

NEURAL INDICES OF EMOTIONAL DISTRACTION

BY

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## Abstract

Emotional stimuli capture our attention. The preferential processing of emotional information is an adaptive mechanism that when relevant to our goal highlights potentially important aspects in the environment. However, when emotional information is task-irrelevant, their presence in the environment can trigger involuntary shifts in attention that cause detriments to performance. One challenge to investigating emotional distraction in the lab is how to objectively investigate the allocation of attention between different elements on the same stimulus display (e.g. between the task and the distractors). One neural measure that overcomes this issue is the Steady-State-Visual-Evoked-Potential (SSVEP). An SSVEP is the neural response of the visual cortex to a flickering stimulus and can be used as a measure of attentional resource allocation (Norcia, Appelbaum, Ales, Cottareau, & Rossion, 2015). In the past, emotional distraction has been studied using spatially separated tasks and distractors. The current thesis presents two experiments using SSVEPs to investigate emotional distraction in a superimposed design. Experiment 1 aimed to conceptually replicate Hindi Attar and colleagues (2010) who developed an SSVEP emotional distraction paradigm to examine attentional resource allocation between background task-irrelevant emotional distractors and a foreground dot-motion task. Participants viewed a stimulus display of moving, flickering dots, while positive or neutrally valenced distractors (or unidentifiable scrambles) were presented in the background of the task. SSVEPs were reduced in the presence of positive intact compared to neutral intact distractors suggesting that the presentation of task-irrelevant emotional stimuli in the same spatial location as a foreground task initiates an involuntary shift of attention away from the task. Unexpectedly, in both Experiments 1 and 2 valence differences were found in

SSVEPs between positive and neutral scrambled images; this suggests that there are some perceptual differences between the stimulus sets (e.g. colour) contributing to the drop in SSVEP found for positive intact images. Importantly, in the SSVEP analysis significant valence x image type interactions were found, demonstrating that the drop for positive images was stronger for intact than scrambled image conditions, suggesting that a significant amount of the drop in SSVEP was driven by a difference in valence between the intact distractors. Behavioural results also suggest evidence for emotional distraction through reduced hit rate in the presence of positive intact images compared to neutral intact images in Experiment 1, and reduced detection sensitivity and response criterion for positive intact images in Experiment 2. Overall, the current thesis demonstrates support for the hypothesis that emotional information is more distracting than neutral information and provides a valuable starting point for the examination of emotion attention interactions when the task and distractors share the same location. Future studies could use SSVEPs to examine neural processing differences between emotional and neutral scrambled images.

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### Neural Indices of Emotional Distraction

Our everyday environment is visually complex. In order to make sense of this complexity, our attentional and perceptual systems give more weight to some events over others (Carrasco, 2011; Desimone & Duncan, 1995). The task for the viewer becomes selecting those events that are relevant to their current goal, and effectively controlling any distractions that might be competing for attention.

One factor that influences the division of attention is the emotionality of the stimulus. Emotional information is preferentially attended to and receives prioritized processing relative to neutral information (Okon-Singer & Tzelgov, 2007; Pourtois, Schettino, & Vuilleumier, 2013; Yiend, 2010). This attentional bias is often helpful as it can signal potential threat or reward, thus facilitating the execution of adaptive behaviours (e.g. avoiding danger, or approaching reward) (Ledoux, 1996). However, there are instances when distraction by emotional information is unhelpful, like when the emotional event is task-irrelevant (e.g. looking at an attractive classmate instead of attending to a lecturer). In these instances, attention must be directed away from the emotional distractor and towards the current goal. Beyond the theoretical importance of examining emotion-attention interactions, the ability to control emotional distraction also has clinical implications; people with clinical disorders such as anxiety and depression are particularly vulnerable to distraction by negative or fearful events (Baert, De Raedt, Schacht, & Koster, 2010; Cisler & Koster, 2010).

In the past, task-irrelevant emotional distraction has been studied using paradigms that have spatially separated tasks and distractors (e.g. Forster & Lavie, 2008a, 2008b; Grimshaw, Kranz, Carmel, Moody & Devue, 2018; Walsh, Carmel,

Harper & Grimshaw, 2018; Yates, Ashwin, & Fox, 2010). For example, in Grimshaw et al., (2018), participants engaged in a central letter search task while emotional images were shown either above or below the target display. When distractors appeared infrequently, emotional images were more distracting than neutral images. While this paradigm is informative in terms of emotion-attention interactions when targets and distractors appear at different places, these tasks do not allow the assessment of attentional competition between events that occupy the same retinotopic space, as attention is manipulated in the spatial domain. Our everyday environment does not always have spatially separated events; for example, when driving along the road, an emotional billboard in the background could distract a driver from the traffic in front. Thus, the examination of spatially overlapping tasks and distractors adds a valuable contribution to the study of emotion-attention interactions.

In this thesis I present two experiments using occipital site electroencephalography (EEG). In Experiment 1, I aim to replicate a study conducted by Hindi Attar and colleagues (2010), investigating the effect of emotion on attention when the task-relevant stimuli and distractors occupy the same space. In Experiment 2, the task was adapted to allow more sensitive analysis of the behavioural data.

## **Emotional Distraction**

Emotional information is preferentially prioritised over neutral information, which can facilitate adaptive behaviour if it is relevant to our goal (Ledoux, 1996; Oksa-Singer & Tzelgov, 2007; Pourtois et al., 2013; Yiend, 2010). However, research so far has been relatively limited in the paradigms that can examine truly *task-irrelevant* emotional distraction. Task-irrelevant emotional distraction is a phenomenon common to all of us, it is when an emotional event (e.g. a crying baby on the bus) takes your

attention away from the task at hand (e.g. reading your book). Investigating task-irrelevant distraction allows the assessment of strategies of cognitive control; what are the mechanisms that allow you to ignore the crying baby and focus on your book?

Methodological challenges arise when investigating task-irrelevant distraction because it is complicated to make a stimulus entirely task-irrelevant. In the emotional Stroop for example, the emotional element (the word) is also the target; this is a problem because the emotional aspect cannot be a true distractor if it shares properties with the target (for a meta-analysis see Phaf & Kan, 2007; for review see Williams, Mathews, & Macleod, 1996). To combat such issues, task-irrelevant distraction paradigms have been achieved, by presenting distractors at unattended locations (Forster & Lavie, 2008a, 2008b; Grimshaw et al., 2018; Walsh et al., 2018; Yates et al., 2010).

Forster and Lavie (2008a; 2008b) developed a flanker task in which entirely irrelevant distractors slowed behavioural performance in a letter search task. Task-irrelevant cartoon figures or shapes were presented in the periphery while the participants' task was to identify whether a central search array contained either an X or an N. The slowing of RTs in the presence of peripheral stimuli is evidence for attentional capture by entirely task-irrelevant distractors.

Adaptations have since been made to Forster and Lavie's (2008) flanker task, enabling the investigation of task-irrelevant emotional distraction by using high arousal images as distractors. Grimshaw, Kranz, Carmel, Moody and Devue (2018) had participants perform a letter search task, in which, positive, negative, neutral or scrambled images appeared above or below a circular letter search array. Participants' task was to indicate the presence of either a K or an N in the array on each trial. Positive and negative images were more distracting than either neutral or scrambled images,

demonstrating emotional distraction when the task and the distractor occupy separate spatial locations.

Task-irrelevant emotional distraction has also been achieved using central distractors with a peripheral task. Walsh, Carmel, Harper and Grimshaw (2018) examined the influence of motivation on cognitive control of emotional distractors. Participants performed a letter search task that surrounded a central, task-irrelevant distractor, which was either positive, negative or neutral in valence. One group of participants received a monetary reward for fast and accurate performance, while those in a control condition did not. Emotional images caused greater distraction than neutral images; an effect that was reduced in the reward condition. This study demonstrates evidence for emotional distraction when the distractor is presented at a central location and suggests that motivation may encourage a cognitive control strategy that maximises reward.

An additional challenge to examining task-irrelevant emotional distraction is the timing synchrony of the task. In the paradigms described so far, the participant performs a dynamic task while the distractor appears at a task-irrelevant location. The abrupt onset of the distractor, while task-irrelevant, may capture attention and disrupt performance because it signals a change in the task environment (see Gibson & Kelsey, 1998 for a discussion on stimulus-driven attentional capture; Burnham, 2007; Yantis, 2000). After repeated trials, the onset of the distractors may become linked to the trial structure, and thus become task-relevant. This is a problem when investigating attentional capture from task-irrelevant stimuli on a primary task because it is unclear whether the onset of the distractor, or the content of the distractor is leading to the detriment in performance.

Forster and Lavie (2011) developed an asynchronous task which avoids this potential issue. Participants performed a continuous forced choice (letter or digit) task on a central alphanumeric matrix while task-irrelevant distractors were shown in the periphery. The alphanumeric matrix remained on the screen until the participant classified the last item in the matrix. The task requires continuous attention, so the participant had no reason to develop an attentional strategy based on dynamic elements of the task (i.e. the onset of distractors). Task-irrelevant distractors slowed performance on the continuous letter/digit classification task, demonstrating that even distractors that are not tied to the onset of the target still produce distraction (Forster & Lavie, 2011).

The investigations mentioned above are informative in terms of emotion-attention interactions when the task and the distractor are at different locations; but they are unable to shed light on the interactions between task-irrelevant emotional and neutral stimuli when they occupy the same space. When targets and distractors are separated in space, we can use *location-based* attention to select the target and suppress the distractors. But when targets are superimposed on distractors that share the same retinal location, we must use *feature-based* attention for target selection. Although emotion prioritises the allocation of location-based attention, we know much less about its effects on feature-based attention. Before introducing a specific superimposed design that allows the examination of emotion-attention interactions at the same location, it is necessary to discuss visual attention, and what is known so far about attention to objects that occupy the same space.

### **Visual Attention**

Vision allows us to locate and identify objects in space. Our everyday environment is so visually complex, our visual system does not process our whole visual

field to the same degree (Carrasco, 2011; Desimone & Duncan, 1995). Instead decades of research into vision and perception show that in most cases object recognition is achieved by visually selecting relevant or salient features of an object and focusing on these aspects, before moving onto another cluster of features. Which features are given priority over others depends on a combination of top-down, and bottom-up influences. Top-down influences are attentional drivers that come from the perceiver's goals (e.g. the perceiver wants a strawberry, so red items will be selected by attention when heading to the fruit bowl). Bottom-up influences are attentional drivers that come from the stimulus (e.g. the one yellow banana in a fruit bowl of red apples and strawberries will seem to 'pop-out') (Yantis, 1998).

