University of Southampton

FACULTY OF SOCIAL, HUMAN AND MATHEMATICAL SCIENCES
SCHOOL OF PSYCHOLOGY

Are Visual Searches Fasters in the Case of Emotionally Threatening Targets?

PSYC6022 – MSc Dissertation

MSc The Foundations of Clinical Psychology

Intake Year: 2017

Candidate ID: 29386063

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Word count: 9171 (Excluding Title Page, Tables, References, Abstract and Appendices)

Submission Date: 11/09/2018

A dissertation submitted in partial fulfilment of the degree of MSc Foundations of Clinical Psychology by taught course

*Academic Integrity Declaration: I am aware of the requirements of good academic practice and the potential penalties for any breaches. I confirm that this assignment is all my own work.

Acknowledgements

I would like to warmly thank Dr Erich Graf for his guidance throughout this academic year and for making it possible to conduct such an innovative experiment in the field of cognitive-clinical psychology. In addition, I would like to thank my sister and my family for their unwavering support throughout this year.

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Abstract

To achieve a robust representation of the external world, different perceptual mechanisms are involved to be submitted for object recognition. Camouflage and its related techniques, such as edge enhancement (EE), are strategies employed in the animal world to avoid detection by fooling these perceptual processes. This predator-prey relationship has been theorised, in snake detection theory (Isbell, 2006), to be a driving force behind the evolution of binocular vision. Previous research also showed that one guiding basis of prioritised attentional allocation is the affective value of the stimuli. Here, we attempted to reconcile these findings in the literature investigating visual search behaviour in naturalistic environments. Participants searched for snakes embedded in leaves in immersive virtual environments after completing a set of clinical measures including Snake Phobia Questionnaire (SNAQ). We aimed to address two hypotheses. We expected that people with heightened levels of snake-phobia would exhibit faster detection speeds than those with low levels. Furthermore, we expect this effect to be larger in camouflaged (EE) environments. For exploratory reasons, camouflage and its relation to self-reported measures were also analysed. Main results showed that having high levels of snake-phobia did not create any significant advantage in terms of supressing the effectiveness of EE as opposed to that of those with low levels of snake-phobia. The limitations that may have caused these results are entirely discussed, along with possible improvements, and future directions for the research are suggested.

Keywords: snake-phobia, edge enhancement, camouflage, VR

Introduction

The primary sensory interface with the external world is vision. The visual system acquaints the viewer with the information about the physical world, such as the size, parallax, texture or movement of objects. However, the capacity of the human visual system in terms of information processing is enforced by the complexity of natural scenes. This is partially due to the transition of 3D view into a 2D retinal representation (Julesz, 1971), which results in an ambiguity in received visual signals, before the allocation of neurological and cognitive processes in the brain function for object recognition. Therefore, to achieve a robust representation of the real-world environments and to keep the amount of received errors to a minimum, different perceptual mechanisms are involved to be submitted for object recognition (see Snowden, Snowden, Thompson, & Troscianko, 2012, for a detailed explanation). The human visual system seems to operates these computational processes effortlessly, hence, takes them for granted. However, little is known about these processes which used to recognise and prioritise important information for future actions while filtering out the unimportant stimuli.

Research on human cognition pays special attention to these perceptual courses that exist in anything involving humans (Kourtzi & DiCarlo, 2006), as an enhanced insight into how these processes work will also considerably advance the understanding of those higher-order cognitive functions such as visual memory or object recognition. The process of identification of an object can be stimulus-driven, (i.e. any alteration in related to the environment is captured automatically; Franconeri & Simons, 2003) or can be in a more strategically controlled manner (i.e. avoiding threatening stimuli to regulate emotion; Calvo & Avero, 2005). The first one is referred to as “bottom up processing” when the stimulus itself is used to drive the human perception whereas the latter is influenced by past human experiences and expectations to recognise the object of interest. Previous research indicated that these information processes (aka figure-ground processing) facilitates the segmentation of objects that eventually leads to object recognition (Vecera & O'reilly, 1998). Then, a question arises which is that how does the brain judge the figure and ground from each other?

Several visual cues assist the segmentation of objects, including monocular depth cues (i.e. involving one eye at once) of relative size or distance (Easa, Mantiuk, & Lim, 2013) or shading and perspective (see Patterson & Martin, 1992, for a comprehensive review), and binocular cues (i.e. involving both eyes at once) such as stereopsis (the ability to appreciate depth), are inherited in our daily lives. Since binocular depth cues aids in encoding the 3D form of objects, this research is concerned only with and take advantage of binocular disparity in recognising objects, which is suggested to provide the most important and accurate information over other visual signals for stereopsis (Poggio & Poggio, 1984).

The prey-predator relationship in the animal kingdom is also influenced by visual cues to avoid recognition and curtail the risk of predation (see Nityananda & Read, 2017, for a comprehensive review), of which camouflage is a widely used strategy, with different forms of crypsis (reviewed by Stevens & Merilaita, 2009a; Stevens & Merilaita, 2011). Whilst beyond the scope of this paper, certain forms of camouflage involve the resemblance of insects to bird droppings (Hebert, 1974), fish can look like fallen leaves on a river bed (Sazima, Carvalho, Mendonca, & Zuanon, 2006), or, bizarrely, a body can adopt a transparent appearance, as seen in a range of aquatic species (Carvalho, Zuanon, & Sazima, 2006). Therefore, camouflage is an adaptation to the perceptual processes and the cognitive functions of other animals. A better example of this cognitive adaptation could include the disruptive colouration patterns in animals like snakes, used to defeat the segmentation processes (see Figure I).

The most familiar and repeatedly referenced (Ruxton, Sherratt, Speed, Speed, & Speed, 2004) camouflage strategy is background pattern matching (e.g. in various moths;

Kettlewell, 1955), in which concealment is obtained by representing a similar colour and form to the background (Endler, 1981). Thayer (1909) and Cott (1940), the pioneers of animal camouflage studies, argued that the optimum level of camouflage would not be achieved only through background matching. The underpinning philosophy of this argument was due to the continuous, clear and distinguished edge information between the animal's body outline and its background (Stevens & Cuthill, 2006). This leads to the conclusion that the distinctive feature in creating a desired level of camouflage might be highly associated with the border shape of the animal in terms of avoiding recognition and object detection. Here, as an alternative strategy, disruptive colouration (e.g. as in marine isopods; Merilaita, 1998), being an efficacious means of camouflage far above background matching (Schaefer & Stobbe, 2006; Cuthill et al., 2005), mainly functions by exploiting the edge detection process with bold contrasting colours on the animal's boundary that weakens the perception of a target as belonging to a definite category of object (Stevens & Merilaita, 2009a). Supporting this, Stevens and Cuthill (2006) offered a computer-based visual pattern for the edge detection process, with an emphasis on facilitating the effect of disruptive colouration. Figure I illustrates the disruptive motives through edge information that can be seen in various snake species; however, it should be noted as a caveat that disruptive colouration through edge enhancement (EE) is best understood by its functioning (i.e. impairing recognition) rather than its surface and appearance (Stevens, 2007; Stevens & Merilaita, 2009b).

Based on the concept of signal-to-noise ratio (Merilaita, Scott-Samuel, & Cuthill, 2017), the effectiveness of EE is derived from its ability to curtail true edge signals as well as to conceive noise through false edges. In this case, EE acts to decrease the signal-to-

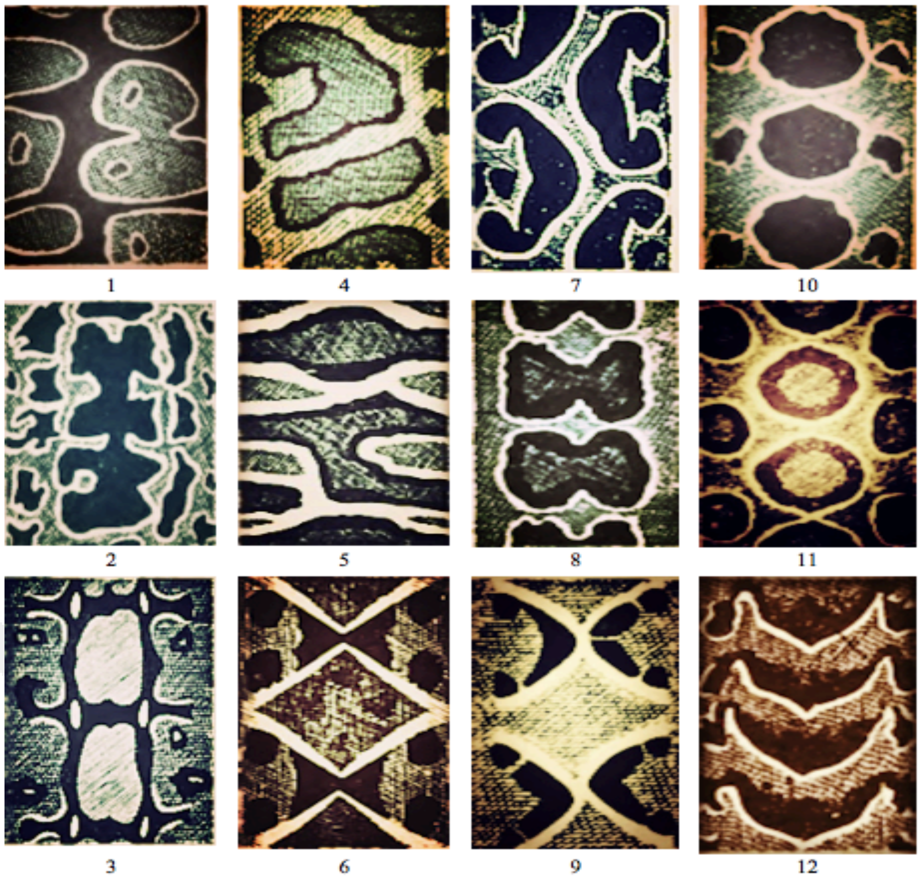


Figure I. Diagrams adapted from the artwork plates by Hugh Cott, illustrating the disruptive motives through edge information of various snakes, *1 Python regius; 2 Python molurus; 3 Constrictor constrictor; 4 Ophibolus doliatus triangulus; 5 Natrix fasciata; 6 Bothrops atrox; 7 Bothrops alternatus; 8 Crotalus confluentus; 9 Bothrops jararaca; 10 Causus rhombeatus; 11 Vipera russellii; 12 Bitis arietans,* modified from Cott (1940; Figure 11, p.58).

noise ratio by lateral inhibition technique and fosters disruptive camouflage (Stevens & Meriliata, 2009a). The decrease in this ratio would be possible with an increase in “noise”, which are generated unreal depth boundaries within animal’s body outline and a decrease in signal, the true edges of an animal’s silhouette.

Recently, research has indicated that EE is an effective means of camouflage for maintaining a disguised appearance and to form visual signal errors under monoscopic vision (Egan, Sharman, Scott-Brown, & Lovell, 2016). These findings are consistent with the prior literature presenting the capability of EE in relation to cryptic appearance (Troscianko, Lown, Hughes & Stevens, 2013). Another study by Adams, Graf and Anderson (in preparation) revalidated the effectiveness of EE. More importantly, they found an emerging conflict under binocular viewing, such that stereoscopic viewing reduced the cryptic effect of EE. Such finding picks up on the commentary of Julesz (1971), who proposed the counteractive influence of stereopsis on camouflage.

In their design, Adams et al created different leaf patterns for each trial (320 trials in total), before snakes were dropped into the leaves for visual search task. They used the Southampton-York Natural Scenes (SYNS; Adams et al., 2016) dataset to determine to colours for the snakes and the leaves behind them, emulating the current research. Their manipulations included the presence or absence of EE, directional or ambient light and the stereoscopic or monoscopic viewing condition. They manipulated EE by creating different levels of contrast in luminance and hue. Participants were presented with spatial quadrants in all combinations of their independent variables and reported which of the spatial quadrants included snakes. As a lab-based experiment, they recorded the amount of time taken to find a snake. They explained the reduced effect of EE under binocular viewing compared to monocular viewing by the binocular advantage in the improvement of precise depth information, which can elucidate ambiguous depth information by pictorial visual cues like texture (Adams & Mamassian, 2004; Knill & Saunders, 2003), shading (Adams, Kerrigan, & Graf, 2010) and shape (Knill, 2007). Their ultimate conclusion seems to imply an advantage for frontally-placed eyes, which successfully gives credibility to the snake detection hypothesis of primate depth perception (Isbell, 2006).

Isbell (2006)'s hypothesis held venomous snakes accountable for the advanced depth information (obtained from stereopsis) by their continuous co-existence with primates, which would eventuate in the specific expansions of primates' brains. In particular, Isbell suggests that the koniocellular pathway in a primate's brain -which is predominantly related to detecting threatening stimuli pre-attentively- becomes enlarged together with the parvocellular pathway, which is associated with object recognition. These discernible expansions of brain structures in primates were linked to the orbital convergence which is a cue to stereopsis and this link has been evidenced employing phylogenetic comparative methods (Barton, 2004). Importantly, the physiological conclusion of Isbell's study accounted for interocular integration (the move toward frontally-placed eyes) that leads to stereopsis. Considering the two interactive aspects of the study (both anatomic and physiologic), an evolutionary drive might have been involved in developing neural systems to detect threats faster, thus linking humans to evolution.

