli (evolutionary relevant or modern) cannot be neglected. Nor can be other factors such as the context, arousal, expectations, and motivation. Previous research tended to only control for and describe one. However, all these should be integrated and seen as different features of the same cue, and therefore, these factors should all be considered or completely ruled out when conducting future research.

The present dissertation has two major advances: First, we have shown that the arousal level of the emotionally charged stimuli is as important as its valence. In a VST (see Study 1) arousal level differentiates between threatening targets of different origin; while in a visual performance task (see Study 2) higher levels of arousal compensates for the effects of negative valence. Second, it seems that some threatening cues are more advantaged than others (see Study 3), however, not based on evolutionary relevance, but rather motivational and individual factors. The fact that these results were achieved using three different paradigms, two of which are coined here add to the validity of these claims. Thus, we hope that the methods and results presented here might add to the better understanding of the phenomenon in question.

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