The spatial location of objects and other elements in the environment also influence the allocation of attention, which in turn has consequences for behaviour. For example, Posner (1980) demonstrated that a light target was detected fastest when appearing at expected locations, slowest when appearing at unexpected locations, and intermediate RTs when no expectation of target location were given. This suggests evidence for directed attention, where a perceiver can direct their attention to locations in space and receive attentional processing benefits if the target and the response are congruent (i.e. for validly cued trials).

However, the two-dimensional stimulus display described in the Poser (1980) experiment does not have the same spatial complexity as our everyday three-dimensional environment. Research on directed attention in 3D space has been mixed, with some researchers reporting an ability to direct attention to locations in 3D space (e.g. Downing & Pinker, 1985; Gawryszewski, et al., 1987), and others suggesting that attention cannot be directed across 3D space (e.g. Ghirardelli & Folk, 1996; Iavecchia &

Folk, 1994). One critical difference between these two groups of studies identified by Hoffman and Mueller (1994) is that it is necessary to define the to-be-attended location with a placeholder object for directed attention in 3D space to be effective. This suggests that attention cannot be directed to empty location across 3D space but directed attention to different objects at different depths is possible.

The literature of *negative priming* demonstrates that not only can we attend to objects at different depths, but we can also ignore objects based on depth. In a paradigm developed by Tipper (1985), participants were presented with a display of two superimposed objects. One object was drawn using a solid red line, and the other a broken green line. The participants' task was to select an object in the display based on the colour (red) and indicate whether the object seen matched a later probe object. If the object to-be-ignored was the same as, or shared the same category as the probe object, RTs to the probe object were delayed. Tipper suggests that negative priming demonstrates inhibition as one mechanism of selective attention, and that unwanted competing representations (i.e. distractors) can be decoupled from response outputs by a process of inhibition.

Taken together, these studies suggest that people can selectively attend to objects at different depths, but it remains unclear what happens to visual attention when emotional perceptual bias is added to the to-be-ignored stimulus in a superimposed design. One problem that arises with superimposed experimental designs, is how can you get an objective measure of which object (foreground or background) the participant is paying attention to? In order to examine emotion-attention interactions in the same location one neural measure that has been shown to be useful is the SteadyState-Visual-Evoked-Potential (SSVEP) (Norcia et al., 2015; Wieser, Miskovic, & Keil, 2016).

## SSVEP

Steady-State-Visual-Evoked-Potentials (SSVEPs) are the electrophysiological response of the visual cortex to a flickering stimulus. The SSVEP works by capitalising on the entrainment of the visual cortex whereby a sinusoidal waveform takes on the same frequency as the driving stimulus (e.g. if you flicker an image at 6Hz, you will get an SSVEP at 6Hz) (Norcia et al., 2015; Regan, 1989; Wieser et al., 2016). The more attention paid to the flickering stimulus, the bigger the amplitude of the SSVEP, thus SSVEPs can be used to investigate attentional resource allocation between competing stimuli (Bekhtereva, Craddock, & Müller, 2015; Hindi Attar, Andersen, & Müller, 2010; Müller, Andersen, & Keil, 2008; Norcia et al., 2015; Wieser et al., 2016).

One way to extract and analyse the SSVEP signal is through a Fast Fourier Transform (FFT). An FFT analysis deconstructs the raw EEG data into a formula of multiple sine and cosine terms, all oscillating at different frequencies, then summed together. The extent to which each frequency accounts for the raw EEG data gives an estimate of the power of that frequency within a given time interval. One of the benefits of doing this analysis is that it is simple, clear and quick. Additionally, you need relatively few trials in order to extract an SSVEP; unlike other approaches (e.g. ERP analysis), in which many more trials are required to extract the component. Akin to other electrophysiological approaches, one of the benefits of using SSVEPs is the timing sensitivity. SSVEP responses can be time locked to the onset of events or binned into time epochs to look at changes in attentional resource allocation across time (Hindi Attar et al., 2010; Norcia et al., 2015; Wieser et al., 2016).

Additionally, experimenters can set up multiple SSVEP driving stimuli on the same stimulus display, to see where in the display a participant is attending. Since SSVEPs are generated in the visual cortex, all the participant has to do is look at the

stimulus in order to get an SSVEP. For example, if you have display with an image on the left (flickering at 6Hz) and an image on the right (flickering at 10Hz), and the results of the FFT analysis showed a bigger peak at 10Hz, than at 6Hz, then it can be concluded that the participant was paying more attention to the image on the right than the image on the left. Experimenters can then compare attentional competition (i.e. the power of the SSVEP FFT peak) between competing stimuli within the same display, or even between stimuli that share the same spatial location. By locking stimuli to their own unique frequencies, SSVEP paradigms enable observable neural distinctions to be made between visual elements that occupy any space within the visual field (Wieser et al., 2016).

Bekhtereva and Müller (2014) demonstrated that when emotional images are the focus of attention they enhance SSVEP amplitudes as long as participants are given enough time to process them. Participants viewed a rapid stream of images that was either negative or neutral in valence. When the images were flickered at a rate of 15Hz (67ms allowed to process each image) there was no significant attentional modulation of SSVEP amplitudes by valence. In Experiment two, however, at a flicker rate of 6Hz (167ms to process each image) a main effect of emotion was found, where SSVEP amplitudes were amplified whenever a negative image stream was being presented. The findings from the second experiment demonstrate modulation of the SSVEP by valence at a flicker rate of 6Hz, suggesting adequate time to process significant features in each image is a requirement to achieving emotional modulation of SSVEP amplitudes.

As well as differentiating attentional resource allocation to different locations on a stimulus display, SSVEP paradigms can also be used to examine superimposed or overlapping stimuli, by flickering the stimuli at a unique frequency. Müller, Andersen,

and Keil (2008) examined the time course of attentional competition between a flickering motion-coherence task and task-irrelevant emotional background distractors. Participants' task was to indicate when they detected short bursts of synchronised motion in an array of randomly moving squares. SSVEP amplitudes to the foreground task were calculated and compared across positive, negative and neutral background distractors. In the presence of emotional, compared to neutral background distractors, SSVEP amplitudes to the foreground task were reduced, which continued for several hundred milliseconds after stimulus onset. Additionally, the drop in SSVEP amplitude happened at the same time as a drop in behavioural performance in the foreground task. Müller, and colleagues (2008) concluded that the arousing background images withdrew processing resources from the foreground task as shown by the drop in SSVEP amplitude and concurrent drop in target detection performance in the motion-coherence task. This study demonstrates that background emotional distractors reduce neural markers of attentional processing to a primary foreground task and that this reduction has consequences for the perceivers' ability to do the task.

**Hindi Attar, Andersen and Müller (2010)**

The work of Müller, Andersen and Keil (2008) encouraged further investigation into emotion-attention interactions using SSVEP when the task and the distractors share the same spatial location. Hindi Attar et al., (2010), used an SSVEP based paradigm to examine the time course and magnitude of competitive interactions between a foreground dot-motion task, and task-irrelevant background distractors. In this design, participants viewed a display of flickering dots which were superimposed on top of a background image. During a trial, the dots moved randomly around the display and then for very short bursts of time, all moved together in the same direction, either up, down,

left, or right. The participants' task during these brief moments of synchrony, or *motion coherence*, was to press the space bar to indicate detection of the coherent motion. The dot-motion task flickered at a rate of 7.5Hz allowing the extraction of an SSVEP as a measure of attention to the foreground task.

On each trial the background image started as an unidentifiable scrambled image, then transitioned either into another scramble of the same image, or an intact version of that image. The participants were told to focus on the foreground dot-motion task and ignore the background images, which were either positive, neutral, or negative in valence when intact. As larger SSVEPs have been linked to increased attentional processing, if the participants are distracted by the background images then their SSVEPs to the dot-motion task will be reduced.

Researchers found reduced SSVEP amplitudes in the presence of both positive and negatively valenced background distractors compared to neutral distractors. When the background distractor transitioned from a scramble into any intact image, there was a reduction in SSVEP amplitude. When the background distractor transitioned from a scramble into another scramble, there was no difference in SSVEP amplitude. The intact-scramble SSVEP reduction emerged earlier and was more pronounced than the emotional-neutral reduction observed. Additionally, researchers found a reduction in target detection rate in the dot-motion task between emotional and neutral background distractors during the same time-windows as the SSVEP reductions.

These findings suggest that the transition from a background scramble into any intact image initiates an involuntary shift of attention away from the foreground task. The valence effect occurred in similar time window (270ms) to the Early Posterior Negativity (EPN), which is an EEG component previously shown to be influenced by

arousal, occurring between 200-300ms after stimulus onset (e.g. Schupp et al., 2004). Thus, once emotional cue extraction on the intact image has taken place, the emotional content of the image takes a further involuntary draw on attention. The reduction of attention to the foreground task hinders performance despite being irrelevant to the current goals of the participant (Hindi Attar et al., 2010).

Since the study by Hindi Attar and colleagues in 2010, others have used superimposed SSVEP-based paradigms to examine interesting questions about emotional distraction. Bekhtereva, Craddock, and Müller (2015) used a SSVEP emotional distraction paradigm to examine the process of attentional shifting and the time course of emotional cue extraction between face stimuli and IAPS (International Affective Picture System, (Lang et al., 1997)) images. Emotional attentional modulation of the SSVEPs occurred earlier for the face stimuli (180ms) than for the more complex IAPSs (550ms). Authors conclude that attentional resource re-allocation occurs after the emotionality of the stimulus has been extracted, as suggested by the longer processing time required to find valence effects with more complex images.

In 2012, Hindi Attar and Müller examined the effect of attentional demand on emotional distraction using SSVEPs. The display was a rapid stream of symbols superimposed on top of emotional or neutral distractors. Participants' task was to either indicate when they saw a blue symbol in the stream (low attentional demand), or indicate when they saw one of two symbols in a specific colour (high attentional demand). Both the symbol task and the distractors flickered at different frequencies (8.6Hz and 12Hz respectively) to determine any differential attentional resource allocation between the distractors and the task under low compared to high attentional demand. SSVEPs to the distractors were enhanced for emotional compared to neutral

distractors, and SSVEPs to the symbol task were reduced for emotional compared to neutral distractors. There were no significant differences in the SSVEPs elicited by the symbol task under high or low perceptual load, leading to the conclusion that emotional distraction in the visual cortex, as measured by the SSVEP, is not modulated by attentional demand (Hindi Attar & Müller, 2012). This finding contrasts from paradigms that use spatially separated tasks and distractors, which show that under high perceptual demands, the effect of emotional distractors is reduced (Erthal et al., 2005; Gupta, Hur, & Lavie, 2016). Hindi Attar and Müller (2012) demonstrates the value of investigating neural responses of emotional distraction with stimuli that share the same reinotopic space, as spatial location can have implications for emotion-attention interactions.