The long history of the human competence in rapidly recognising, detecting and reacting towards a threat-related stimuli could be a reasonable justification for this drive, which has led researchers to postulate that a special pathway in the threat detection mechanism should have developed within human cognitive perception.

Operationally, by their nature of worry and fear, the systems underlying anxiety and phobias serve a function in moving attention to a potentially threatening target by increasing the likelihood of an anxious state and enhancing the possibility of target detection (Bishop, 2007). For example, at a neurological level, previous research suggested an early-warning mechanism which is influenced by the amygdala (Dennis, Chen & McCandliss, 2008; Phelps & LeDoux, 2005). This underlying mechanism functions by first receiving fast and pre-attentive appraisals in relation to the external world and immediately shifting attention towards the emotionally relevant threatening stimuli, which causes an increase in anxious symptoms. The enhanced neural functioning of the amygdala in terms of threat processes was rendered as a mediator of "attentional bias" (Bar-haim, Lamy, Pergamin, Bakermans-Kranenburg. & Van Ijzendoorn, 2007). Attentional bias favouring threats refers to people's inclinations not to consider alternative sources of information as fear influences them

(MacLeod, Mathew, & Tata, 1986), and the facilitated detection of threat that signifies fear and danger is an observable idiosyncrasy of attentional biases (e.g. LeDoux, 1996; see Bar-Haim et al., 2007, for other observable idiosyncrasies).

To some extent, several models of the anxiety and phobias have been theorised within the literature to categorise the mechanisms underlying attentional bias (Beck, Emergy, & Greenberg, 1985; Eysenck, 1992; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). Although it would be implausible to mention all of them, there is a central theme of those empirically-supported cognitive and/or theoretical models of theories, which is inclusive of the objectives of this paper. According to these theories, the common ground was that the attention of anxious or phobic people must have been biased selectively and voluntarily towards fearing threatening stimuli (see Cisler & Koster, 2010, for a review). In other words, regarding these biases, the importance here is the early, selective and strong prioritising of the detection of threats: special biases increase information processing related to the external world merely for the threat-relevant object.

One of the common symptoms of general anxiety disorders (Rinck, Becker, Kellermann & Roth, 2003) and specific phobias (Okon-Singer, Alyagon, Kofman, Tzelgov, & Henik, 2011) is attentional bias. According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-V; American Psychology Association [APA], 2013), a specific phobia is recognised by a persistent and extreme fear of the existence of the object of the stimulus, which leads to function impairment in daily life.

Indeed, the concept of attentional bias in relation to anxieties and phobias has been investigated in a wealth of empirical studies, employing various experimental tasks and visual search paradigms. Upon closer scrutiny, previous research has demonstrated that emotional stimuli evoking fear such as angry faces (Fox, Mathews, Calder, & Yiend, 2007) or modern threat objects (e.g. guns; Blanchette, 2006) are detected quicker than those evoking no fear, and has confirmed the effectiveness of a visual search for threatening targets. Furthermore, a line of research has also confirmed that this effect is increased in magnitude within clinical populations, namely people with state-trait anxiety and subjective phobia (Flykt, 2005). For instance, Mathews and MacLeod (1994) reported that patients with high clinical anxiety symptoms are biased in their selective attention processes related to fear-relevant events. Socially phobic people were found to detect angry faces quicker than the control groups (Gilboa-Schetman, Foa, & Amir, 1999). Additionally, Weierich and Treat (2015) examined spider-phobic individuals in relation to threat detection, suggesting that threat-specific stimuli are a facilitator in the threat detection process. Another finding from a spider phobia study was that spider-phobic people responded slower than non-phobics, when a neutral target (a mushroom) was displayed with fear-relevant distracters (spiders) (Miltner, Krieschel, Hecht, Trippe, & Weiss, 2004). By inspecting the participants' eye movements, the researchers indicated that the phobic participants seemed to be attracted by the spiders, which accounts for the slower response times in relation to the images of mushrooms.

In visual search tasks, adults detected the presence of snakes quicker than the presence of other forms of visual stimul, (e.g. Shibasaki & Kawai, 2011). In the same vein, fearful reactions to snakes have been observed in many animals (Cook & Mineka, 1989) and in young children (LoBue & DeLoache, 2008). Albeit the two studies mentioned did not annotate the speed of fearful reactions, the reaction patterns to venomous snakes as an instance of intense sensitivity might be evidence of the enhanced visual detection of evolutionarily relevant threat stimuli.

Snakes were found to constitute one of the most common objects of extreme fears and phobias (Fredrikson, Annas, Rischer, & Wik, 1996), and snake-phobia is regarded as a phenomenon that has been widespread throughout human evolution (Isbell, 2009). A recent

Dutch survey indicated that snake-phobia was amongst the most prevalent phobias, with a lifetime prevalence of 5.4% (Oosterink, Jongh, & Hoogstraten, 2009).

This clinical superiority of snake-phobia within humans might lead some researchers (e.g. Ohman & Mineka, 2001; Seligman, 1970) to give an evolutionary description to fear processing and threat detection. Along with being a remarkably influential (and arguable) theory in evolutionary pressures, their research deemed the prevalence of snake fear as an example of prepared learning, which holds the idea that humans have an evolved inclination to relate snakes to fear. The model by Öhman and Mineka (2001) describes a perceptual detection system which automatically assesses the importance of output. According to the model, primary access to this system is obtained from evolutionary threatening events. According to this view, venomous snakes have formed a continuous threat to survival for most animals through evolution, so, animals that quickly learned to avoid them had the greater chance to survive, reproduce, and transfer their genes. As a result of this, an evolutionary inclination to learn to fear snakes has occurred in humans and other mammals. This might be an implication of snake-phobics having a more specialised system for reacting to snakes, since being fearful of them might have an evolutionary origin (Hoehl, Hellmer, Johansson, & Gredebacket, 2017). Indeed, previous research exhibited faster reaction times in pre-school children (Masataka, Hayakawa, & Kawai, 2010) and infants (LoBue & DeLoache, 2010). As for the evidence of prepared learning in animals, Öhman and Mineka (2001) showed that monkeys quickly learn to fear snakes by observing another monkey's expressions or even by watching a model monkey's videotaped reaction (Cook & Mineka, 1990) to the presence of a snake. This claim was supported empirically by an influential paper in the field of anxiety and phobias field (Öhman, Flykt, & Esteves, 2001). The researchers pointed out that the evolutionary threatening stimuli were effective in capturing attention. To test this hypothesis, their participants were displayed with 2x2 and 3x3 matrices of threatening (snakes and spiders) and non-threatening stimuli (flowers and mushrooms). Some matrices consisted of the same category of stimuli (e.g. nine photos of mushrooms), and in others a single threat-relevant stimuli subsisted (e.g. one snake and eight mushrooms). They indicated that snakes and spiders (fear-stimulated objects) placed on flowers and mushrooms (fear-irrelevant distracters) resulted in shorter latencies than the other way around. This suggests that snakes, but not flowers or mushrooms, were located by an automatic perceptual processing that readily detected target stimuli that seemed to "pop out" from the matrix in isolation from the number of distractor stimuli. Furthermore, this effect was further facilitated when the stimulus was emotionally provocative. Participants whose fear of snakes was more considerable than other participants exhibited even greater performance in detecting snakes. Therefore, when snakes evoked fear in the participants, this feeling stimulated their perceptual processing to be able to locate snakes in an even more efficient way.

Considering all of this information, the binocular visual advantage in breaking EE and the snake-phobia advantage in detecting threats could be nicely attributed to an evolutionary drive in humans, essentially derived from the co-existence of snakes with primates. Hence, the aim of this paper hence is to connect the established camouflage mechanisms with threat perception. The main objective was to reconcile some of the findings in the literature investigating visual search behaviour in naturalistic environments and its relationship with self-reported measures (i.e. anxiety, specific phobias, uncertainty, and attention control). In particular, two primary hypotheses were tested. Firstly, it is expected that individuals with a higher snake-phobia score will display greater advantages in enhanced engagement with threat-related information, measured by their reaction times (RTs) when searching for snake-like targets as opposed to those with low levels of snake-phobia. Furthermore, this proposed mean difference will still exist and increase in magnitude in camouflaged environments. This knowledge will hopefully demonstrate the effectiveness of human visual processes in the presence of emotional threatening stimuli (snakes). Second, it is expected that more attentional control will predict more tolerance to uncertainty, and together these two constructs will create an advantage in the participants' visual search behaviour, measured by their RTs, especially in camouflaged visual scenes. Furthermore, as the current experimental design allowed, we are interested in the interaction between the target proximity and EE.

Method

Participants

Eighty-six participants (36 females) were recruited through opportunity sampling for a laboratory study. Seventy of them were undergraduate and postgraduate students in the University of Southampton who were asked for their voluntary participation. Undergraduate psychology students at the University of Southampton were offered course credits for their participation. The rest of the recruitment was done through word-of-mouth.

Some of the participants were excluded from the study. Specifically, the *a priori* inclusion criteria for the study were that the participants should have (a) normal or corrected-to-normal vision (i.e. corrective eyewear or contact lenses) and (b) stereoscopic depth perception at or better than 40 arc seconds, as assessed by the Titmus Fly Stereotest (Stereo Optical Co., INC). This stereotest contains nine stimuli with graded difficulty - 800 arc seconds for the first stimuli, and 40 arc seconds for the last stimuli, with four circles embedded within each stimulus. Only one of the circles has a degree of crossed disparity. The participants' levels of stereopsis were recorded based upon their judgements on the circle with the fine depth cue (i.e., the one that appears to "pop out"). Two participants had stereopsis less than 40 arc seconds and, thus, they were excluded from the study. Additionally, two participants withdrew for personal reasons and two others were also excluded due to changes in the experimental design. Therefore, the final sample consisted of

80 participants. The data reduction and subsequent analyses were carried out on this final sample. See Appendix A for the recruitment process.

Participants were provided with an online informed consent document (Appendix B) which they had to sign in order to participate in the study. The University of Southampton Ethics Committee (ERGO) granted ethical approval for this experiment (Appendix C) and any foreseen risk was eliminated before the recruitment process (see Appendix D, for the risk assessment).

Materials

Measures. The participants were first asked to complete the Positive and Negative Affect Schedule questionnaire (PANAS; Watson, Clark & Tellegen, 1988). PANAS assesses the extent to which participants currently feel a variety of positive and negative emotions. In particular, PANAS consists of two subscales: positive affect (PA) and negative affect (NA). The PA subscale comprise 10 items (e.g., “excited,” “interested”) indicating positive feelings and the NA subscale comprise 10 items (e.g., “upset,” “scared”) indicating negative feelings. Participants responded on each item on a 5-point scale (1 = *very slightly or not at all*, 5 = *extremely*). Previous research has determined the reliabilities of the PANAS PA and NA scales using Cronbach’s alpha (α). Cronbach’s α was .89, 95% CIs [-.88 –.90] for the PA scale, and .85, 95% CIs [-.84 –.87] for the NA scale (Crawford & Henry, 2004). The Cronbach’s α reliability test was computed for each subscale for the current study and found a high level of reliability for both PA (α = .89) and NA (α= .86) subscales. Finally, the responses were summed to compute PA scores (*M* = 33.25, *SD* = 7.84) and NA scores (*M* = 16.01, *SD* = 6.28).

Next, participants completed the General Anxiety Disorders questionnaire (GAD-7; Spitzer, Kroenke, Williams, & Löwe, 2006). In particular, participants were asked to respond to seven items (e.g., “Feeling nervous, anxious or on edge;” “Not being able to stop or control worrying") that assess the extent to which they have felt anxiety over the previous two weeks (0 = *not at all,* 3 = *nearly every day*). The GAD-7 has been established as an efficient tool for screening for anxiety disorders and evaluating their severity in clinical practice and research. Specifically, a score of 10 or higher on the GAD-7 represents a reasonable cut-off point for determining cases of GAD-7. The internal consistency of the GAD-7 was excellent, (α = .92; Spitzer et al., 2006). The Cronbach's α reliability test for the current sample was conducted and found that the GAD-7 demonstrated high levels of reliability for this study (α = .89). Thus, the responses were summed to compute GAD-7 scores (M = 5.78, SD = 4.48).

Afterwards, participants completed the Intolerance of Uncertainty scale (IoU; Buhr & Dugas, 2002) which evaluates participants' emotional, cognitive and behavioural responses to ambiguous circumstances. In particular, they were instructed to indicate the extent to which 27 statements are characteristic of them (1 = *Not at all Characteristic of me*, 5 = *Entirely Characteristic of me*). 9 items assessed the belief that uncertainty is stressful and upsetting (e.g., "Being uncertain means that a person is disorganized";α =.91), 9 items assessed the belief that uncertainty leads to the inability to act (e.g., "Uncertainty stops me from having a firm opinion";α = .90), 5 items assessed the belief that (c) unexpected events are negative and should be avoided (e.g., "It frustrates me not having all the information I need";α = .83), and 4 items assessed the belief that (d) being uncertain is unfair (e.g., "I always want to know what the future has in store for me"; α =.80; Buhr & Dugas, 2002, p.940). The overall scale's internal consistency of the IoU was excellent, (α =.94). Regarding the current study, each subscale formed a reliable index. The overall scale also formed a reliable index (α = .96) and, thus, the items were summed to compute a total IoU score (M = 62.81, SD = 23.96).