### **Current Experiments**

Experiment one aims to conceptually replicate the emotional distraction effects found in Hindi Attar and colleagues (2010), using a version of their task that we created. In the future, this paradigm will allow the assessment of interesting questions about how emotion affects feature-based location, but the first step is to replicate the basic effect in our own lab. Participants were set up with EEG recording equipment and asked to perform a flickering dot-motion task while emotional images (or scrambles) were presented in the background. SSVEPs were calculated through Fast Fourier Transform (FFT) to determine the power (mean voltage squared) of the signal generated by the foreground dots. SSVEP amplitudes were then compared across positive and neutral stimulus conditions to determine if the attentional resource allocation between the foreground task and the background distractors is influenced by the emotionality of the background stimulus. Experiment 2 follows the same trial procedure as Experiment 1

with an adapted behavioural task to increase sensitivity to detect behavioural distraction, and more participants to increase statistical power.

For both experiments, it is predicted that SSVEP amplitudes will be reduced in the presence of any intact image compared to a scramble. More importantly, if emotional stimuli are more distracting than neutral stimuli, then; when the images are intact the drop in SSVEP amplitude will be greater for positive images than for neutral images. Additionally, we would also predict behavioural performance on the dot-motion task to follow the same pattern; whereby performance will drop in the presence of any intact image compared to scrambles, with a further reduction in performance when comparing positive intact to neutral intact distractors.

## **EXPERIMENT 1**

The purpose of Experiment 1 was to develop an effective SSVEP emotional distraction paradigm, based of the work of Hindi Attar and colleagues (2010). The dot-motion task was chosen for the current experiments because of the requirement to maintain attention across the whole trial. This factor avoids the problem of the onset of any distractor being linked to the foreground task, and thus the distractors remain task-irrelevant. Additionally, the dot task ensures that attention is dispersed across the whole foreground plane of space, while the emotional distractor occupies the same space in the background. This arrangement provides an equal spatial location when comparing the effect of emotional distractors on a primary task, allowing a fine-tuned assessment of emotion-attention interactions.

Only positive and neutral distractors were used for the current experiments, without the typical inclusion of negative distractors as well. Similar levels of distraction occur for both valences when matched in arousal (e.g. Schupp, Junghfer, Weike, Hamm,

2003), and both types of distractors require similar levels of cognitive control to reduce their detriment on performance (Grimshaw et al., 2018; Walsh et al., 2018). Since the research question is not related to valence, and in the interest of keeping our experimental running time down, it was decided to compare the effects of only positive distractors to neutral distractors.

Coloured distractors and scrambles were used in the current experiments as Bekhtereva and Müller (2017) demonstrated the modulatory role of colour in emotional perceptual processes. Participants in their study performed a foreground visual detection task while briefly presented neutral and negative distractors were presented in the background, either in greyscale or in colour. Greater SSVEP amplitude reductions were found for the coloured distractors compared to greyscale distractors, and the reduction lasted longer for coloured unpleasant images, than for greyscale unpleasant images. In line with the neural data, coloured negative pictures were rated by participants as slightly more arousing and more emotionally negative than the greyscale images. Although the colour palettes of positive and neutral images might differ, we can control for such low-level differences by using scrambled versions of each image in the control condition. If effects are driven by emotional valence, they should be observed in intact images, but not in scrambles.

The proportion of distractors used in the current experiments was decreased from 50% of trials in Hindi Attar et al., (2010), to 33% used here in both Experiments 1 and 2. This change was implemented to allow an increased likelihood of finding a valence difference, as suggested by the greater influence of emotional distractors on neural responses and behaviour when presented on a lower proportion of trials (Grimshaw et al., 2018; Lavie, 2005; Murphy, 2016).

## Method

### Participants

A total of 28 participants signed up and participated in Experiment 1. Of those 28 participants 7 were excluded due to a programming error causing the second half of the behavioural data to be lost. A further 3 participants were excluded due to high impedences, and technical issues. After exclusions the remaining sample ( $n = 18$ ) had a mean age of 18.39 years ( $SD = 0.92$ ), and were mostly right-handed women (male = 4, left = 3). The sample size was estimated based on previous experiments as effect size was unknown. Similar experiments used between 15-20 participants (e.g. Bekhtereva et al., 2015; Bekhtereva & Müller, 2014; Hindi Attar et al., 2010; Hindi Attar & Müller, 2012), so we aimed for the same in Experiment 1. All participants had normal, or corrected to normal vision, with no current diagnosis of anxiety or depression, and no history of neurological disorder.

Participants received course credit for their participation and were recruited through the Introductory Psychology Participant Pool at Victoria University of Wellington. Ethical approval for the experiment was granted by School of Psychology Human Ethics Committee, under the authority of the Victoria University Human Ethics Committee. All participants gave informed consent before participation, were debriefed after the experiment, and were told they could leave at any point without penalty.

### Apparatus

The task was administered using a Dell Precision T1600 computer running PsychoPy (version 1.85.6, Peirce, 2007) on a 23'' Alienware 2310 monitor with a refresh rate of 60Hz. Participants were seated with a chinrest 57.3 cm from the display monitor.

## Stimuli

The images used in Experiment 1 came from the International Affective Picture System (IAPS) database (Lang, Bradley & Cuthbert, 2008). For a list of the 70 images used along with their individual valence (scale of 1 – 9, where higher numbers represent a more positive image) and arousal ratings (scale of 1 – 9, where higher numbers represent a more arousing image) see Appendix A. For examples see Figure 1. Our positive (erotic) image set was selected based on the highest arousal and valence ratings (using the combined male and female average) provided by the IAPS data base, (average valence rating: 6.50 ( $SD = 0.44$ ), average arousal rating: 6.39 ( $SD = 0.43$ )). The neutral images were selected based on neutral valence and arousal ratings (average valence rating: 4.99 ( $SD = 0.37$ ), average arousal rating: 3.66 ( $SD = 0.53$ )). People are quicker to detect faces than other objects in their environment (Crouzet, Kirchner, & Thorpe, 2010), so because our positive image set contained faces and bodies, only neutral images that also contained these elements were used.

Images were rescaled to remove any borders (size  $25.28^\circ \times 14.24^\circ$  in visual angle). Images were luminance matched across both valences using the MatLab SHINE toolbox (Willenbockel et al., 2010). Two Fourier phase scrambles were created for each image. A Fourier phase transform extracts the amplitude and phase components of each image, replaces the original phase spectrum with random values, then rebuilds the image using the inverse Fourier transform. The resulting scramble has the same low-level properties of the original image such as luminance and spectral energy, but none of the semantic content information contained within the original image. Including phase scrambles of the original images controls for these low-level features of the image set; this way we can ensure that any differences we find between our conditions are due to

the emotional information contained in the image, rather than some other salient aspect of the image (e.g. colour, luminance, spectral energy).



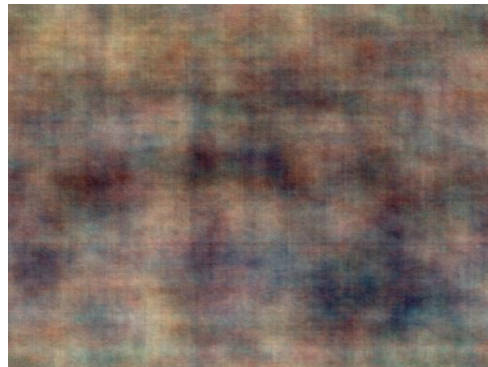
Neural Image Example



Positive Image Example



Phase Scramble of the Neutral Image



Phase Scramble of the Positive Image

*Figure 1:* The top panel shows an example of a neutral image on the left, and a positive image on the right. The bottom panel shows Fourier Phase transforms of the images above them.

A set of 100 moving yellow dots was superimposed over the image. A single dot was 15 pixels in size. Dots moved randomly, but occasionally 50% of them moved synchronously in the same direction, showing coherent motion. Participants were required to indicate when the dots briefly became coherent – these moments of coherence were called *motion-targets*.

The dots were flashed at a rate of 7.5Hz, created by presenting the dots ‘on’ for four frames, and then ‘off’ for 4 frames throughout the entirety of image presentation. Each motion target lasted for approximately 250ms, which corresponds to two on/off cycles at a refresh rate of 60Hz (16.67ms to render each frame).

### **Trial Procedure**

A trial started with a fixation cross, then a central phase scrambled image was presented. After a variable time-interval, the phase scramble transitioned into an intact version of the scramble (33% of trials), or into a different scramble of the same image (66% of trials). During image presentation, the dot-task was superimposed on top of the images and remained (flashing at 7.5Hz) for the entire image sequence (roughly 4.5 seconds). The dots were not present during the inter-trial interval and the yellow fixation cross remained throughout the experiment. Participants’ task was to identify incidents of coherent motion by pressing the spacebar. There could be up to 4 motion targets on any one trial and the dots could move either up, down, left, or right. A single trial lasted for roughly 6 seconds, including the inter-trial interval. Each block consisted of 30 trials, with a total of 14 blocks. For an illustration of the trial procedure see Figure 2