Participants subsequently completed the Attentional Control Scale (ACS; Derryberry & Reed, 2002) which assesses individual differences in the voluntary control of attention (or attentional control). Specifically, they were instructed to indicate the extent to which they agreed with 20 statements on a 5-point scale (1 = *almost never*, 5 = *always*). X items assessed their ability to focus attention (e.g. "My concentration is good even if there is music in the room around me"; α = .86), X items assessed their ability to shift attention between tasks (e.g. "It is easy for me to read or write while I'm also talking on the phone"; α = .85), and X items assessed their ability to control thought flexibly (e.g. "I can become interested in a new topic very quickly when I need to"; α =.83)" (Derryberry & Reed 2002). Previous research has reported the internal consistency of overall ACS as good (*α* = .84; Ólafsson et al., 2011). In the current work, each subscale formed a reliable index. The overall scale also formed a reliable index (α = .82) and, thus, the items were summed to compute a total ACS score (*M* = 50.81, *SD* = 8.29).

Lastly, participants completed the Snake Questionnaire (SNAQ-12; Zsido, Arato, Inhof, Janszky & Darnai, 2018). Specifically, participants were instructed to indicate whether they agree (0 = *No*, 1 = *Yes*) with 12 items (e.g., "I dislike looking at pictures of snakes in a magazine.") assessing their fear to snakes. The SNAQ-12 scale has been used to discriminate between people with specific snake-phobia and without specific snake-phobia. Specifically, previous research has shown that participants who score "*Yes*" to eight or more of the SNAQ-12 statements should be considered potentially snake-phobic (Zsido et al., 2018). SNAQ-12 had excellent internal consistency (*α* =.88). The current overall scale formed a reliable index (α = .83) and, thus, the items were summed to compute a total SNAQ-12 score (*M* = 4.00, *SD* = 3.04).

Virtual Reality (VR) Task. The VR stimuli, viewed with two eyes, was used to record participants' search behaviour in relation to threat-related object (snake). The colours for the target snake and the background leaves were determined by publicly-available sampling scenes from the Southampton-York Natural Scenes dataset (https://syns.soton.ac.uk, SYNS; Adams et al., 2016). The outdoor scenes from the deciduous forest category were selected from the full set. In SYNS, the scenes were measured at a three-dimensional range from diverse real-world locations. The sampling scenes from SYNS allowed to tailor more plausible instances comparable to the 'real-world' situations in which the decisions would be made. Matlab 8.5.0 (The MathWorks Inc., Natick, MA) was used for camouflage texture generation. The generation of trials and the experiment, and the saving of the data, were done using the Unity 5.6.5 game engine (Unity Technologies, 2018). The stimuli were viewed using an Oculus® Rift VR head-mounted display (Facebook Inc.) running on a Viglen Genie computer with an intel i7 processor (Windows 10 operating system).

Design

A factorial mixed-design was implemented to examine the effect of Camouflage strategy on RT. In particular, the main independent variable was the within-subjects variable of Camouflage strategy. The Camouflage strategy composed of *only* two levels: Edge Enhancement (EE) and No Edge Enhancement (NEE). Each Camouflage condition consisted of 20 trials. The order of levels was randomised within the trials. For exploratory reasons, categorical groups were included in the analysis for measures of positive and negative affect, uncertainty, attentional control and specific phobia measures as additional variables. The primary dependent variable was the simple RTs (the time required to make the response; Welford, 1980) of the participants averaged across the levels of the within-subject independent variable.

Procedure

The participants were welcomed to the lab in the School of Psychology, at the University of Southampton. First, participants were presented with an online-formatted information sheet explaining the study before giving their consent to participate (Appendix E) . To ensure that participants understood the experimental process, they were also provided with a verbal explanation of the study. Following this, participants were instructed to complete the Titmus Fly Stereotest (Stereo Optical Co., INC) which measured their current levels of stereoscopic discrimination. Next, participants were instructed to respond to some demographic questions (i.e. gender, age) and subsequently completed the measures of the study in an online platform (iSurvey). See the Materials section for a more detailed description of each scale and Appendix F for the scales.

Following the measures, participants completed the VR task. They were first provided with the virtual reality headset and a virtual reality controller. Their search performance was recorded in an immersive environment. The snake target, coiled on the leaves, was present in all trials. As shown in Figure II, each trial commenced with a red fixation circle (O), anchored at the participant's standing position, accompanied by a sign which read, "Shoot the ball to start." The task then presented trials at a random orientation, with each trial involving a target snake located within the leaves, positioned at an angle between -90 and 90 degrees. For each trial, the participant's task was to report which quadrant (leftmost, left, right or rightmost) contained the snake, as quickly and accurately as possible using the VR controller. There were two practice trials to help the participants become familiar with the task. Trial durations which surpassed 20 seconds were terminated automatically and were coded as missed events. The participants were given unlimited time to report the chosen quadrant for their correct responses. After the completion of the VR task, the participants were debriefed online (Appendix G) and were thanked for their participation.

Data Reduction and Analytic Strategy

As mentioned, the sample was consisted of 80 participants after the initial exclusion of some participants (see "Participants" section). In the data reduction process, 11 additional participants were excluded from the final sample due to performing poorly in the task. That is, these participants could not accurately locate snakes in more than half of the trials (13.92% of the total trials). The reasoning behind this decision was to eliminate possible uncontrolled situations (e.g. fatigue, boredom, attention or vision problems or experimental design problems) that could bias the results.

The final sample was consisted of 69 participants (25 females, M_{age} = 27.43 SD_{age} = .62 $Range_{\text{age}}$ = 20-47). The statistical analyses presented in the "Results" section are based on this sample size. These analyses were conducted using the Statistical Package for Social Sciences (SPSS) version 24.0 by SPSS Inc. (Chicago). Power was calculated using G*Power version 3.1 (Faul, Erdfelder, Lang & Buchner, 2007) for the main analysis. Assuming that the aim was to achieve a medium effect size equivalent to Bar-Haim et al. 2014, (d = 0.45), an a-priori power analysis to test the interaction effect between four independent means identified that at least 41 participants in each group is needed to test a two tailed hypothesis, with a power greater than .80 and significance level of p = .05.

The researcher categorised each RT on each trial as correct, incorrect or a "missed event". Incorrect and/or "missed event" RTs and pre-emptive RTs (less than 200ms; Jain, Bansal, Kumar, & Singh, 2015) -1.6% among 2760 trials-) to account for accidental button presses, were removed before the calculation of the mean RTs. The overall response accuracy

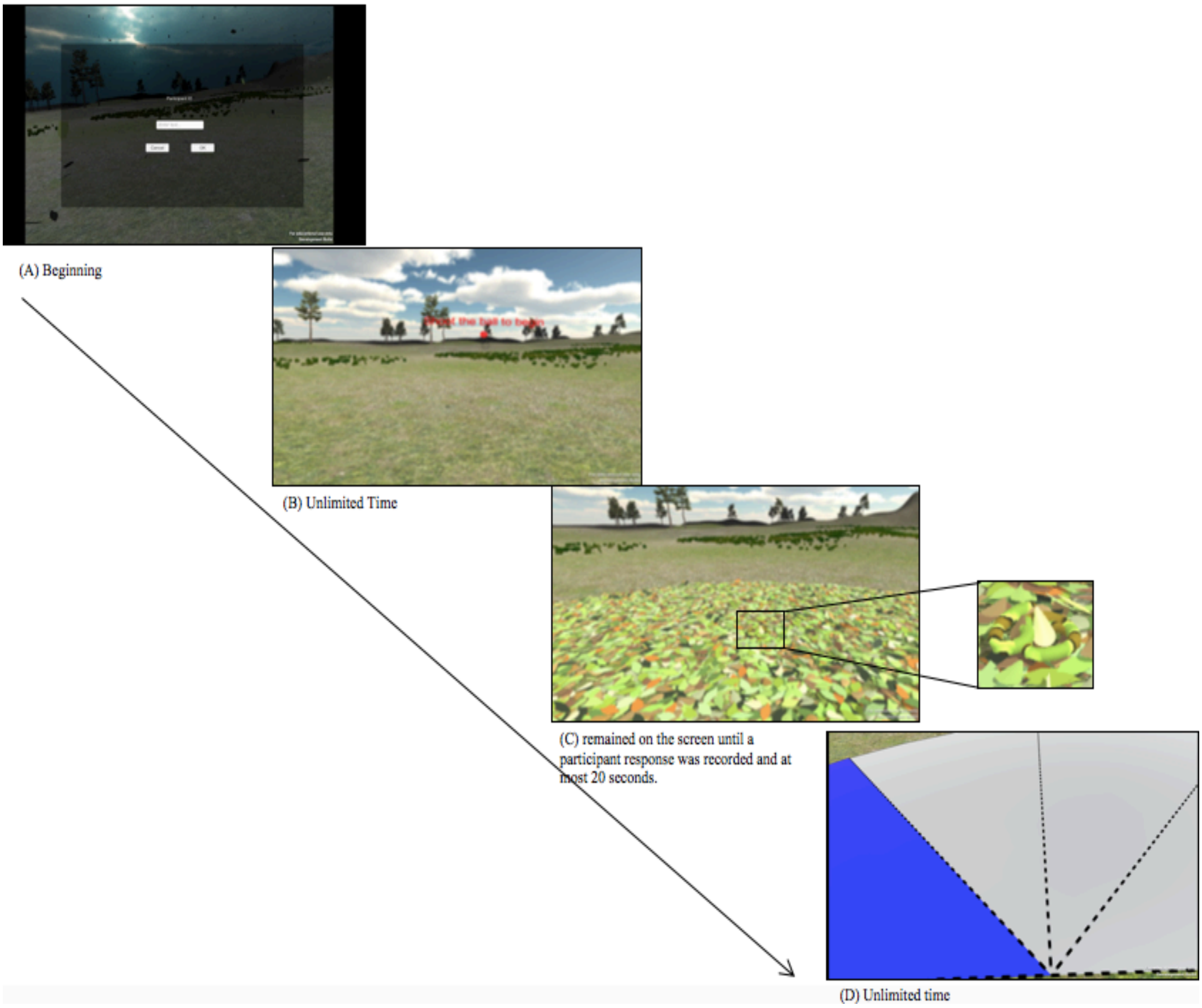


Figure II. An example illustration of an experimental trial employed in the study. The sequence starts with (A) in which participants' unique numbers are recorded. (B) shows the beginning of each trial. (C) indicates an example of visual stimuli used in the study with the forest texture from SYNS dataset (Adams et al., 2016). Once participants press the touch controller to capture the target (snake), (D) appears and participants determine the correct quarter of the target. If the participant does not locate the snake within 20 seconds, the trial returns to beginning, which is (B) without displaying (D).

in this experiment was 65.2% (22.3 % missed events and 12.5% inaccurate responses). A log transformation was applied to improve data normality and to minimise the impact of outliers on the mean and standard deviation (Ratcliff, 1979). After the log-transformation, there were no extreme outliers (i.e., determined as $SD_{RTs} > 3.00$). The researcher collapsed each participant's data, leaving one within-subjects independent variable with *only* two levels (Edge Enhancement-EE- X, No Edge Enhancement-NEE-) and a categorical independent variable of SNAQ-12 (low phobia X high phobia). Log-transformed mean RTs were calculated for each Camouflage condition, and submitted to a 2 x 2 mixed-design ANOVA in SPSS for the main analysis. Allocating a mixed-design ensured the independence of scores which otherwise would have caused severe problems (Field, 2013).

In an explorative manner, all the potential interaction effects among IoU, ACS and Camouflage, as well as of Proximity and Camouflage were examined. Additionally, before the main analysis, the researcher computed the mean difference of the RTs between the Camouflage conditions (i.e. EE and NEE), the correlations were examined for exploratory purposes. All the survey data have been log-transformed to conduct ANOVAs to ensure the allocation of similar metrics of survey and experimental data.

To examine whether the process of removing data influenced the results, a sensitivity analysis was conducted, as recommended by Lachaud and Renaud (2011). In particular, the researcher run the analyses presented in the "Results" section on the original sample ($N = 80$) as well as on the final sample ($N = 69$). This analysis revealed that the results were similar on both samples for the all of the analyses conducted. For the sake of transparency, the protocol of the current data cleaning is given in Appendix H.

Results

ExclusionCriteria.

RTs of less than 200ms (pre-emptive) or more than three standard deviations above the participant's mean, trials with errors, and uncooperative subjects' data were discarded before the calculation of the mean log-transformed RTs.

Main Analysis

Camouflage and Snake-Phobia. To examine whether the mean differences of the RTs would change based on the heightened levels of anxiety to snakes and/or the presence of snake-phobia, a 2 (Camouflage: EE vs. NEE) X 2 (Snake-phobia: High snake-phobia vs. Low snake-phobia via media split) mixed ANOVA was conducted. This ANOVA included camouflage (EE vs. NEE) as within-subject factor, snake-phobia (high snake-phobia vs. Low snake-phobia) as between-subjects factor and RTs as dependent variable. The hypothesis was that participants with high levels of snake-phobia will show faster RTs on detecting snakes. Furthermore, the snake-phobic participants were expected to have an advantage in terms of their speed of visual search, reducing the cryptic effect of EE, measured by the mean differences of two categorical snake-phobia groups in two Camouflage conditions.

Initially, the scoring instructions on the SNAQ-12 was implemented to identify the highly phobic people participating in the experiment (i.e. a score of > 8 could be considered snake phobic, Zsido et al., 2018). However, due to the narrow and unequal distribution of the SNAQ-12 scores of two groups (n*high-phobia*= 8, n*low-phobia*= 61), a median-split on the SNAQ-12 scores was executed (*Med* = 4) and served as a between-subject factor (n*high-phobia* =30, n*low-phobia* =39). The mean RTs and the standard deviations for all of the conditions are displayed in Table 1.

The results revealed that the main effect of camouflage was significant, $F(1,67) = 4.94$, $p = .030$, $\eta_p^2 = .069$ (see Figure III), meaning that camouflage influenced participants' RTs on detecting snakes. Surprisingly, participants located snakes slightly faster in the EE condition than in the NEE condition. The main effect of snake-phobia was not significant, $F(1,67) = 0.13$, $p = .715$, $\eta_p^2 = .002$, meaning that the participants' levels of snake-phobia did not significantly influence their RTs in detecting snakes.

Table 1

Mean Reaction Time (RTs) and Standard Deviation of SNAQ-12 Groups at Two Levels of Camouflage Condition

	SNAQ-12	
	Low phobia *(n* = 39)	High phobia (*n* = 30)
Level of Camouflage	M (*SD*)	M (*SD*)
EE	3.77 (*.09)*	3.76 *(.11)*
NEE	3.78 *(.10)*	3.81 *(.10)*

Note. EE = edge enhancement, NEE= no edge enhancement. SNAQ-12 is Snake-Phobia Questionnaire from Zsido et al., 2018. All the values were log-transformed.

The interaction of Camouflage x Snake-phobia was not significant, $F(1,67) = 1.39$, $p = .243$, $\eta_p^2 = .020$ (Figure IV). In other words, the main effect of Camouflage on RTs did not depend on the participants' levels of snake-phobia. Although the interaction effect was non-significant, an observation of the mean RTs revealed that the mean difference between the conditions of EE and NEE was bigger in the high snake-phobia group than in the low snake-phobia group. This interaction effect was consistent with the main hypothesis, yet revealed no significance.

In all, these findings do not support the main hypothesis. That is, having high levels of snake phobia neither predicts a visual search advantage in snake detection nor creates any significant advantage in terms of supressing the effectiveness of EE. Possible explanations regarding these findings are mentioned in the Discussion section.

Exploratory Analysis

Demographics. The group differences between the high and low snake-phobia groups was not significant for age, t (67) = 1.38, p = .090. However, the independent samples T-test

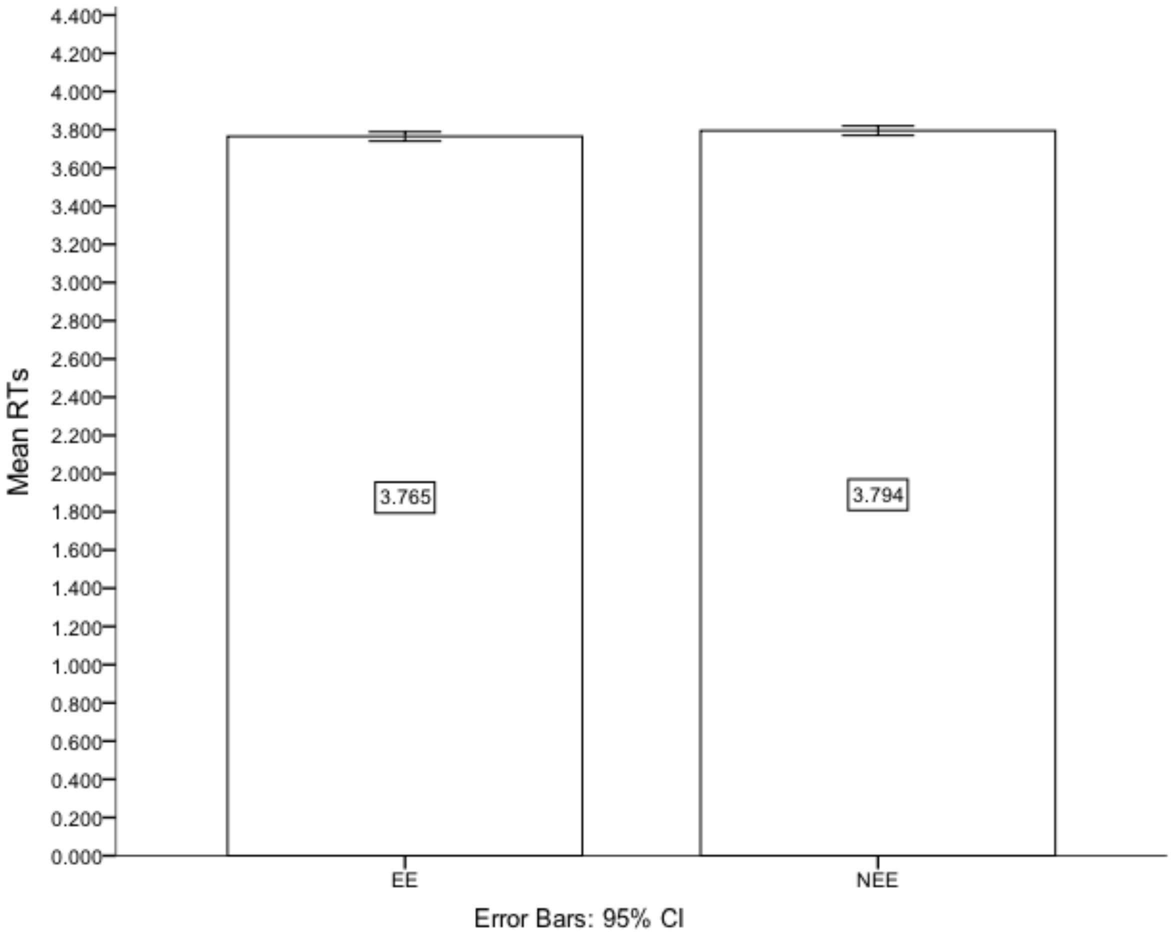


Figure III. The average reaction times for the two camouflage conditions. EE= Edge Enhancement, NEE= No Edge Enhancement. Mean RTs have been log-transformed. Error bars represent +/-2 standard error.

demonstrated that the group differences in gender was significant for low and high snake-phobia groups, *t* (67) = -2.23, *p* = .029. In particular, males showed lower snake phobia compared to females (mean difference = -1.65, 95% CI [-3.1313, -0.1760]). This finding is consistent with the past research (e.g. Fredrikson, Annas, Fischer, & Wik, 1996; Polák, Sedláčková, Nácar, Landová, & Frynta, 2016). Additionally, the group differences in gender was significant for GAD-7 scores, *t*(67) = -2.27, *p* = .026. Specifically, the males scored significantly lower on GAD-7 compared to females (mean difference= -2.47, 95% CI [-4.6486, -0.2987]). This finding is in line with previous research (e.g. Löwe et al., 2008).

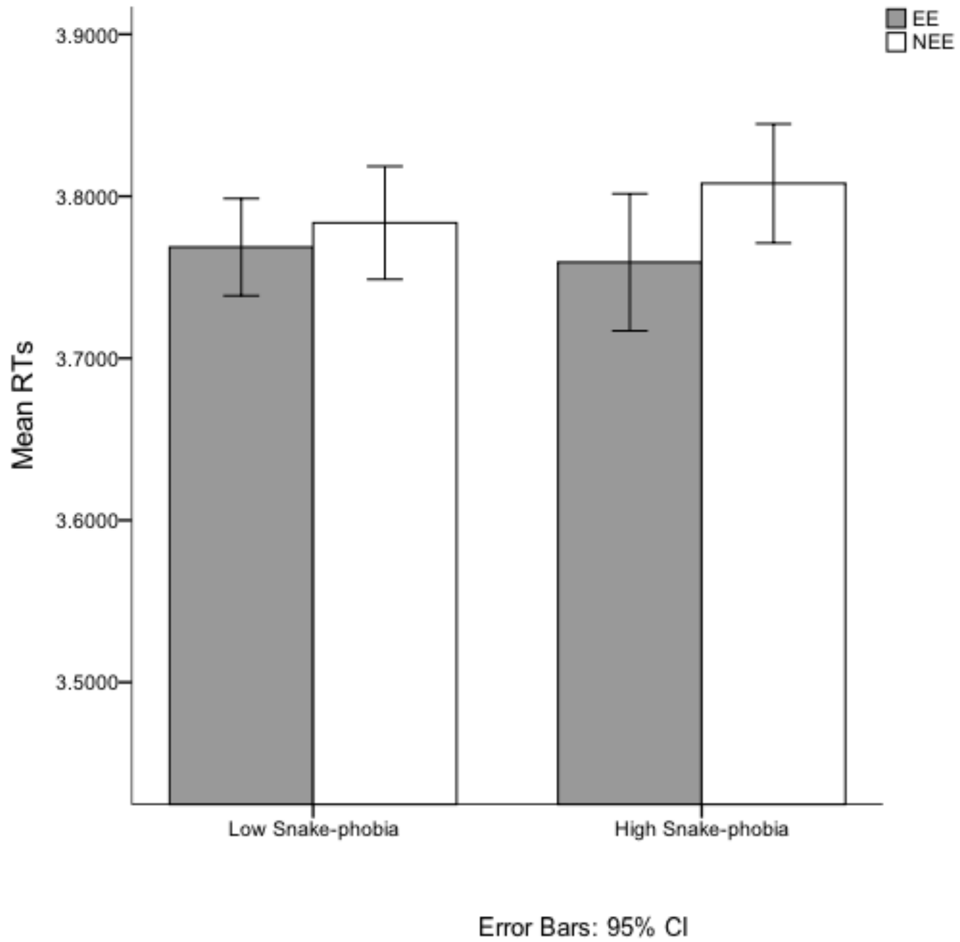


Figure IV. Mean reaction times of median-split snake-phobia groups at two different camouflage conditions. CI = confidence interval.

Zero-order Correlations. To explore all of the possible relationships among the measured variables, the Pearson's product-moment correlation coefficients (two-tailed) were computed. Intolerance of Uncertainty (IoU) was significantly and positively related to SNAQ-12, demonstrating that participants with a lower tolerance towards uncertainty are more likely to show increased levels of snake-phobia. Furthermore, IoU was significantly and positively related to GAD-7, indicating that participants with lower tolerance of uncertainty are more likely to exhibit greater anxiety. This finding is congruent to previous research (Dugas, Gosselin, & Ladouceur, 2001; Dugas, Gagnon, Ladouceur, & Freeston, 1998). Lastly, IoU was significantly and negatively related to Attentional Control Scale (ACS), indicating that participants with higher tolerance for uncertainty are more likely to show greater attention control. This finding supports prior work (e.g. Mushtaq, Bland, & Schaefer, 2011). It also provides a reasonable justification to further explore the relationship between IoU and ACS under the two conditions of the dependent variable (i.e. EE and NEE). All of the rest of the correlations among the measured variables are depicted in Table 2.

Exploring Camouflage Attentional Control and Intolerance of Uncertainty.

Camouflage and Attentional Control. To explore the Camouflage x Attentional Control interaction, a 2 (Camouflage: EE vs. NEE) X 2 (ACS: High attentional control vs. Low attentional control via median-split) mixed ANOVA was performed. This ANOVA included camouflage (EE vs. NEE) as within-subject factor, ACS (high attentional control vs. low attentional control) as between-subjects factor and RTs as dependent variable.

The results indicated that the main effect of Camouflage was significant, $F(1,67) = 4.25$, $p = .043$, $\eta_p^2 = .060$, as was shown in the main analysis. The main effect of ACS was not significant, $F(1,67) = 0.82$, $p = .367$, $\eta_p^2 = .012$. That is, there was no significant difference in the mean RTs between the two groups of high and low attention. The Camouflage X ACS interaction was not significant, $F(1,67) = .19$, $p = .660$, $\eta_p^2 = .003$. That means, the effect of camouflage on the RTs was similar for both the high and low attentional control groups.

Camouflage and Intolerance of Uncertainty. To explore the IoU x Camouflage interaction, a 2 (Camouflage: EE vs. NEE) X 2 (IoU: High intolerance of uncertainty vs. Low intolerance of uncertainty via media split) mixed ANOVA was conducted. This ANOVA included camouflage (EE vs. NEE) as within-subject factor, IoU (High intolerance of uncertainty vs. Low intolerance of uncertainty) as between-subjects factor and RTs as dependent variable.