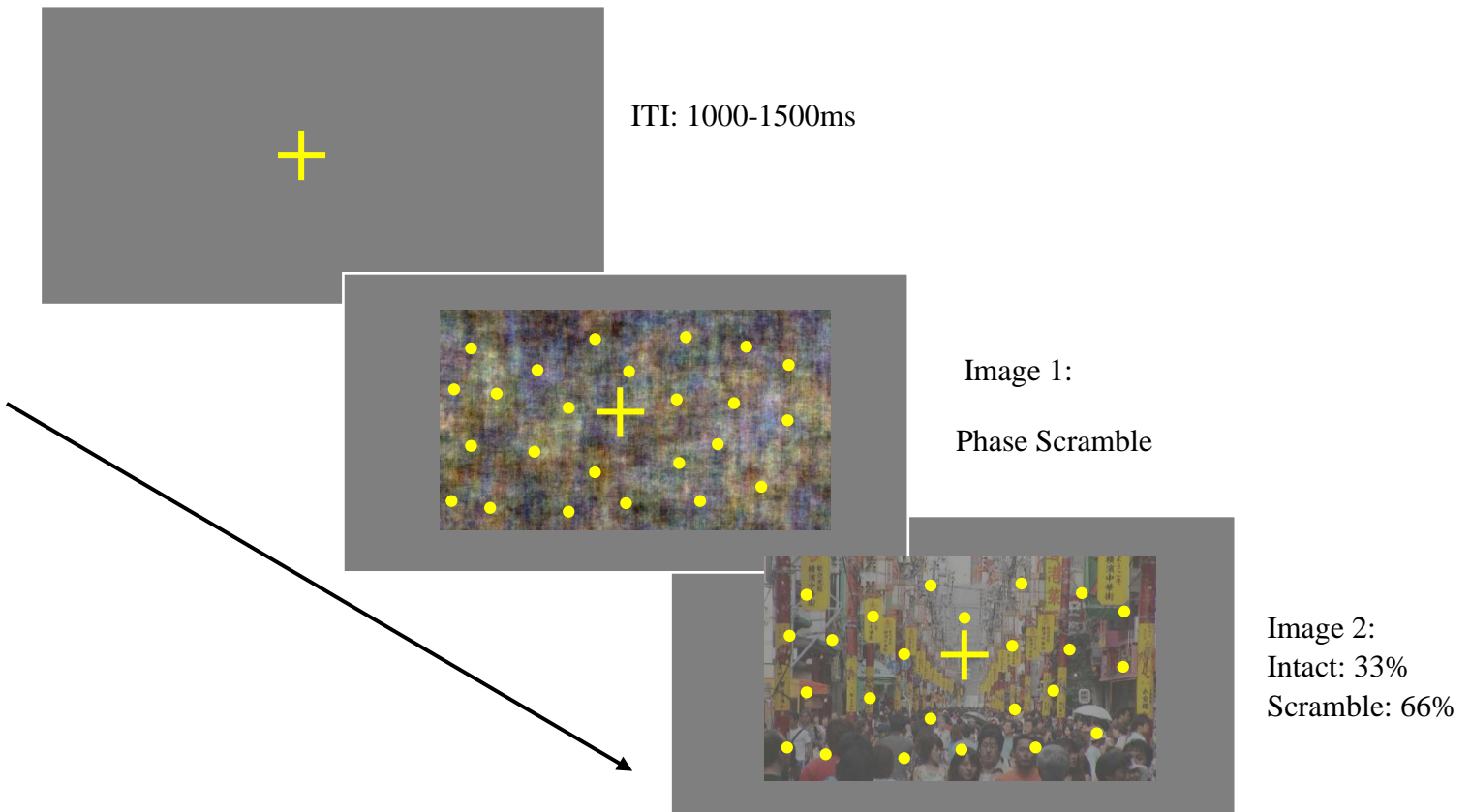


Figure 2: Schematic of trial procedure.

Note: Figure is for illustrative purposes only; stimuli are not depicted in actual size or ratio used. The transition time between image 1 and image 2 varied, but the total duration of the image sequence was always 4.55seconds in total.

In order to prevent the participants from predicting the timing of the transition from Image 1 to Image 2, transition time was divided into the following time bins after the onset of the first scramble: early 133-1067ms (7% of trials), middle 1200-2267ms (80% of trials), or late 2400-4400ms (13% of trials). The early and late transitions served to protect against anticipation of the image transition and were excluded from further analysis (henceforth known as *anticipation trials*), only the trials which fell into the middle transition window were used (as in Hindi Attar et al., 2010).

Over the course of one block 6 of the trials fell into either the early or late time

windows, and the rest (24 trials) fell into the middle transition time and were used for analysis. When Image 2 was an intact image, half of the images presented were positive and the other half were neutral (10 intact trials per block: 2 anticipation, 4 positive, 4 neutral). When Image 2 was a scramble, the same proportions were maintained (20 trials: 4 anticipation, 8 positive, 8 neutral)

Participants completed 14 blocks, with self-paced breaks in-between. A single block lasted for about 3 minutes and participants could rest for as long as they chose between blocks (most rested for under 2mins). The task was structured so that they completed seven blocks, then the experimenter took them out of the chamber and the participant was asked to complete a mindfulness questionnaire. The questionnaire administered was for another research purpose and is not discussed further here. Participants were then given the option to have a stretch and a break, and then were taken back into the testing chamber to complete the remaining 7 blocks when they felt ready. The whole experiment (including set up) took approximately 2 hours for each person.

To ensure that participants clearly understood the task, a series of graded practice trials were administered before the experimental trials. First the participant was shown one motion-target at 100% coherence (with an option to repeat the example); once detected, they were shown one motion-target at 50% coherence (again, with the option to repeat if required). Then participants completed a block of 10 trials where up to four targets could appear on one trial. All trials in this first practice block only contained the dots superimposed on scrambles. Finally, a second block of 10 trials was given, where the task was the same as the trial procedure described in Figure 2.

## **Behavioural Analysis**

To assess performance in the dot motion task, hit rate was calculated per image condition. A hit was defined as a response that was made between 200-1000ms after motion target onset; any target that was not detected within this window was classified as a miss. To see if participants were randomly responding during the task, the total number of false alarm incidents were counted per image condition. A false alarm was defined as a detection response when no motion-target was presented. A false alarm rate could not be calculated because the task was not a forced choice (e.g. participants respond 'Yes' when they see a target and 'No' when they do not see a target). Unfortunately, due to the programming of the task, I could not determine whether each motion target occurred either before or after picture change (an issue resolved in Experiment 2).

## **EEG Set-up, Recording and Analysis**

EEG was recorded during the dot-motion task with a Lycra Quick-Cap (Compumedics NeuroMedical Supplies) embedded with Ag/AgCl electrodes at 28 sites (FP1, FP2, F3, F4, F7, F8, FZ, FT7, FT8, FC3, FC4, C3, C4, CZ, T8, TP7, TP8, CP3, CP4, P7, P3, PZ, P4, P8, O1, OZ, O2 according to the modified 10-20 system; American Electroencephalographic Society, 1994). Electrooculogram (EOG) was recorded from electrodes placed on the outer canthus of each eye to detect horizontal eye movements, and above and below the left eye to detect vertical movements (blinks). Electrodes were also placed behind the left and right ears on the mastoid bones, where all electrodes were referenced online to the left mastoid and re-referenced to the left/right average for analysis. Impedances were set to be below 5 k $\Omega$  and were checked during the halfway break to ensure that the electrode impedances were still below 5 k $\Omega$ . EEG signals were

amplified by Professional BrainAmps and digitized using Brain-Vision Recorder (Brain Products, Gilching, Germany).

EEG and EOG were digitised at a sampling rate of 500Hz. The raw data was filtered using zero phase shift Butterworth filters with a low cut off at 0.1Hz, a high cut off at 30Hz, and a notch filter at 50Hz. EEG data were analysed with Brain Vision Analyzer 2.0 (Brain Products, Gilching, Germany). Vertical EOG activity was calculated by subtracting activity at the electrode above the eye from the activity at the electrode below the eye.

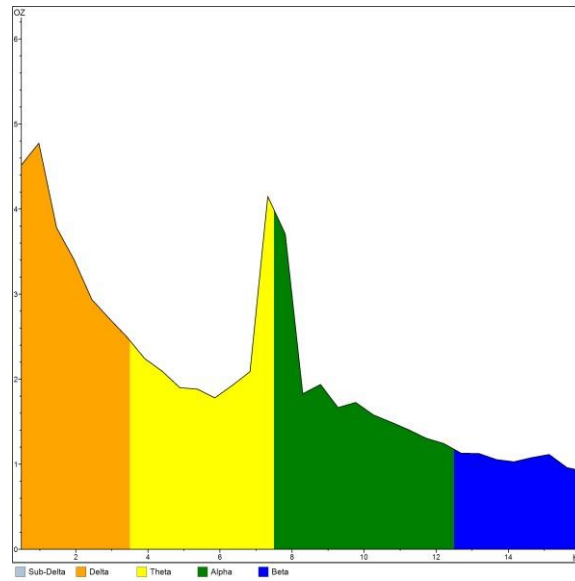
Horizontal eye movements were calculated by subtracting activity at the left EOG electrode from the activity on the right electrode. Negative values indicated a saccade to the left, and positive values indicated a saccade to the right. Typically, in EEG experiments these horizontal saccades are removed from the data, however since the current task is a dot-motion task, requiring participants to follow the motion left or right (or up or down), these saccades were kept because removing them would have created unacceptable levels of data loss. Ocular artefacts from horizontal eye movements are unlikely to propagate strongly back to occipital sites (Lins, Picton, Berg, & Scherg, 1993), where the SSVEP is generated. If a small amount of activity is propagated it should be equal across all stimulus conditions, so not correcting for HEOG activity may add a level of noise to the data but no confounds. I performed an ICA artefact rejection on the raw data for each participant with the HEOG channels excluded, which removed vertical eye-blinks and artefacts from the data. Additionally, noisy segments of the data (e.g. block breaks) were manually removed.

### **SSVEP Data preparation**

After filtering and the ICA artefact rejection, the data was segmented into different image conditions defined by the second image presented on each trial (positive intact, positive scramble, neutral intact, neutral scramble). The data was then further split into two time-windows: before picture change, and after picture change. This was possible in the EEG data (unlike the behavioural data), because the EEG data file included a trigger to mark the point of transition.

To determine the power ( $\mu V^2$ ) of the SSVEP signal a Fast Fourier Transform (FFT) was performed after segmentation. Raw EEG data is represented as complex waves across time, and just like any complex wave, the EEG signal can be broken down into its component waves. An FFT analysis deconstructs the raw EEG data into a formula consisting of multiple sine and cosine terms, all oscillating at different frequencies, then summed together. The extent to which each frequency accounts for the raw EEG data gives an estimate of the power of that frequency within a given epoch.

The dots are flickering at a rate of 7.5Hz, so when the FFT is performed, I would expect to see a big spike of power at 7.5Hz. As a measure of attentional resource allocation to the dot-task, the peak of the FFT (highest power point) for each participant was calculated per image condition before and after picture change around 7.5Hz. To see an example of an FFT peak, see Figure 3



*Figure 3:* Displays an example of the spectral distribution for a single participant of the FFT peak around the stimulation frequency of 7.5Hz at electrode site OZ. The y-axis shows the amplitude power ( $\mu V^2$ ), and the x-axis shows the frequency (Hz).

## Procedure

Participants were welcomed into the EEG lab room and given some study information. Once consent was obtained EOG and EEG electrode set-up began. First, participants' skin was cleaned with exfoliant and alcohol wipes to prepare the skin for the facial electrodes. Facial electrodes were placed above and below the left eye and on the left and right temple and on both mastoids. Next, participants were fitted with an EEG cap and moved into the faraday chamber to complete the gelling. We then led the participant through the practice trials, ensured that they understood the task and were comfortable, and then left the chamber while they did the task.

Halfway through the experiment the participant was removed from the chamber for a break and a brief questionnaire, then returned to the chamber when they were ready to complete the rest of the task. Upon completion of the task participants removed their facial electrodes and EEG cap. Before leaving, participants were thanked for their time and debriefed as to the purpose of the experiment.

## Results and Discussion

### Behavioural Data

Mean motion target detection proportions were calculated for each image condition see Table 1. A hit was defined as a response between 200-1000ms after motion target onset. Any target not identified within this time range was classified as a miss. Hit proportions were calculated as an average across the whole trial, because the transition time between image 1 and 2 could not be linked to the behavioural data.

A 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) repeated measures ANOVA was performed to assess the effect of the emotional distractors on motion target detection. For hits, main effects for valence  $F(1, 17) = 18.88, p < .001, \eta_p^2 = .53$ , and image type  $F(1, 17) = 42.04, p < .001, \eta_p^2 = .71$  were found, qualified by a significant valence x image type interaction  $F(1, 17) = 15.62, p = .001, \eta_p^2 = .48$ . Post-hoc paired t-tests revealed that target detection was reduced for positive compared to neutral distractors when images were intact ( $p < .001$ ), but no valence difference was revealed when the images were scrambled ( $p = .448$ ). See Figure 4.

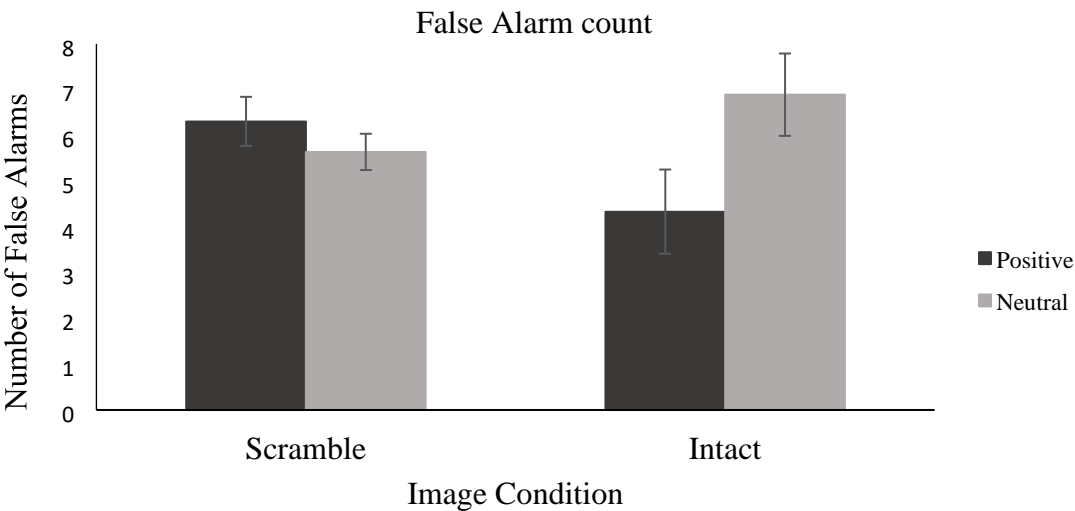
To see if participants were randomly responding during the task, the number of false alarms made per image condition was counted. The number of false alarms made in the scrambled image conditions was halved because there are twice as many scrambles as intact images. Mean false alarm counts were calculated for each image condition see Table 1. The same 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) ANOVA was run for false alarms, revealing a main effect of valence  $F(1, 17) = 5.03, p = .039, \eta_p^2 = .228$ , qualified by a significant valence x image type interaction  $F(1, 17) = 12.478, p = .003, \eta_p^2 = .423$ . Paired samples t-tests showed that fewer false alarms were made during positive compared to neutral distractors when

images were intact ( $p = .005$ ), but there was no difference between positive and neutral false alarms when the distractors were scrambled ( $p = .074$ ). See Figure 5.

Table 1

*Mean (SD) Hit proportion and False alarm count per image condition in Experiment 1 and mean (SD) FFT peak for the valence x image type interaction.*

Image Condition	Hit (%)	False Alarm (Average count)	FFT Peak ( $\mu V^2$ )
Positive Intact	0.65 (0.15)	4.33 (5.98)	7.41 (3.18)
Neutral Intact	0.72 (0.15)	6.89 (5.38)	8.97 (3.16)
Positive Scramble	0.75 (0.16)	6.31 (6.21)	9.05 (3.23)
Neutral Scramble	0.74 (0.16)	5.64 (5.74)	10.11 (3.26)



*Figure 4:* shows the average hit rate per image condition. Error bars were calculated within subjects (Cousineau, 2005).

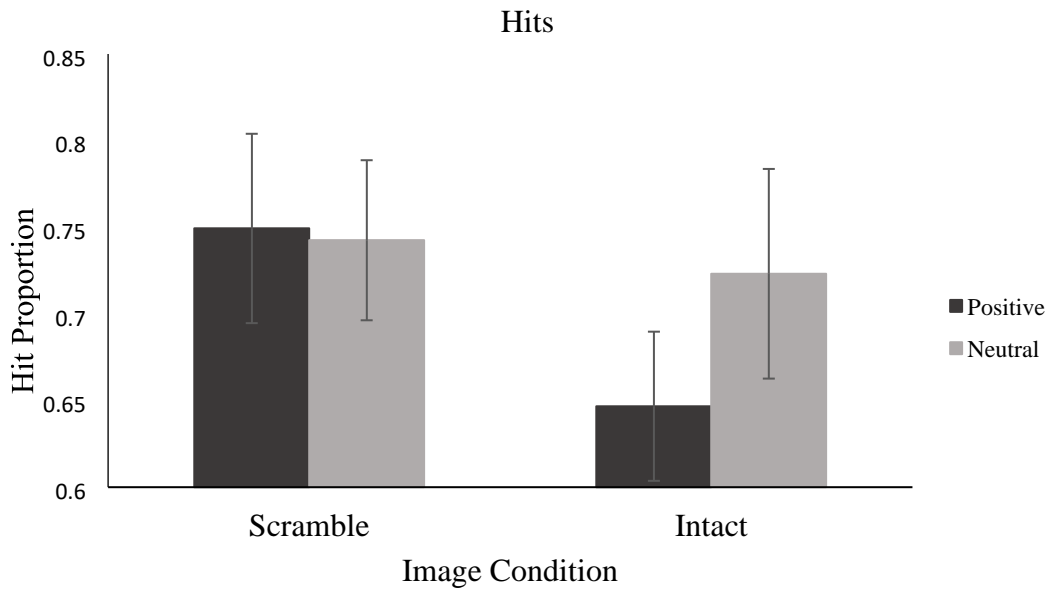


Figure 5: shows the average false alarm count per image condition. Error bars were calculated within subjects.

The current results support the hypothesis that emotional images are more distracting than neutral images, as target detection was reduced in the presence of positive intact images compared to neutral intact images. This suggests that task-irrelevant high arousal images capture attention more than neutral images when presented in the background of a foreground task.

The results from the false alarm analysis also support the hypothesis that emotional images are more distracting than neutral images. Additionally, the decreased number of false alarms made in the presence of positive intact distractors suggests a response bias, where participants are less likely to respond in the presence of intact emotional distractors.

It became clear during data analysis that calculating the hit rate and counting the incidents of false alarms was not an ideal way to analyse the behavioural data. A more robust measure of random responding would be to calculate a false alarm *rate*, where the number of false alarms is calculated in proportion to the number of correct rejections

(i.e. a ‘No’ response when no target was presented). That was not possible in this experiment because the number of targets within a trial varied, and it was possible to make multiple false alarms on a single trial. A false alarm rate would allow calculation of the signal detection measures, which can be used to determine whether emotional images affect the perception of coherent motion (as indicated in the sensitivity measure  $d'$ ) or response bias (as indicated in the criterion measure  $c$ ). This problem will be addressed in the second experiment. A good behavioural measure is important when investigating emotional distraction because even if there was a valence difference in the neural measures between positive and neutral distractors, if there is no valence difference in behaviour, it cannot really be emotional distraction.

An additional problem encountered was that the transition time between the two images was not recorded. The data showed the time range in which the image transitioned (early, middle, or late) but not the specific millisecond that it happened. For this reason, it was not possible to determine which responses occurred during the pre-change image, and which occurred during the post-change image. This was not an issue for the SSVEP analysis because the EEG recording equipment used timing triggers to capture the transition time between the two images. In Experiment 2 an additional component was added to the experimental programming to export the transition time between the two images to the behavioural data.

### **SSVEP Peak**

An example of the spectral distribution of the FFT peak is displayed in Figure 3. Mean peak FFTs were calculated for each image condition see Table 2. One peak was calculated per participant at electrode site OZ between the frequencies 6.5 - 8.5Hz to capture the peak power ( $\mu V^2$ ) of the SSVEP signal at the stimulation frequency of

7.5Hz. A 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) x 2 (picture change: before, after) repeated measures ANOVA was performed to assess the effect of the emotional distractors on peak FFT before and after picture change. See Figure 6

A main effect of picture change was found  $F(1, 17) = 32.18, p < .001, \eta_p^2 = .65$ , demonstrating that FFT peaks were reduced after the transition to the second image. Main effects of valence  $F(1, 17) = 38.62, p < .001, \eta_p^2 = .69$ , and image type  $F(1, 17) = 37.60, p < .001, \eta_p^2 = .69$ , were also found, qualified by a valence x image type interaction.

A valence x image type interaction  $F(1, 17) = 22.96, p < .001, \eta_p^2 = .58$ , was found where post-hoc paired t-tests revealed (see means and SDs in Table 1) that SSVEP peaks were reduced in the presence of positive compared to neutral distractors when images were intact ( $p < .001$ ), and when images were scrambled ( $p < .001$ ). The significant interaction shows that the difference between positive and neutral pictures was bigger when the images are intact, than when they are scrambled.

In support with the hypothesis, the valence x image type interaction suggests that task-irrelevant high arousal distractors capture more attentional resources than neutral distractors when presented in the background of a foreground task. An unexpected aspect of the result is the significant difference in SSVEP peaks between positive and neutral scrambled images; this finding suggests that there are features of the stimulus set (e.g. colour) contributing to the reductions in SSVEP amplitude. The valence x image type interaction, however, demonstrates that the valence difference was greater when the images were intact than when they were scrambled; suggesting that only some of the valence effect can be attributed to features of the stimulus sets, so the remaining difference can be attributed to the difference in valence in the intact images.

A valence x picture change interaction  $F(1, 17) = 11.55, p = .003, \eta_p^2 = .41$ , was also found where post-hoc paired t-tests showed that SSVEP peaks were reduced for positive compared to neutral distractors, both before ( $p < .001$ ), and after ( $p < .001$ ) picture change. The significant interaction demonstrates that the difference between positive and neutral images was larger after picture change, but that a small difference between positive and neutral scrambled images also exists in the pre-change pictures.

In line with the current predictions, when positive intact images were used as distractors there was a greater reduction in SSVEP peak than for neutral intact images, suggesting that high arousal images capture more attentional resources than low arousal images when presented in the background of a foreground task. The valence x picture change interaction demonstrates that the difference between positive and neutral SSVEP peaks was stronger after picture change than before picture change; this is as expected because all images before picture change were scrambles, and only after picture change could images appear intact.