Table 2

Pearson correlations (two-tailed) between the clinical measures and mean RTs

	1	2	3	4	5	6	7	8
Age (1)								
Gender (2)	-.23							
PA (3)	.15	.08						
NA (4)	-.11	.15	.10					
GAD_7 (5)	-.09	.27*	.05	.56**				
IoU (6)	-.16	.07	.27*	.42**	.62**			
ACS (7)	-.09	-.08	.07	-.21	-.39**	-.27*		
SNAQ-12 (8)	.23	.26*	.10	.25*	.39**	.38*	-.30*	
RTs (MD) (9)	-.04	-.24	.17	.05	-.11	-.07	.05	-.07

Note. * = $p < .05$; **=$p<.01$. $N= 69$. All variables were log-transformed. MD = Mean Difference. The Positive and Negative Affect Schedule (PANAS) is from Watson et al., 1988, PA = Positive Affect, NA = Negative Affect; General Anxiety Disorder (GAD_7) is from Spitzer et al., 2006; Intolerance of Uncertainty (IoU) is from Buhr & Dugas, 2002; Attention Control Scale (ACS) is from Derryberry & Reed, 2002; and the Snake-Phobia Questionnaire (SNAQ-12) is from Zsido et al., 2018.

The findings showed that the main effect of Camouflage was significant, $F(1,67) = 4.23$, $p = .044$, $\eta_p^2 = .059$, as shown in the main analysis. The main effect of IoU was not significant, $F(1,67) = 2.68$, $p = .106$, $\eta_p^2 = .038$, indicating that there was no significant difference in the mean RTs between the two groups of high and low levels of IoU. The Camouflage X IoU interaction was not significant, $F(1,67) = 0.23$, $p = .879$, $\eta_p^2 = .000$, indicating that the effect of camouflage on the RTs was similar for both the high and low levels of IoU groups.

Camouflage, Attentional Control and Intolerance of Uncertainty. In order to explore the three-way interaction, a 2 (Camouflage: EE vs. NEE) X 2 (ACS: High attentional control vs. Low attentional control) X 2 (IoU: High intolerance of uncertainty vs. Low intolerance of uncertainty) mixed ANOVA was conducted. The median-split of the IoU (n*lowIoU*=33, *N*=69) and ACS (n*lowACS*=34, *N*=69) scores served as between-subject factors. The camouflage condition, with two levels (EE X NEE), was a within-subject factor. As the dependent variable, the average of the RTs was examined according to the levels of Camouflage condition.

The findings demonstrated that the Camouflage x ACS x IoU interaction was not significant, $F(1,65) = 0.19$, $p = .666$, $\eta_p^2 = .003$. That is, the interaction among the IoU and ACS did not significantly differ across the RTs of both Camouflage conditions. Contrary to the expectation, as seen in Figures V and VI, a high intolerance of uncertainty and/or low levels of attentional control accelerated the participants' RTs, yet revealed no significance.

The main effect of camouflage almost reached statistical significance: $F(1,65) = 3.61$, $p = .062$, $\eta_p^2 = .053$. The interaction of ACS x IoU was not significant: $F(1,65) = 1.52$, $p = .221$, $\eta_p^2 = .023$, indicating that the participants' attentional control levels were not significantly dependent on their responses to uncertainty or ambiguous situations. The remaining findings of the two-way interactions (i.e. ACSxCamouflage, IoUxCamouflage) were not significant, as they indicated no difference other than that of the Univariate ANOVAs mentioned above.

Exploring Camouflage and Distance.

Camouflage and Distance. To observe the fine differences of target distance and whether this could interact with Camouflage, the distance was binned into five categories and a 2x5 (Camouflage [EE, NEE] x Distance [very close, close, intermediate, far, very far]) mixed-ANOVA was conducted.

The interaction of Camouflage X Distance was significant, $F(1,64) = 2.58$, $p = .045$, $\eta_p^2 = .14$, demonstrating that there were difference on participants' RTs across the five different levels of distance (Figure X). To examine the pattern of this interaction, pairwise comparisons were conducted, with Distance compared by Camouflage. These analyses

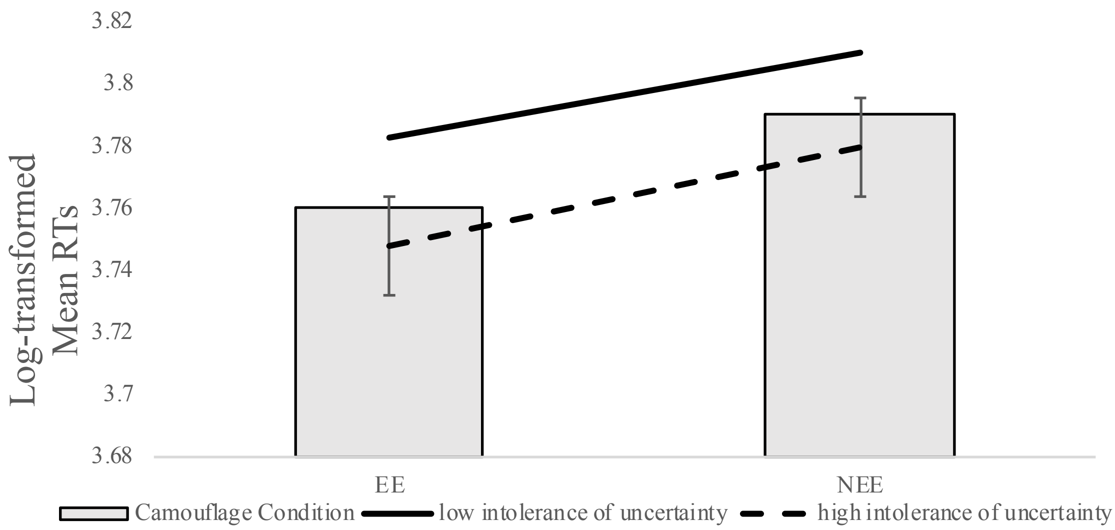


Figure V. Mean reaction times (RTs) of high and low intolerance of uncertainty groups at two different camouflage conditions: EE = Edge Enhancement, NEE= No Edge Enhancement. Error bars represent -/+2 standard error.

revealed that the mean difference in the participants' RTs across two Camouflage conditions was not significant for the distance labelled "close", $F(1,64) = 0.64$, $p = .428$, $\eta_p^2 = .010$, the distance labelled "intermediate", $F(1,64) = 0.01$, $p = .974$, $\eta_p^2 = .000$ and the distance labelled "far", $F(1,64) = 0.15$, $p = .704$, $\eta_p^2 = .002$. However, participants RTs changed significantly among two Camouflage groups at the distances of "very close", $F(1,64) = 4.74$, $p = .033$, $\eta_p^2 = .069$ and "very far", $F(1,64) = 9.54$, $p = .003$, $\eta_p^2 = .130$. Figure VII shows that participants in EE condition (exposed camouflage) located snakes significantly faster than those in NEE conditions (exposed no camouflage) when the snake was "very close" (Mean Difference = .71). Furthermore, this mean difference significantly increased in magnitude when the snake was located "very far" (Mean Difference = .90),

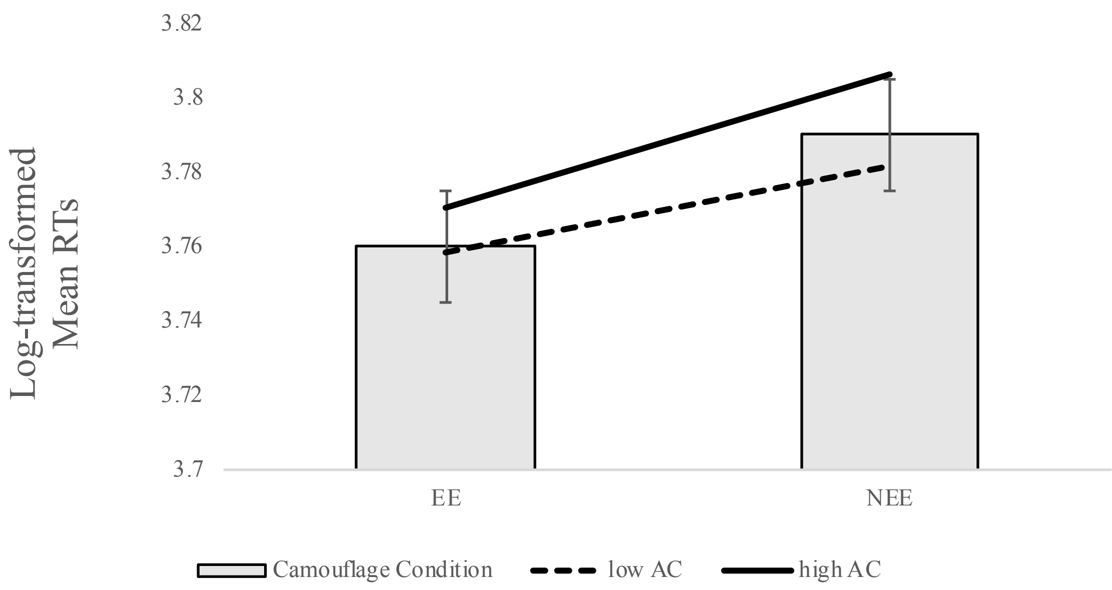


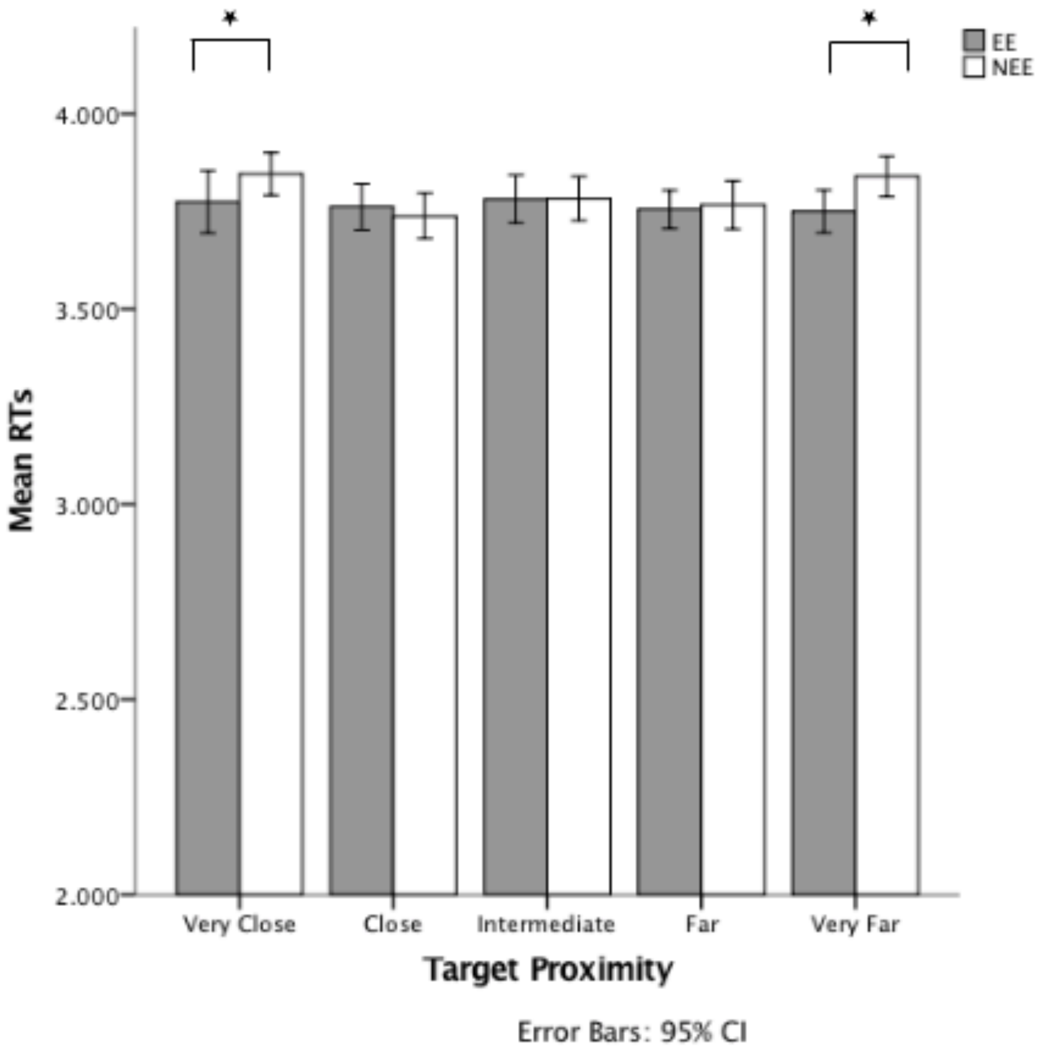
Figure VI. Mean reaction times (RTs) of high and low attention control groups at two different camouflage conditions. EE = edge enhancement. NEE= no edge enhancement. AC = Attentional control. Error bars represent -/+2 standard error.

indicating EE is being significantly less efficient in far compared to close distance. The results showed that the main effect of Distance was not significant, $F(1, 64) = 1.15$, $p = .342$, $\eta_p^2 = .067$, meaning that the distance to a snake target did not significantly influence participants' overall RTs.

Taken together, these results illustrate that although there was no significant main effect of distance on the RTs, this effect depended on Camouflage (EE or NEE), with a significant Camouflage X Distance interaction. Necessary explanations are mentioned in the Discussion section.

Discussion

The aim of this research was to elucidate the adaptive significance of edge enhancement (EE) for breaking up camouflage: the ineffectiveness of EE under binocular



F*igure VII.* The mean RTs of two Camouflage conditions across different distance proximities. * = $p < .05$. Mean RTs are log-transformed. EE = Edge Enhancement, NEE= No Edge Enhancement. Error bars represent Confidence Intervals (CI 95%).

viewing, and to examine the interaction between binocularity and threat-superior visual search tendency among people with heightened anxiety and phobias.

The findings revealed that EE as a well-established cryptic strategy did provide a significantly poor threat concealment. Surprisingly, participants found the snakes faster when they were camouflaged. On one hand, this is not in line with the previous research which indicated the effectiveness of EE (Egan et al. 2016, Adams et al., in preparation). This inconsistency between these findings and those of Egan et al. might be due to the different designs implemented on these two studies: their participants observed the snake-shaped figures only under monoscopic viewing conditions, while the current research employed only binocularity as a viewing condition. On the other hand, this may indirectly confirm the findings of Adams et al. (in preparation): they observed diminished RTs under binocular viewing compared to monocular viewing condition. Although the current design did not allow the researcher to make a complete comparison of the two viewing conditions (i.e. the design did not have a monocular viewing condition), it would still signify binocularity by its naturalistic 3D design in visual search. Then, this may validate the given argument as it stands.

The main findings did not show a significant interaction between EE and snake-phobia. There are several possible explanations for this finding. Firstly, due to the time constraints during data collection, the distribution of snake-phobic scores on SNAQ-12 was not satisfactory. In particular, the researcher had only eight phobics from the total of 69 participants based on SNAQ-12 instructions (Zsido et al., 2018). Therefore, a median-split was performed to create two groups and they were labelled for the instances of “low phobia” or “high phobia”. Although previous research advise for using a median-split when the independent variables are not correlated (Iacobucci, Posavac, Kardes, Schneider, & Popovich, 2015), which was the case in this research, such categorising might cause a loss of statistical power (i.e. no effect was found when actually there was; Aiken & West, 1991). One possible solution to overcome this would involve creating three groups and then dropping the middle group to create some plausible distinctions between the groups.

However, this solution requires a bigger sample size to reduce the negative impact of data loss on the findings.

There are several further limitations that should be noted. Firstly, the current work didn't manage to successfully control the confounding effect of camouflage due to the nature of the design. Specifically, the design did not systematically distinguish between the possible influence of EE and background matching on visual search behaviour *per se.* A reason that could be associated with the diffused functioning of EE in achieving crypsis rather than operating in a single and unambiguous way. This, then might obstruct developing provable hypotheses about disruptive colouration, EE and its effectiveness in concealment through unreal edges. Despite their extensive application (e.g. military, artistic painting), the presence of only a few experimental studies (e.g. Stevens, Cuthill, Widsor, & Walker, 2006; Cuthill et al., 2005) directly handling this issue could affirm this fact, as well. Concerning the current experimental design, a way to tackle this problem could be incorporating some control variables with a different *shape* or *outline* than a snake. For instance, Merilata and Lind (2005) used pattern elements found in the background, but their sample distribution for preys was not based on a constant size or shape. They made minor changes in the shape or size of sample to improve the functioning of disruption. Secondly, the outcome of the visual search task was assessed by measuring RTs of the participants. This has been criticised (Finke et al., 2005), because such attempts would also require an effort on the motor response performance. Previous research compared the two different visual detection paradigms (i.e. button-press and touch-screen) and concluded that touch-screen paradigms provided faster RTs when searching threat-relevant stimuli than traditional button-press methods in overall detection speeds (LoBue & Matthews, 2014). Additionally, they reported that they did not observe any avoidant behaviour that would result in longer latencies to touch the screen. Indeed, based upon the obtained feedback after the VR task in the current study (Appendix I), one of the common themes was related to wrong button-press thus touch-screen could be considered as a good alternative for future research.

Despite these limitations, there is a strength that is worth mentioning. This study and only few of the other studies have examined the effect of snake-phobia employing a 3D world (e.g. Yuan et al., 2018), which is seen frequently in daily life. Since the perceived "presence" is ultimately responsible for heightened autonomic responses (Weierich & Treat, 2015), VR as an emerging technology might allow to investigate specific phobias in a controlled environment by increasing the realism of the task (Mitrousia & Giotakos, 2016). Furthermore, regarding the cognition aspect, a human's vision is almost never static; the received information is constantly altering since humans always behave in a task-dependent way (Mennie, & Rusted, 1999). This completely contrast with conventional experimental methods in which the observer cannot cooperate with external information in any meaningful way. For example, previous research argued that depth perception involves considerable individual differences for static and non-static observers (Tcheang, Gilson, & Glennerster, 2005) and can be only understood when the observers can naturally interact with the external world. Given this, the integration of experimental designs within VR into human perception studies would ensure the ecological validity and offers a natural and controlled way of observation in which reflecting realistically to the external world is possible. Additionally, stereoscopic 3D displays are considered as the most useful tasks involving the manipulation of objects and for finding or classifying objects (McIntire, Havig, Geiselman, 2014). Due to the outlined reasons, researchers could use the design of this study as a valid tool to examine visual paradigms. Moreover, to the best of the my knowledge, while the theoretical models of anxiety and phobias were successfully investigated to the testing theories on the attention, emotion (e.g. fear) and threat appraisals, their usefulness in understanding how camouflage works does not exist.

This research also promises in various directions to deepen and widen our knowledge. Utilising the facilitating effect of binocular information and understanding the mechanism underpinning camouflage could help a variety of users to develop techniques for breaking the concealing effect of camouflage. For instance, machine learning algorithms that could lead to more efficient object recognition Convolutional neuronal networks which is a a class of deep to aid solving complex visual input in computer science literature, inspired by biological processes (Matsugu, Mori, Mitari, & Kaneda, 2003). This means, the connection of convolutional neurons mimic the system of an animal’s visual cortex. A recent study used panoramic images with LIDAR range data for an attempt to develop a baseline for local edge classification by direct observation (Ehinger, Adams, Graf, & Elder, 2017). They investigated whether a convolutional neuronal network could be the ideal model for edge discrimination. They concluded that these networks might exploit some visual cues that humans do not employ and argued its competence as superior than humans for human edge discrimination. This finding implies that the study of vision has much to offer to the machine field from an applied viewpoint of human vision. Furthermore, the researchers (Lee, Kim, Kang, Kim, & Kwak, 2003) created a vehicle consisting of three parts -front frame, body and rear frame-. The vehicle was developed for the purpose of human-inaccessible applications such as firefighting and mine detection and it communicates visual input to operator. Such situations would require human-like vision to reach desired utilisations (Reddy, Chakravarty, Chattopadhyay, Sinha, & Pal, 2014). Thus, human vision has much more to offer than only to those who are concerned with solely technological developments.

Although the study failed to support the hypothesis, this research still warrants further clinical inquiry. Specific phobias are one of the least examined anxiety disorders, despite their high prevalence (European Study of the Epidemiology of Mental Disorders [ESEMeD], 2000). They have been linked to cardiac disease, migraine and thyroid disease. Furthermore, the recurrent anxious feeling may diminish the immune system which results in reduced vaccine efficiency and a routine sentiment of feeling unwell (Witthauer et al., 2016; Roy-Byrne et al., 2008). In this regard, an understanding into the visual search patterns that phobic individuals possess might further advance the knowledge on aetiology and maintenance of the phobias. Furthermore, the use of a virtual environment might allow therapists to develop better interventions. As a supporting claim, the treatment efficacy of VR within anxiety disorders is well-researched by four different meta-analysis and is proven to lead significant decreases in anxiety-related symptoms (Parsons & Rizzo, 2008; Morina, Ijntema, Meyerbröker, & Emmelkamp, 2015; Opris et al., 2012; Powers, & Emmelkamp, 2008). With regard to introducing therapies, these immersive displays could be beneficial in terms of a more therapeutic use as phobics are more receptive to persisting through a session. Garcia-Palacios, Botella, Hoffman and Fabregat (2007) indicated that the utilisation of VR exposure during exposure therapy improves the participation to exposure methods among phobics. These reasons are eminently encouraging for the future utilisation of VR to mental health.

Conclusion

The current research examined the efficacy of visual search in a 3D environment. Although the findings did not support the main hypothesis, future research could take into account both the weaknesses and strengths to further explore camouflage, threat-superiority tendency among clinical populations and its evolutionary origin. Additionally, there are reasons to believe that the use of VR has positive implications for future research.

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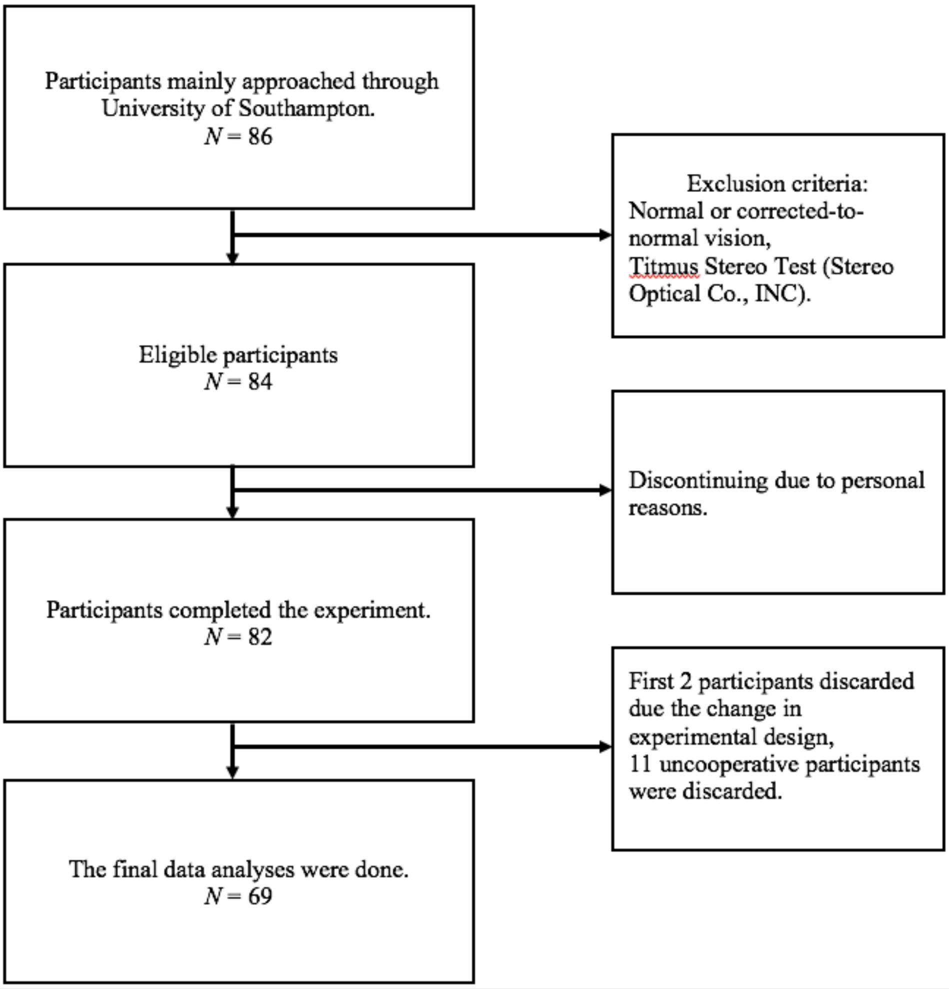
Appendices

Appendix A

Recruitment Flow Chart



Appendix B

Consent Form

UNIVERSITY OF Southampton

CONSENT FORM

Study title: Visual search in virtual environments: The effect of threat and target camouflage

Researcher names: Erich Graf, Wendy Adams, Matthew Anderson, 29386063

ERGO number: 31641

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet (*Date: 02/02/2018; Version 1.0*) and have had the opportunity to ask questions about the study.	
I agree to take part in this research project and agree for my data to be used for the purpose of this study.	
I understand my participation is voluntary and I may withdraw at any time for any reason without my rights being affected.	
I am happy to be contacted regarding other unspecified research projects. I therefore consent to the University retaining my personal details on a database, kept separately from the research data detailed above. The 'validity' of my consent is conditional upon the University complying with the Data Protection Act and I understand that I can request my details be removed from this database at any time.	

Name of participant (print name)..

Signature of participant..

Date..

[02/02/2018] [Version 1.0]

Appendix C

Ethics Form

ETHICS Form Psychology

Please use the tick boxes provided to indicate when the following items have been completed

If appropriate, have you discussed this application with your Supervisor/Grant-holder	☒
If applicable, attached copies of your consent documents	☒
If applicable, attached copies of any letters to participants	☐
Attached a copy of your debriefing statement	☒
If applicable, have you attached a copy of the questionnaire/s you intend to use?	☒
Attached a copy of your risk assessment	☒
If applicable, attached a copy of your eFolio advert and other forms of recruitment	☒

Version 1.0. Date: 02/02/2018

ID: 31641

DEPARTMENT OF PSYCHOLOGY

OUTLINE OF PROPOSED RESEARCH TO BE SUBMITTED FOR

ETHICAL COMMITTEE APPROVAL

PLEASE NOTE: You will need to discuss this form with your Supervisor or Grant-holder. In particular, you should ask him/her for any School guidelines relating to this area of research which you must read and understand. You should also read and understand the Ethical Principles for Conducting Research with Human Participants published by the British Psychological Society.