A image type x picture change interaction  $F(1, 17) = 35.98, p < .001, \eta_p^2 = .68$ , was also found where post-hoc paired t-tests demonstrated that SSVEP peaks were significantly reduced for trials showing intact compared to scrambled images after picture change ( $p < .001$ ). However, these trial types did not differ before picture change, when scrambles were presented in both conditions ( $p = .957$ ). Note that the image conditions were defined by the second image presented (positive intact, neutral intact, positive scramble, or neutral scramble), thus even a 'positive intact' trial starts with a scrambled image (image 1), then a positive intact image is presented after picture change (image 2). The three-way valence x image type x picture change interaction was non-significant ( $p = .921$ ). See Figure 6

Taken together the findings from the SSVEP peak analysis suggest support for the hypothesis that task-irrelevant emotional information captures more attention than neutral information when presented in the same location as a foreground task. Interestingly, there also appears to be some attentional capture by the positive scrambled images, as they also have significantly reduced SSVEP peaks compared to neutral scrambled images. It may be the case that the participants are learning the colour pallets of the image sets (e.g. the positive scrambles contain more flesh tones compared to the neutral scrambles), since a scramble always precedes the intact image, they could develop some anticipation and expectation about which (if any) intact image will be shown after transition. Even if this was the case, the two-way interactions demonstrate that the valence difference found was stronger for intact images than for the scrambles, suggesting that a good portion of the drop in SSVEP amplitudes between positive and neutral conditions can be attributed to the difference in valence

Table 2

*Mean (SD) FFT peak per image condition before and after picture change in*

*Experiment 1*

	FFT Peak ( $\mu V^2$ )		FFT Peak ( $\mu V^2$ )
<b>Before Picture Change</b>		<b>After Picture Change</b>	
Positive Pre-Intact	9.25 (3.18)	Positive Intact	5.56 (1.87)
Neutral Pre-Intact	10.59 (3.38)	Neutral Intact	7.50 (2.23)
Positive Scramble	9.62 (2.95)	Positive Scramble	8.89 (2.95)
Neutral Scramble	10.21 (3.40)	Neutral Scramble	10.03 (3.21)

Note: All images before picture change are scrambled images, the image condition is defined by the second picture presented on each trial.

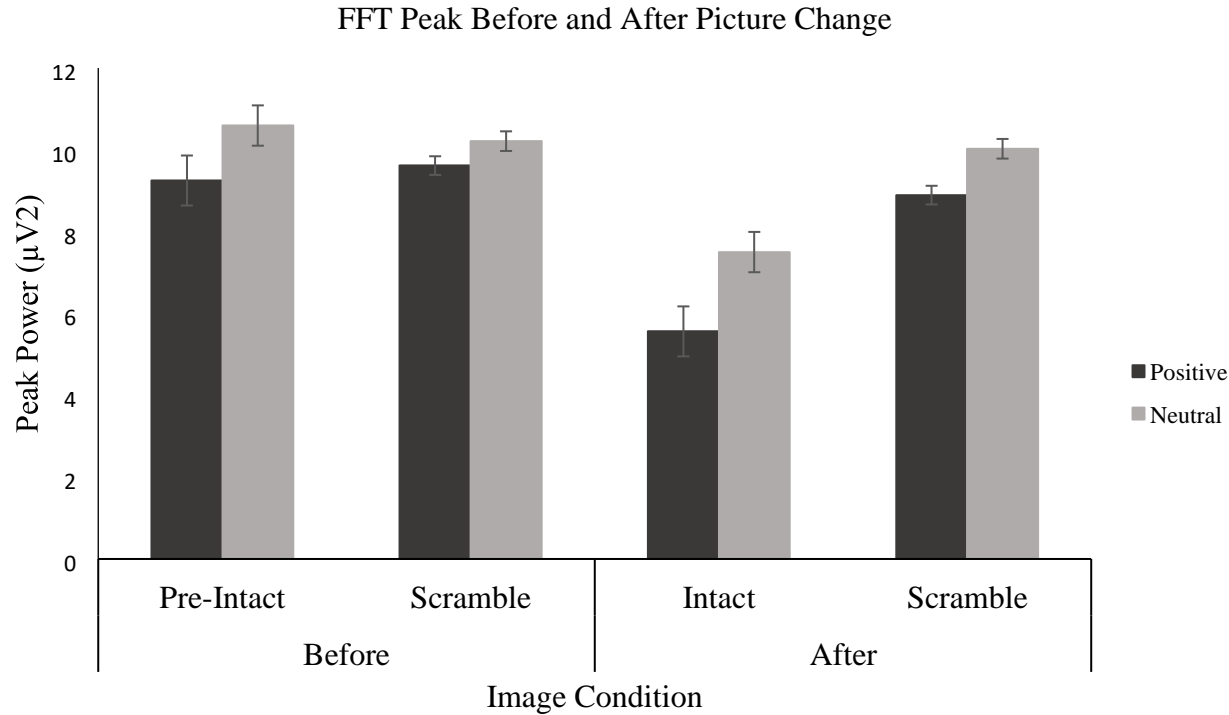


Figure 6: shows the average FFT peak ( $\mu V^2$ ) per image condition, before picture change on the left, and after picture change on the right. Error bars were calculated within subjects.

## EXPERIMENT 2

The motivation for Experiment 2 was to modify the behavioural task so that Signal Detection Theory could be used to analyse the behavioural data. This change was implemented because in Experiment 1 behavioural performance was categorized as either a hit (i.e. a response within 200-1000ms after motion target onset), or a miss (no response to a presented target within the time window), with only a count of false alarms per image condition. The fact that both hits and false alarms were reduced in the presence of positive background images means that the images might disrupt behavioural responses (i.e., producing a response bias), and not perception of motion coherence per se. In order to make the analysis of signal detection possible, the number of targets on each trial was controlled in a way that made it possible to calculate both a hit rate and a false alarm rate. Additionally, the task was changed from detection to

discrimination; now the participants' task was to discriminate between horizontal and vertical motion targets, instead of simply responding to indicate the presence of a target by pressing the spacebar. Because many participants were quite good at the task in Experiment 1 (8 out of the 15 participants had an average hit rate of above 80%), RT was also measured in Experiment 2 to provide another measure of behavioural distraction, as it is most informative when accuracy is high. The sample size was also increased in Experiment 2, to increase the power of the experiment. The analysis of the SSVEP remained the same as in Experiment 1.

Having a robust behavioural measure of emotional distraction is important because even if valence differences were found in the neural measures between positive and neutral distractors, if there was no effect on behaviour (i.e. no distraction), then the differences in the neural signals may simply reflect differential neural processing, rather than a neural measure of attentional competition between positive and neutral stimuli.

The predictions of Experiment 2 are the same as Experiment 1, that if emotional stimuli are more distracting than neutral stimuli, then SSVEP amplitudes will be reduced in the presence of any intact image compared to a scramble. More importantly, if emotional stimuli are more distracting than neutral stimuli, then when the images are intact, it is predicted that the drop in SSVEP amplitude will be greater for positive images than for neutral images. Additionally, we would also predict that behavioural performance on the dot-motion task will follow the same pattern; whereby performance will drop in the presence of any intact image compared to scrambles, with a further reduction in performance when comparing positive intact to neutral intact distractors. The signal detection measures will make it possible to determine whether positive distractors disrupt perceptual sensitivity, response bias, or both.

## **Method**

### **Participants**

A total of 33 participants signed up and participated in Experiment 2. Of those 33 participants two were excluded due to technical failures during the experiment. After exclusions the remaining sample ( $n = 31$ ) had a mean age of 20.93 years ( $SD = 5.94$ ) and were mostly right-handed (left = 5). Thirteen of the participants were female, 16 were male, and one person identified as agender. All had normal, or corrected to normal vision, with no current diagnosis of anxiety or depression, and no history of neurological disorder

Participants received course credit for their participation and were recruited through the Introductory Psychology Participant Pool at Victoria University of Wellington. Ethical approval for the experiment was granted by School of Psychology Human Ethics Committee, under the authority of the Victoria University Human Ethics Committee. All participants gave informed consent before participation, were debriefed after the experiment, and were told they could leave at any point without penalty.

### **Apparatus**

The task was administered using the same apparatus as Experiment 1, with a Dell Precision T1600 computer running PsychoPy (version 1.85.6, Peirce, 2007) on a 23" Alienware 2310 monitor with a refresh rate of 60Hz. Participants were seated with a chinrest 57.3 cm from the display monitor.

### **Stimuli**

The stimuli used for Experiment 2 were the same as Experiment 1, with the exception that in Experiment 2 the previously unanalysed anticipation trials that were in

Experiment 1 were not included. The rationale for the anticipation trials in Experiment 1 was to protect against the prediction of the image transition from a scramble into a potentially intact image. To achieve this the timing of the transition between image 1 and image 2 was broken up into three time-bins, early (7% of trials), middle (80%) and late (13%), of which only trials that used the middle range transitions were included in analysis. Upon reflection, because the middle transition window is already jittered across the image sequence, an additional protection against anticipation seemed superfluous, so the anticipation trials were removed for Experiment 2. According to the self-reports from a few participants, they did not feel that the transition between the two images was predictable or linked to the foreground task in any way. See Figure 1 for examples of the stimuli and Appendix A for a list of the images used.

### **Trial Procedure Modifications**

The trial procedure for Experiment 2 differed slightly from Experiment 1 in order to use signal detection theory to analyse the behavioural data. The basic trial structure remained the same, see Figure 2. Participants' task in Experiment 1 was motion-target detection (i.e. no matter the direction of the target, they pressed spacebar when a target was seen). This was changed in Experiment 2, so the participants' task was to discriminate between horizontal and vertical motion-targets using a number keypad.

The number of motion-targets used in Experiment 2 was increased compared to the number used in Experiment 1. Experiment 1 had between 1-4 motion-targets per trial, making for an indeterminate number of non-target windows, therefore precluding the calculation of a false alarm rate. In Experiment 2 we set clear target and non-target windows. Either 1 or 2 targets could appear before picture change (in target windows 1

and 2), and similarly 1 or 2 targets could appear after picture change (in target windows 3 and 4). Our analysis focused on the first and third target windows (which were present on every trial) because any distraction should occur soon after picture change in the background image. The other two motion-targets (which sometimes appeared during target windows two and four) served to protect against anticipation of the motion-targets and were excluded during analysis.

One block consisted of 24 trials. The first image presented was always a phase scramble. Image two was either an intact version of the scramble (33% of trials; half positive, half neutral), or another phase scramble of the same original image (66% of trials, half positive, half neutral). The administration of the task, practice blocks, and block structure of Experiment 2 was the same as Experiment 1.

### **EEG Set-up, Recording and Analysis**

The same EEG set up, recording, and data processing was used in Experiment 2 as in Experiment 1.

### **Behavioural Analysis**

To assess the performance to the foreground dot-motion task in Experiment 2, two signal detection distributions were calculated; one for target detection (target vs. no target), and the other for target discrimination on those trials in which a target was detected (horizontal vs. vertical targets). Criterion was calculated as a measure of participants' likeliness to respond and reaction time was calculated from the onset of the motion-target between 200-1000ms after target onset.