You must not begin your study until School of Psychology ethical and Research Governance Office approval have been obtained. Failure to comply with this policy could constitute a disciplinary breach.

1. Name(s): Erich Graf, Wendy Adams, Matthew Anderson, 29386063

2. Supervisor: Erich Graf, Wendy Adams

3. How may you be contacted (e-mail and/or phone number)?

Matt Anderson, ma19g13@soton.ac.uk , 29386063 at XXXXX, *Erich Graf at E.W.Graf@soton.ac.uk or Wendy Adams at W.Adams@soton.ac.uk.*

4. Into which category does your research fall?

Undergraduate Student Research ☒

Postgraduate Student Research ☒

Staff Research ☒

5. Title of Project:

Visual search in virtual environments: The effect of threat and target camouflage

6. Briefly describe the rationale for carrying out this project and its specific aims and hypotheses

The sheer complexity of real-world environments imposes constraints on the processing capacity of the human visual system. To cope with the overwhelming amount of incoming sensory information, visual attention is used to preferentially select parts/subregions the environment, allocating cognitive resources to process those elements in greater depth. Little is known about the computational processes used to identify and prioritize relevant stimuli, while filtering out irrelevant/unimportant stimuli.

One guiding principle of attentional allocation is the affective value of a stimulus. Threatening stimuli, such as snakes, spiders and angry/fearful faces, are localised more rapidly than emotionally neutral stimuli, and this effect is modulated by state and trait anxiety. Observers with phobias of noxious stimuli equally show faster detection speeds, and training anxious populations to deviate their visual attention away, rather than towards, threatening stimuli, has produced therapeutic effects.

Problematically, most existing visual search studies use two-dimensional computer displays. Since the perceived 'presence' of fear-relevant objects heightens autonomic responses, it stands to reason that the effect of presenting threatening versus neutral targets may be affected (i.e., increased in magnitude) by manipulating the immersiveness, and thereby the realism, of the stimuli/task. Hence, we intend to examine whether humans are faster at detecting threatening stimuli (in our case, snakes are the threat stimulus, as opposed to neutral mushrooms) in virtual environments, and moreover, whether this effect is larger or smaller in magnitude than existing effect sizes reported in the emotion and cognition literature.

We will also investigate the visual properties of animal camouflage. Owing to the attentional prioritization of salient stimuli (stimuli different from their direct surroundings), predators and prey with conspicuous surface patterns are placed at a disadvantage. Many animals have evolved camouflage to avoid rapid detection. One such method of camouflage is edge enhancement: salient edges within an animal's patterning that produce illusory depth boundaries. Egan et al. (2016) demonstrated that edge enhancement imitates the visual regularities than define depth-boundaries, creating the impression of pictorial relief. In other words, the true outline of an animal is concealed by visual signals that would usually describe a segmented (non-animal) shape.

Binocular depth cues might facilitate the recovery of three-dimensional form by segregating the concealed animal from its background depth plane. A pilot computer-based experiment suggests that binocular depth cues do indeed break camouflage. Therefore, we endeavour to extend this investigation into a virtual environment with rich three-dimensional depth cues.

In summary, we aim to address two hypotheses in an investigation of visual search behaviour in virtual environments:

- Are threatening targets detected more efficiently than emotionally neutral targets? Is this effect larger for trait / state-anxious, or snake-phobic observers?
- Do binocular depth cues break the camouflaging effect of edge enhancement?

7. What intervention/procedure will be used? (Briefly describe the design. Explain what participants will experience, including duration of any task/test).

Participants will be asked to attend a lab-based session lasting approximately one hour. They will fill out a number of questionnaires measuring their phobia of snakes and state / trait anxiety. There will be two experiments: both of which require the subject to wear a virtual reality headset:

1. The participant will view a series of threatening (snakes) and non-threatening (mushrooms) targets embedded on a local floor plane consisting of 3D-rendered leaves. They will use a handheld controller to point to the location of the target object on each trial. The distance from the observer and visual eccentricity of the target will vary from trial to trial.

2. The participant will view a series of snakes on the same type of floor plane as described above. The surface pattern of the snake, lighting type, availability of binocular depth cues, distance from observer, and target eccentricity will vary from trial to trial.

8. What measurement procedures will be used? Please attach copies of any questionnaires to be used.

The following questionnaires will be used (and are attached in full as separate word/pdf documents):

- GAD-7 Anxiety Questionnaire (Spitzer et al., 2006)
- The Positive and Negative Affect Schedule (PANAS; Watson et al., 1988)
- The Spider Questionnaire and Snake Questionnaire (SPQ short version, SNAQ short version; Zsido, Arato, Inhof, Janszky, & Darnai, 2018)
- Intolerance of Uncertainty Scale (IUS; Buhr & Dugas, 2002)
- The Attentional control Scale (ACS; Derryberry & Reed, 2002)

For the main experiment, response times, error rates, and the head location will be measured on each trial.

9. Who are the participants?

University of Southampton Undergraduate/Postgraduate Students and department staff.

10. How many participants will you recruit?

60

11. How will they be identified, approached and recruited?

Via eFolio and word-of-mouth.

12. How will you obtain the consent of participants?

Written consent will be obtained prior to the start of the experiment.

13. Is there any reason to believe participants may not be able to give full informed consent?

Yes **No** ☒

If yes, what steps do you propose to take to safeguard their interests?

14. If participants are under the responsibility of others (such as parents/carers, teachers or medical staff) have you obtained permission to approach the participants to take part in the study?

Yes ☐ **No** ☐ **N/A** ☒

15. Detail any possible discomfort, inconvenience or other adverse effects the participants may experience, including after the study, and how this will be dealt with.

Mild eye strain, fatigue.

To prevent discomfort, participants will be explicitly encouraged to take regular breaks.

16. How will it be made clear to participants that they may withdraw consent to participate at any time without penalty?

The consent form will contain a paragraph explicitly informing them of their freedom to withdraw consent. This will be reiterated verbally.

17. Will the procedure involve deception of any sort?

Yes ☐ **No** ☒

If yes, what is your justification?

18. How do you propose to debrief participants and/or provide them with information about the findings of the study?

By the use of a debriefing statement (attached).

19. How will information obtained from or about participants be protected?

Data will be stored on a password protected computer. Access will be given only to the researchers involved in the study.

20. Experimental apparatus employed must be approved for safety by a member of the School of Psychology technical team. Has this approval been given?

Yes ☒ **No** ☐

21. Do you intend to make a submission through the NRES? ***(certain projects may need NRES approval, please check with your supervisor)***

Yes ☐ **No** ☒

22. Does this research involve work with children?

Yes ☐ **No** ☒

If yes, has a DBS check been carried out?

Yes ☐ **No** ☒

23. Outline any other information you feel may be relevant to this submission.

N/A

Appendix D

Risk Assessment

UNIVERSITY OF Southampton

Version 1.0. Date: 02/02/2018
ID: 31641

Risk Assessment Form for Assessing Ethical and Research Risks

- Please see Guidance Notes at the end of this document.
- *Students*: Please make sure you have discussed this form with your supervisor!

Researcher's name: *In case of students:*	Erich Graf, Wendy Adams, Matthew Anderson *29386063*
Supervisor's name:	Wendy Adams, Erich Graf
Degree course:	BSc Psychology, MSc Research Methods, MSc Foundations of Clinical Psychology

Part 1 – Research activities
What do you intend to do? Prior to the experiment, participants will complete anxiety and phobia self-report questionnaires. Subsequently, participants will wear a virtual reality headset and view a series of immersive virtual environments. They will be instructed to search for threatening target objects (i.e., snakes and mushrooms), and point to them using a hand-held controller. Response times, error rates will be measured.
Will your research involve collection of information from other people? Yes – we will recruit University of Southampton Undergraduate students in return for course credit.
If relevant, what locations are involved? Lab-based study in the Psychology building (44).
Will you be working alone or with others in the data collection process? A number of other researchers will be involved in data collection, including a small group of third-year undergraduates, and several MSc students (see names above).
Part 2 – Potential risks to YOU as the researcher
Please specify potential safety issues arising from your proposed research activity. *None.*
What precautions will you take to minimise these risks?

N/A
Please specify potential distress or harm to YOU arising from your proposed research activity. None.
What precautions will you take to minimise these risks? N/A
Part 3 – Potential risks to YOUR RESEARCH PARTICIPANTS
Please consider potential safety risks to participants from taking part in your proposed research activity? (*Give consideration to aspects such as location of the research, risks associated with travel, strain from participation, and assess the likelihood and severity of risks.) If you have already completed a departmental H&S risk assessment, this may be attached to cover these aspects.* Participants will have an immersive 360-degree view of virtual environments, and will be encouraged to search for targets across the entire scene. Freedom to turn around and explore each stimulus comes at the risk of being entangled by the wire attached to the headset, thereby introducing a potential trip hazard.
What precautions will you take and/or suggest to your participants to minimise these risks? The headset wire will be connected to an adjustable overhead rig, so that no wires will be left trailing at ground or body-level.
Please specify potential harm or distress that might affect your participants as a result of taking part in your research. (*Give consideration to aspects such as emotional distress, anxiety, unmet expectations, unintentional disclosure of participants' identity, and assess the likelihood and severity of risks.)* Participants who have an extreme phobia of snakes may find the snake stimuli emotionally distressing.
What precautions will you take and/or suggest to your participants to minimise these risks? Participants will be given a description of the task, and the type of stimulus they will view, before starting the task, and will be informed that they are free to withdraw from the experiment at any time. They will be told that withdrawal will not affect credit allocation.
Part 4 – Potential wider risks
Does your planned research pose any additional risks as a result of the sensitivity of the research and/or the nature of the population(s) or location(s) being studied? *(Give considerations to aspects such as impact on the reputation of your discipline or institution; impact on relations between researchers and participants, or between population sub-groups; social, religious, ethnic, political or other sensitivities; potential misuse of findings for illegal, discriminatory or harmful purposes; potential harm to the environment; impacts on culture or cultural heritage.)*

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What precautions will you take to minimise these risks? N/A

CONTINUED BELOW …

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Part 5 – International Travel
If your activity involves international travel you must meet the Faculty's requirements for Business Travel which are intended to: 1. Inform managers/supervisors of the travel plans of staff and students and identify whether risk assessment is required. 2. Provide contact information to staff and students whilst travelling (insurance contact details, University contact in case of emergency etc.) Full details are provided in the Faculty H&S Handbook in the **Business Travel** section. Selecting **Business Travel** from the Contents list will take you straight to the relevant section.

Departmental H&S risk assessment attached (for Part 2/3)	**NO**	**(Delete as applicable)**
Business Travel and Risk Filter Form attached (Part 5)	**NO**	**(Delete as applicable)**

Appendix E

Participant Information Sheet

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Participant Information Sheet

(Date: 02/02/2018, Version Number: 1.0)

Study Title: Visual search in virtual environments: The effect of threat and target camouflage

Researchers: 29386063, Matt Anderson, Wendy Adams, Erich Graf

Ethics number: 31641

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

The present research will attempt to investigate the efficiency of visual search in virtual environments.

Why have I been chosen?

You have been chosen as part of an opportunity sample from the school of psychology participant pool.

What will happen to me if I take part?

You will be asked to meet at an experimental lab in the Shackleton Building (44, top floor). After being given a series of instructions, you will be given an opportunity to ask any questions you have about the research.

Firstly, you will fill out a set of anxiety / phobia questionnaires, before wearing a virtual reality headset and searching for target snakes in a virtual environment. You will locate the target as quickly as possible, and 'zap' it by pointing at it with a handheld controller and pressing a button.

The full duration of this experiment will be around 30 minutes. You will not be required to take part in any follow up after this 30-minute period.

Are there any benefits in my taking part?

You will gain 12 credits for your participation. Your participation will help increase our current understanding of visual search behaviour in virtual environments.

Are there any risks involved?

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There is the risk of eye strain, from viewing close-up images over a sustained period. You will stand during the VR search task, which may be tiring. You will be encouraged to take breaks between blocks of trials to reduce these risks. If you feel uncomfortable with this, you may withdraw at any point during the experiment.

Will my participation be confidential?

Participation will be made confidential in accordance with both the data protection act and University policy. Your identifying personal information will not be used at any point in the analysis or presentation of data. Experimental data will be kept on a secure, password protected computer. Data will only be viewed by those directly involved in running the experiment or analysing the data:, 29386063, Matt Anderson, Wendy Adams, Erich Graf.

What happens if I change my mind?

You retain your right to withdraw at any point throughout the experimental procedure and if you wish to leave the experiment you may do so. If you choose not to participate there will be no consequences to your grades or to your treatment as a student in the Academic Unit of Psychology.

What happens if something goes wrong?

In the unlikely event of a problem, you may contact the Chair of the Ethics Committee, Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: +44 (0)23 8059 3856, email fshs-rso@soton.ac.uk

Where can I get more information?