When using signal detection to assess behavioural performance it is necessary to define participants' possible response patterns by way of hits, misses, correct rejections

and false alarms (Macmillan, Creelman, & Macmillan, 1990). How I have defined these elements in terms of motion-target *detection* are as follows. When a motion-target was presented during a trial and detected by the participant between 200-1000ms after motion-target onset this was classified as a hit (no matter the direction of the target, or the response). When a motion-target was presented but not detected by the participant this was classified as a miss. When there was no motion-target presented and no target detected this was classified as a correct rejection. And finally, when there was no motion-target presented, but a target was detected (i.e. a response outside the hit response window) this was classified as a false alarm.

The behavioural classifications for the *discrimination* distribution are as follows. Only trials that were counted as hits in the detection distribution were used in the discrimination analysis because only if they were detected in the first place, can they be discriminated. When a horizontal motion-target was presented during a trial and a horizontal target was discriminated by the participant this was classified as a hit. When a horizontal motion-target was presented but a vertical target was discriminated this was classified as a miss. When a vertical motion-target was presented, and a vertical target was discriminated this was classified as a correct rejection. And finally, when a vertical target was presented, but a horizontal target was discriminated this was classified as a false alarm.

An assumption had to be made for  $d'$  to be calculated in the detection distribution. As a function of the task set up, the closest measure to a correct rejection we can get is when a participant does not respond when no target is presented (i.e. the inverse of the false alarm rate). A truer classification of a correct rejection is like the one used in the discrimination distribution where it is associated with a response (vertical

presented, vertical discriminated, i.e., not horizontal). This assumption only becomes a problem if a participant makes multiple false alarms on one trial, which happened only once for one participant; a tolerable trade-off.

Calculation of *criterion* (*c*) was performed in excel as  $(- (\text{Hit rate} + \text{False Alarm rate})/2)$  as a measure of likeliness to respond. Negative values indicate liberal responding (a low criterion, more likely to say ‘Yes’ to seeing a motion-target), and positive values indicate conservative responding (a high criterion, more likely to say ‘No’).

## Results and Discussion

### Behavioural

#### Detection

Calculation of *d'* was performed in excel as the standardised difference between the signal present (i.e. hit rate), and the signal absent distribution (i.e. false alarm rate) as a measure of motion-target detection sensitivity. Mean detection sensitivity (*d'*) was calculated for each condition see Table 3. The hit and false alarm rates used for the calculations are presented in Table 4. A 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) x 2 (picture change: before, after) repeated measures ANOVA was performed to assess the effect of the emotional distractors on target detection before and after picture change. See Figure 7.

A main effect of picture change was found where participants were less accurate at detecting targets after than before picture change  $F(1, 30) = 10.52, p = .003, \eta_p^2 = .260$ ; and a significant main effect of valence  $F(1, 30) = 5.97, p = .021, \eta_p^2 = .166$ ,

where participants were less accurate at detecting targets during positive distractors than neutral distractors.

A two-way valence x image type interaction was observed  $F(1, 30) = 10.06, p = .003, \eta_p^2 = .251$ , qualified by a three-way, valence x image type x picture change interaction  $F(1, 30) = 9.71, p = .004, \eta_p^2 = .245$ . See Figure 7. The three-way interaction was explored by performing an additional 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) repeated measures ANOVA for image one, and another for image two. As expected, the results from image 1 (always a scramble), were no significant main effects of valence ( $p = 0.113$ ), image type ( $p = 0.616$ ), nor any valence x image type interaction ( $p = 0.170$ ). This result is in line with the predictions for Experiment 2 because all distractors on image 1 are scrambles, and thus no valence differences, or effects or image type would be expected.

The results from image 2 (33% intact, 66% scrambled), were a significant main effect of valence  $F(1, 30) = 5.64, p = .024, \eta_p^2 = .158$ , qualified by a valence x image type interaction  $F(1, 30) = 20.10, p < .001, \eta_p^2 = .401$ . Follow up paired samples t-tests revealed that there was a reduction in motion target detection during positive compared to neutral images when distractors were intact ( $p < .001$ ), but not when they were scrambled ( $p = .331$ ). This result supports the hypothesis as behavioural performance was hindered in the presence of positive compared to neutral distractors when images were intact, but not when scrambled; suggesting that it is the difference in valence between the two image sets that is driving the drop in behavioural performance when presented in the background of a foreground task.

Table 3

*Mean (SD) detection and discrimination  $d'$ s, RT in milliseconds, and mean (SD) FFT peak ( $\mu V^2$ ) per image condition before and after picture change in Experiment 2*

Condition	Detection ( $d'$ )	Discrimination ( $d'$ )	RT (ms)	FFT Peak ( $\mu V^2$ )
<b>Before Picture change</b>				
Positive Pre-Intact	3.36 (0.64)	2.97 (0.79)	585.36 (68.42)	4.09 (1.76)
Neutral Pre-Intact	3.55 (0.76)	3.05 (0.81)	588.48 (68.42)	4.33 (1.87)
Positive Scramble	3.48 (0.68)	3.10 (0.77)	583.98 (65.35)	4.08 (1.73)
Neutral Scramble	3.49 (0.84)	2.86 (0.68)	584.32 (66.03)	4.25 (1.87)
<b>After Picture change</b>				
Positive Intact	3.05 (0.73)	2.70 (0.87)	563.86 (54.65)	3.17 (1.17)
Neutral Intact	3.48 (0.72)	2.96 (0.74)	557.77 (61.99)	3.58 (1.45)
Positive Scramble	3.38 (0.72)	2.69 (0.76)	568.94 (55.59)	4.01 (1.76)
Neutral Scramble	3.30 (0.76)	2.71 (0.79)	564.95 (56.70)	4.26 (1.88)

Note: All images before picture change are scrambled images, the image condition is defined by the second picture presented on each trial.

Table 4

*Mean (SD) detection and discrimination Hit (%), False Alarm (FA) (%) rates, and*

*Criterion (c) per image condition before and after picture change in Experiment 2*

Condition	Detection Hit (%)	Detection FA (%)	Discrimination Hit (%)	Discrimination FA (%)	Criterion c
<b>Before Picture change</b>					
Positive Pre-Intact	0.91 (0.07)	0.04 (0.03)	0.92 (0.07)	0.11 (0.07)	-0.47 (0.04)
Neutral Pre-Intact	0.91 (0.09)	0.03 (0.02)	0.93 (0.06)	0.11 (0.08)	-0.47 (0.04)
Positive Scramble	0.89 (0.07)	0.03 (0.03)	0.91 (0.04)	0.12 (0.11)	-0.48 (0.03)
Neutral Scramble	0.92 (0.08)	0.04 (0.04)	0.91 (0.04)	0.13 (0.09)	-0.48 (0.03)
<b>After Picture change</b>					
Positive Intact	0.84 (0.11)	0.04 (0.03)	0.93 (0.06)	0.16 (0.09)	-0.44 (0.06)
Neutral Intact	0.90 (0.08)	0.03 (0.03)	0.94 (0.05)	0.13 (0.11)	-0.47 (0.04)
Positive Scramble	0.90 (0.08)	0.03 (0.03)	0.91 (0.06)	0.12 (0.09)	-0.47 (0.04)
Neutral Scramble	0.89 (0.08)	0.04 (0.04)	0.91 (0.06)	0.13 (0.07)	-0.47 (0.04)

Note: All images before picture change are scrambled images, the image condition is defined by the second picture presented on each trial. Criterion was calculated using the detection distribution hit and false alarm rates

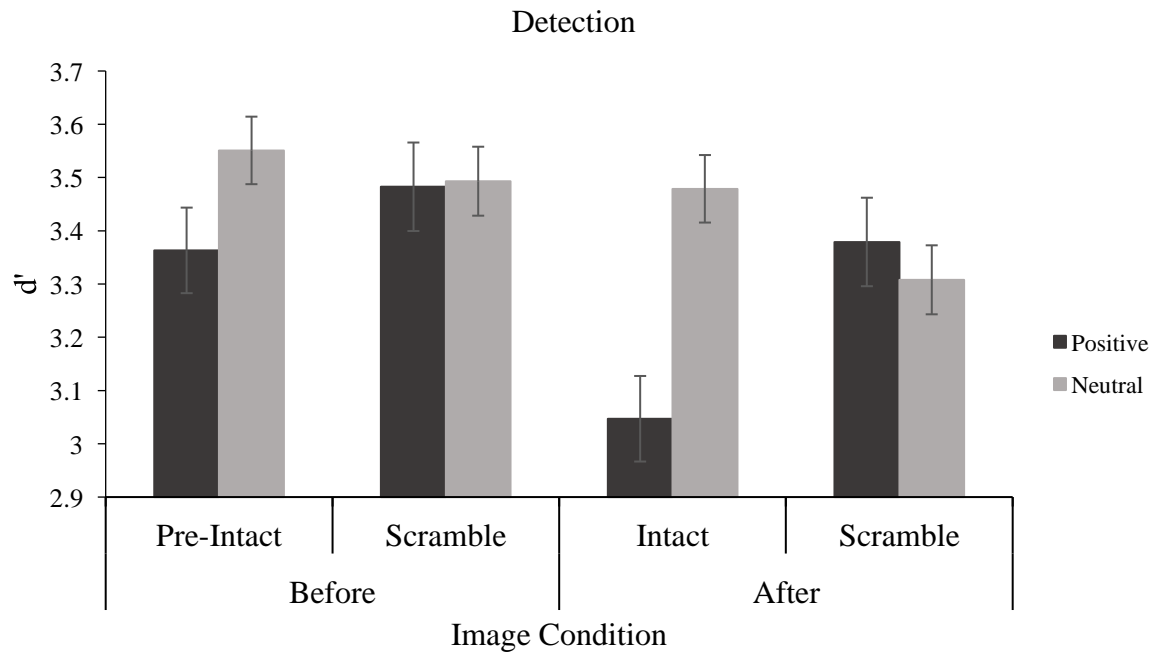


Figure 7: Shows the average detection ( $d'$ ) per image condition, before picture change on the left, and after picture change on the right. Error bars were calculated within subjects.

### Discrimination

Calculation of  $d'$  was performed in excel as the standardised difference between the hit rate, and the false alarm rate, as a measure of motion target discrimination sensitivity. Mean discrimination sensitivity ( $d'$ ) was calculated for each condition see Table 3. The hit and false alarm rates used for the calculations are presented in Table 4. A 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) x 2 (picture change: before, after) repeated measures ANOVA was performed to assess the effect of the emotional distractors on motion target discrimination before and after picture change. A main effect of picture change was found  $F(1, 30) = 8.33, p = .007, \eta_p^2 = .217$ , where participants were better at discriminating the direction of the motion targets before, than after picture change. The main effects for valence ( $p = .672$ ), and image type ( $p = .316$ ), were non-significant. See Figure 8.