If you have any further questions about the research, please contact Matt Anderson at ma19g13@soton.ac.uk), 29386063 at XXXXX, Erich Graf at E.W.Graf@soton.ac.uk or Wendy Adams at W.Adams@soton.ac.uk.

Appendix F

Clinical Measures

Worksheet 3.1 The Positive and Negative Affect Schedule (PANAS; Watson et al., 1988)

1	2	3	4	5
Very Slightly or Not at All	A Little	Moderately	Quite a Bit	Extremely

___________ 1. Interested	___________ 11. Irritable
___________ 2. Distressed	___________ 12. Alert
___________ 3. Excited	___________ 13. Ashamed
___________ 4. Upset	___________ 14. Inspired
___________ 5. Strong	___________ 15. Nervous
___________ 6. Guilty	___________ 16. Determined
___________ 7. Scared	___________ 17. Attentive
___________ 8. Hostile	___________ 18. Jittery
___________ 9. Enthusiastic	___________ 19. Active
___________ 10. Proud	___________ 20. Afraid

Scoring Instructions:
Positive Affect Score: Add the scores on items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19. Scores can range from 10 – 50, with higher scores representing higher levels of positive affect. Mean Scores: Momentary 29.7 (*SD* 7.9); Weekly 33.3 (*SD 7.2)*

Negative Affect Score: Add the scores on items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20. Scores can range from 10 – 50, with lower scores representing lower levels of negative affect. Mean Score: Momentary 14.8 (*SD* 5.4); Weekly 17.4 (*SD* 6.2)

The official citation that should be used in referencing this material is Watson, D., Clark, L. A., & Tellegan, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. Journal of Personality and Social Psychology, 54(6), 1063–1070.

GAD-7 Anxiety

Over the last 2 weeks, how often have you been bothered by the following problems? *(Use "✔" to indicate your answer")*	Not at all	Several days	ﾉore than half the days	Nearly everyday
1. Feeling nervous, anxious or on edge	0	1	2	3
2. Not being able to stop or control worrying	0	1	2	3
3. Worrying too much about different things	0	1	2	3
4. Trouble relaxing	0	1	2	3
5. Being so restless that it is hard to sit still	0	1	2	3
6. Becoming easily annoyed or irritable	0	1	2	3
7. Feeling afraid as if something awful might happen	0	1	2	3

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all	**Somewhat difficult**	**Very difficult**	**Extremely difficult**
☐	☐	☐	☐

Intolerance of Uncertainty (IoU)

You will find below a series of statements which describe how people may react to the uncertainties of life. Please use the scale below to describe to what extent each item is characteristic of you. Please circle a number (1 to 5) that describes you best.

	Not at all characteristic of me		Somewhat characteristic of me		Entirely characteristic of me
1. Uncertainty stops me from having a firm opinion.	1	2	3	4	5
2. Being uncertain means that a person is disorganized.	1	2	3	4	5
3. Uncertainty makes life intolerable.	1	2	3	4	5
4. It's unfair not having any guarantees in life.	1	2	3	4	5
5. My mind can't be relaxed if I don't know what will happen tomorrow.	1	2	3	4	5
6. Uncertainty makes me uneasy, anxious, or stressed.	1	2	3	4	5
7. Unforeseen events upset me greatly.	1	2	3	4	5
8. It frustrates me not having all the information I need.	1	2	3	4	5
9. Uncertainty keeps me from living a full life.	1	2	3	4	5
10. One should always look ahead so as to avoid surprises.	1	2	3	4	5

	Not at all characteristic of me		Somewhat characteristic of me		Entirely characteristic of me
11. A small unforeseen event can spoil everything, even with the best of planning.	1	2	3	4	5
12. When it's time to act, uncertainty paralyses me.	1	2	3	4	5
13. Being uncertain means that I am not first rate.	1	2	3	4	5
14. When I am uncertain, I can't go forward.	1	2	3	4	5
15. When I am uncertain I can't function very well.	1	2	3	4	5
16. Unlike me, others always seem to know where they are going with their lives.	1	2	3	4	5
17. Uncertainty makes me vulnerable, unhappy, or sad.	1	2	3	4	5
18. I always want to know what the future has in store for me.	1	2	3	4	5
19. I can't stand being taken by surprise.	1	2	3	4	5
20. The smallest doubt can stop me from acting.	1	2	3	4	5
21. I should be able to organize everything in advance.	1	2	3	4	5
22. Being uncertain means that I lack confidence.	1	2	3	4	5

	Not at all characteristic of me		Somewhat characteristic of me		Entirely characteristic of me
23. I think it's unfair that other people seem sure about their future.	1	2	3	4	5
24. Uncertainty keeps me from sleeping soundly.	1	2	3	4	5
25. I must get away from all uncertain situations.	1	2	3	4	5
26. The ambiguities in life stress me.	1	2	3	4	5
27. I can't stand being undecided about my future.	1	2	3	4	5

Origianl French Version: Freeston, M.H., Rhéaume, J., Letarte, H., Dugas, M.J., & Ladouceur, R. (1994): Why do people worry? *Personality and Individual Differences, 17* (6), 791-802.
English Version: Buhr, K., Dugas, M. J. (2002). The intolerance of uncertainty scale: psychometric properties of the English version. *Behavior Research and Therapy, 40* , 931-945.

Attentional Control Scale (ACS; Derryberry & Reed, 2002)

Item No	Item Content
1	It's very hard for me to concentrate on a difficult task when there are noises around. (R)
2	When I need to concentrate and solve a problem, I have trouble focusing my attention. (R)
3	When I am working hard on something, I still get distracted by events around me. (R)
4	My concentration is good even if there is music in the room around me.
5	When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me.
6	When I am reading or studying, I am easily distracted if there are people talking in the same room. (R)
7	When trying to focus my attention on something, I have difficulty blocking out distracting thoughts. (R)
8	I have a hard time concentrating when I'm excited about something. (R)
9	When concentrating I ignore feelings of hunger or thirst.
10	I can quickly switch from one task to another.
11	It takes me a while to get really involved in a new task. (R)
12	It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures. (R)
13	I can become interested in a new topic very quickly when I need to.
14	It is easy for me to read or write while I'm also talking on the phone.
15	I have trouble carrying on two conversations at once. (R)
16	I have a hard time coming up with new ideas quickly. (R)
17	After being interrupted or distracted, I can easily shift my attention back to what I was doing before.
18	When a distracting thought comes to mind, it is easy for me to shift my attention away from it.
19	It is easy for me to alternate between two different tasks.
20	It is hard for me to break from one way of thinking about something and look at it from another point of view. (R)

Note. Items are scored on a 4-point scale (1 almost never; 2 sometimes; 3 often; 4 always). R reverse-scored item.

SNAQ-12 (Snake-Phobia Questionnaire; Zsido et al., 2018)

Item No	Item Content	Answer Choices	
1	I would feel some anxiety holding a toy snake in my hand.	Yes	No
2	If a picture of a snake appears on the screen during a motion picture, I turn my head away.	Yes	No
3	I dislike looking at pictures of snakes in a magazine.	Yes	No
4	I am terrified by the thought of touching a harmless snake.	Yes	No
5	If someone says that there are snakes anywhere about, I become alert and on edge.	Yes	No
6	When I see a snake, I feel tense and restless.	Yes	No
7	I feel sick when I see a snake.	Yes	No
8	The way snakes move is repulsive.	Yes	No
9	If I came upon a snake in the woods I would probably run.	Yes	No
10	I'm more afraid of snakes than any other animal.	Yes	No
11	I would prefer not to finish a story if something about snakes was introduced into the plot.	Yes	No
12	Even if I was late for a very important appointment, the thought of snakes would stop me from taking a shortcut through an open field.	Yes	No

Appendix G

Debriefing Form

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Visual search in virtual environments: The effect of threat and target camouflage

Debriefing Statement *(written)* (ID: 31641, Version 1.0, Date: 02/02/2018)

Thank you for participating in this study.

The aim of this experiment was to (i) investigate whether response times and levels of accuracy for detecting camouflaged targets are affected by the availability of binocular depth cues, and (ii) examine the efficiency of search behaviour for threatening versus non-threatening targets, determining the association of any differences in search patterns with individual self-report anxiety/phobia.

Previous research has demonstrated that a common type of camouflage called edge enhancement operates by disrupting the visual cues typically used for segregating separate objects in space (Egan, Sharman, Scott-Brown & Lovell, 2016). Since binocular depth cues help to encode the 3D form of objects, we hypothesise that camouflage will be less effective when binocular disparity is available.

Moreover, visual search experiments have shown that threatening stimuli are detected more efficiently than non-threatening stimuli (Flykt, 2005). This effect is increased in magnitude by state-trait anxiety and subjective phobia (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & Van Ijzendoorn, 2007). Hence, we predict that (i) high snake-phobic observers will localise snakes faster than low snake-phobic observers, and (ii) this mean difference will still exist for observers high in anxiety / snake phobia in camouflaged environments.

Your participation in this research will help inform current understandings of visual search behaviour, and will provide a step forward in enhancing the naturalism and complexity of laboratory search experiments.

If you have any further questions about the research, please contact Matt Anderson at ma19g13@soton.ac.uk, 29386063 at XXXXXX, *Erich Graf at E.W.Graf@soton.ac.uk or Wendy Adams at* W.Adams@soton.ac.uk.

To learn more about the role of camouflage and threat/anxiety in search behaviour, the references appended to this document are available Online.

If you have questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the Chair of the Ethics Committee, Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: +44 (0)23 8059 3856, email fshs-rso@soton.ac.uk

Thank you for your participation in this research.

Signature _______________________________ Date __________________

Name _______________________________

References:

Egan, J., Sharman, R. J., Scott-Brown, K. C., & Lovell, P. G. (2016). Edge enhancement improves disruptive camouflage by emphasising false edges and creating pictorial relief. Scientific reports, 6, 38274.

Flykt, A. (2005). Visual search with biological threat stimuli: Accuracy, reaction times, and heart rate changes. Emotion, 5(3), 349.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & Van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. Psychological bulletin, 133(1), 1.

Appendix H

Data Cleaning Protocol

Steps	Action	Data format
1	Missing data were removed.	Long
2	Inaccurate and “missing event” trials that are 50% or more per participant were removed (11 uncooperative participants).	Long
3	Pre-emptive trials (less than 200ms -1.6% among 2760 trials-) were removed.	Long
4	Only accurate performances were included among all trials.	Long
5	The distribution was explored (positively skewed). RTs log-transformed.	Long
6	Possible outliers were checked by -/+ 3 SD.	Long
7	Collapse log-transformed RTs in the levels of Camouflage (within-subjects).	Long to wide
8	Match up the experimental data with the survey data	Wide
9	Log-transform the variables of the survey data that is included in the analyses.	Wide

Appendix I

Participant Feedback

Participant Number	*Feedback in relation to experiment experience*
2010	I think it was great , the guidance was fine, but it didn't work well with the touch controller because I am left handed.
2011	It was a bit uncomfortable to wear the machine with glasses.
2015	I was scared to look down just because there could be snakes. So if there were any close to my legs, I am afraid I didn't look at it at all.
2018	N, I didn't tell you but I am colour blinded. Do you think it will be fine?
2025	Very pleasant experience. I thoroughly enjoyed it and I thought it well organised and executed!
2028	Your dissertation is cool! But I wonder why you use snakes?
2036	It was fun.
2037	I think I got my problem. I can see better in dark green leaves.
2039	The algorithms are so predictable. After a few trials, I was able to see the pattern.
2041	I pressed the touch controller wrong many times. I hope this will not cause any problems.
2054	When the head is lifted up (snake), that is where I lost my patience.
2057	The touch controller might cause data problems. The possibility of pressing the wrong button is really high.. And I guess I did it many times.
2060	The visor (crosshair?) disappears when you press the button that sends you to the quadrant choosing bit. That means that if you were looking at a snake, and then it seems ambiguous which quadrant it is in, you no longer have your visor as a reference to help you choose. So you might make a mistake even though you clearly found where it is.
2063	An external factor about your experiment, the temperature of the room, it is quite hot (Laughs). But I had fun!
2065	I was thinking to buy an Oculus for myself too. That is why I had asked if the headset was VR. Otherwise, I wouldn't be here… (Laughs). Just kidding.. I think this was a great experience for me N. Thank you!

2066	It was an interesting one. Did I do well? Can I see my results?
2067	I definitely enjoyed this experience. Thank you N. But how did you create all these stuff? Did you do another course or something?
2068	It was more of a game for me. After work, having something like that to have fun… It was great. When you told me that there will be snakes, I was nervous but when I started doing the trials, it was not that scary.
2069	This experiment made me reflect on my biases and fears toward inanimate objects in terms of physiological effects. The questionnaire that precedes the virtual reality experiment is very apposite to study ones physiological behaviour. And also I believe it is pertinent and indispensable to know personal traits of an individual.
	N, I thought that I might have panic attack. That's why I asked you if this was possible. Again thank you for your understanding on that. But when I started finding snakes, it wasn't that bad as I had expected.
2070	I pressed the button twice and then the experiment started again. So you might want to change touch controller with something has a more control on the responses. But it was lovely to be your participant.
2071	Very interesting. Nothing unusual had happened to me.