The image type x valence interaction was marginal ( $p = .051$ ), no other significant two-way or three-way interactions were found (picture change x image type,  $p = .488$ ; valence x picture change,  $p = .082$ ; valence x picture change x image type,  $p = .791$ ). See Figure 8. The graphical representation of the results bears a similar resemblance to the trends in the detection data, but with more variability in responses and less clear valence differences between intact and scrambled distractors. The discrimination results do not support the hypothesis that emotional intact distractors will lead to worse performance, rather taken together with the detection results, they suggest that if a motion-target is detected, the direction can also be discriminated in the presence of task-irrelevant background emotional distractors. Additionally, they show that participants were generally very accurate in the task.

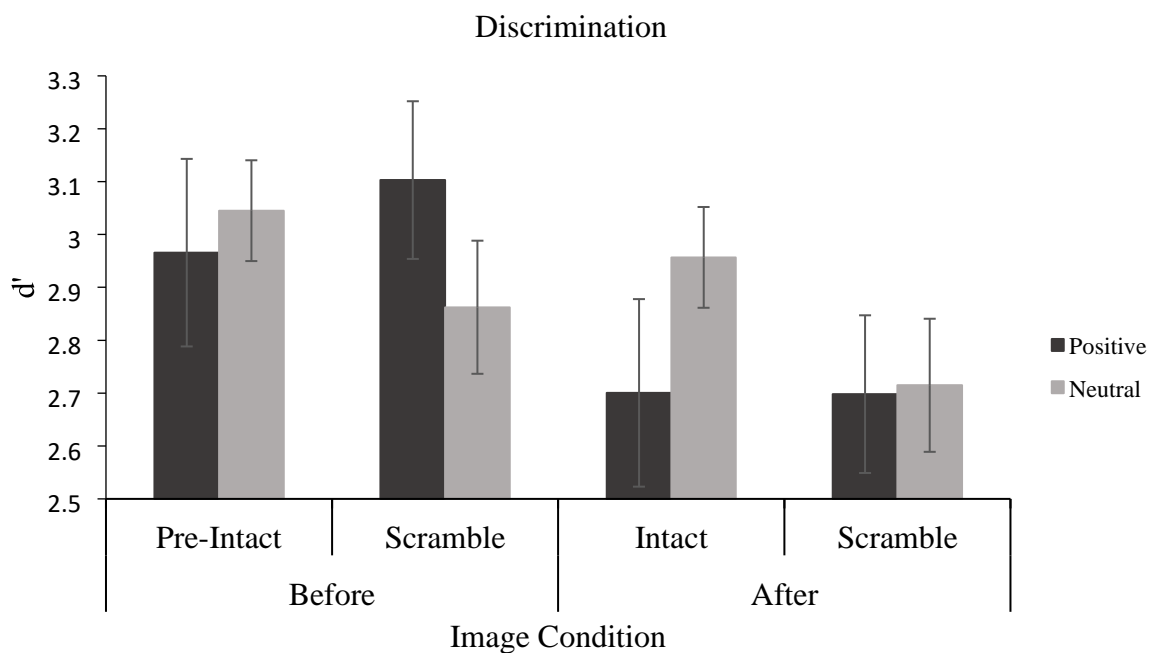


Figure 8: shows the average discrimination ( $d'$ ) per image condition, before picture change on the left, and after picture change on the right. Error bars were calculated within subjects.

### Criterion

Calculation of criterion was performed in excel as  $(- (\text{Hit rate} + \text{False Alarm rate})/2)$  from the detection distribution. Mean criterion thresholds ( $c$ ) were calculated for each condition see Table 4. A 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) x 2 (picture change: before, after) repeated measures ANOVA was performed to assess the effect of the emotional distractors on participants' likeliness to respond before and after picture change. See Figure 9.

All main effects were significant: valence  $F(1, 30) = 6.37, p = .017, \eta_p^2 = .175$ , image type  $F(1, 30) = 4.60, p = .040, \eta_p^2 = .133$ , and picture change  $F(1, 30) = 14.54, p < .001, \eta_p^2 = .326$ . These were qualified by two significant two-way interactions, valence x image type  $F(1, 30) = 4.95, p = .034, \eta_p^2 = .142$ , and valence x picture change  $F(1, 30) = 4.88, p = .035, \eta_p^2 = .140$ ; and a significant three-way valence x image type x picture change interaction  $F(1, 30) = 8.49, p = .007, \eta_p^2 = .221$ .

The three-way interaction was explored by performing two additional 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) repeated measures ANOVAs, one before picture change, and another after picture change. Before picture change (image 1 = scramble), there were no significant main effects of valence ( $p = 0.965$ ), image type ( $p = 0.439$ ), nor a significant valence x image type interaction ( $p = 0.886$ ). This result is in line with the predictions for Experiment 2 because all distractors on image 1 are scrambles, and thus no valence differences, or effects of image type would be expected.

After picture change (image 2 = 33% intact, 66% scrambled), there were significant main effects of valence  $F(1, 30) = 6.46, p = .016, \eta_p^2 = .177$ , and image type  $F(1, 30) = 4.59, p = .040, \eta_p^2 = .133$ , qualified by a valence x image type interaction  $F(1,$

30) = 9.58,  $p = .004$ ,  $\eta_p^2 = .242$ . Follow up paired samples t-tests revealed that criterion threshold increased during positive compared to neutral distractors when images were intact ( $p = .004$ ), but not when they were scrambled ( $p = .958$ ).

Overall, participants demonstrated a liberal response pattern (i.e. a low criterion to say ‘Yes’ to a motion target). Their response criterion was increased in the presence of positive intact distractors demonstrating a more conservative response pattern after picture change when distractors were emotional. This result supports the hypothesis that emotional images are more distracting than neutral images because participants were less likely to respond in the presence of positive compared to neutral intact distractors; an effect not present for the scrambled distractors. On the basis of Experiment 1 it could not be determined whether emotional images disrupt the ability to discriminate between coherent and incoherent motion or cause a behavioural “freezing” response. This is because emotional images affected both the hit rate and the number of false alarms. Experiment 2 demonstrates that emotional images disrupt both perceptual sensitivity ( $d'$ ) and behavioural responses (c).

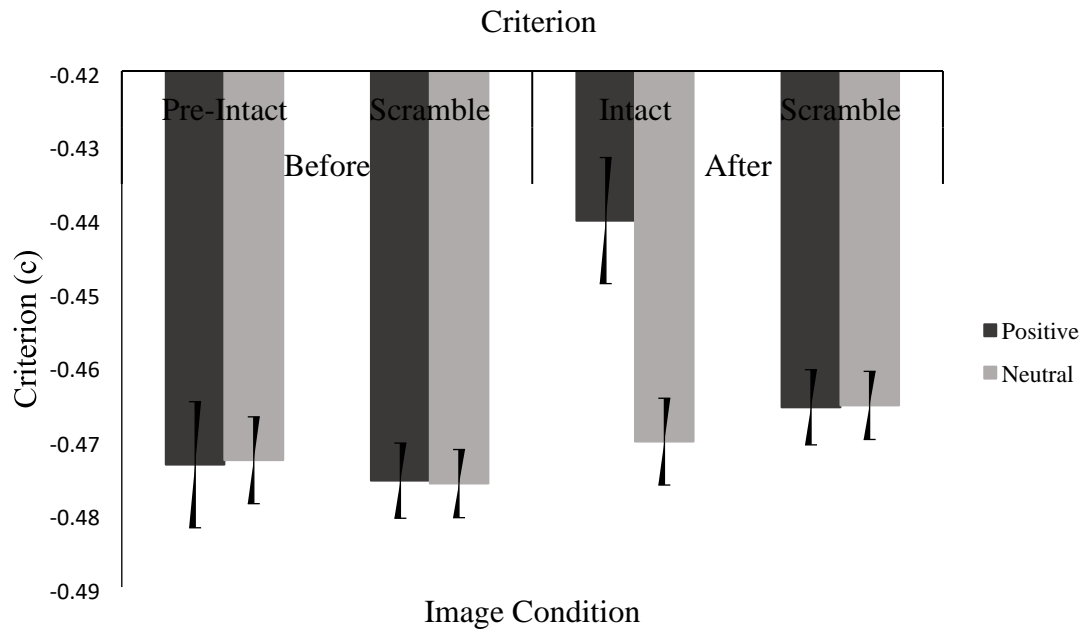


Figure 9: shows the average criterion (c) per image condition, before picture change on the left, and after picture change on the right. Error bars were calculated within subjects.

## RT

Mean response times (RTs) were calculated for each condition see Table 3. A hit was defined as any response made between 200-1000ms after motion target onset, as such, RT data was collected within this response window for detected targets. A 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) x 2 (picture change: before, after) repeated measures ANOVA was performed to assess the effect of the emotional distractors on RT before and after picture change.

There was a main effect of picture change  $F(1, 61) = 25.80, p < .001, \eta_p^2 = .297$ , qualified by a two-way image type x picture change interaction  $F(1, 61) = 5.08, p = .028, \eta_p^2 = .077$ . Post hoc paired samples t-tests demonstrated that both intact ( $p < .001$ ) and scrambled ( $p < .001$ ) images had faster RTs after picture change. The significant

image type x picture change interaction shows that the reduction in RT was bigger for intact images than scrambled images. There were no significant main effects of valence ( $p = .400$ ), or image type ( $p = .510$ ), and no significant interactions with valence found (valence x type,  $p = .941$ ; valence x target,  $p = .103$ ; valence x target x type,  $p = .643$ ). See Figure 10.

It is suggested that the reduction in RT after picture change might be due to the constraints of the task, rather than participants meaningfully becoming quicker. Participants' task is to maintain attention during image presentation, so when presented their first motion-target, they are just coming into a new trial, out of the inter-trial interval. By the time the participant encounters the motion-target after picture change, they are already in a state of vigilance, so will be quicker at the task.

The image type x picture change interaction was explored by doing two 2 (image type: intact scrambled) x 2 (picture change: before, after) repeated measures ANOVAs, for positive and neutral distractors separately. For both positive and neutral distractors there was no main effects of image type (positive:  $p = .576$ , neutral:  $p = .669$ ), nor any significant image type x picture change interactions (positive:  $p = .318$ , neutral:  $p = .095$ ). Both positive and neutral distractors had main effects of picture change (positive:  $p < .001$ , neutral:  $p < .001$ ), demonstrating that for both valences RTs were reduced after picture change for both intact and scrambled images.

The results from the RT analysis do not show support for the hypothesis that emotional images are more distracting than neutral images when presented in the background of a foreground task. There were none of the predicted significant effects of image type or valence. It could be the case that the constraints of the task make RT not a useful behavioural measure in the current paradigm.

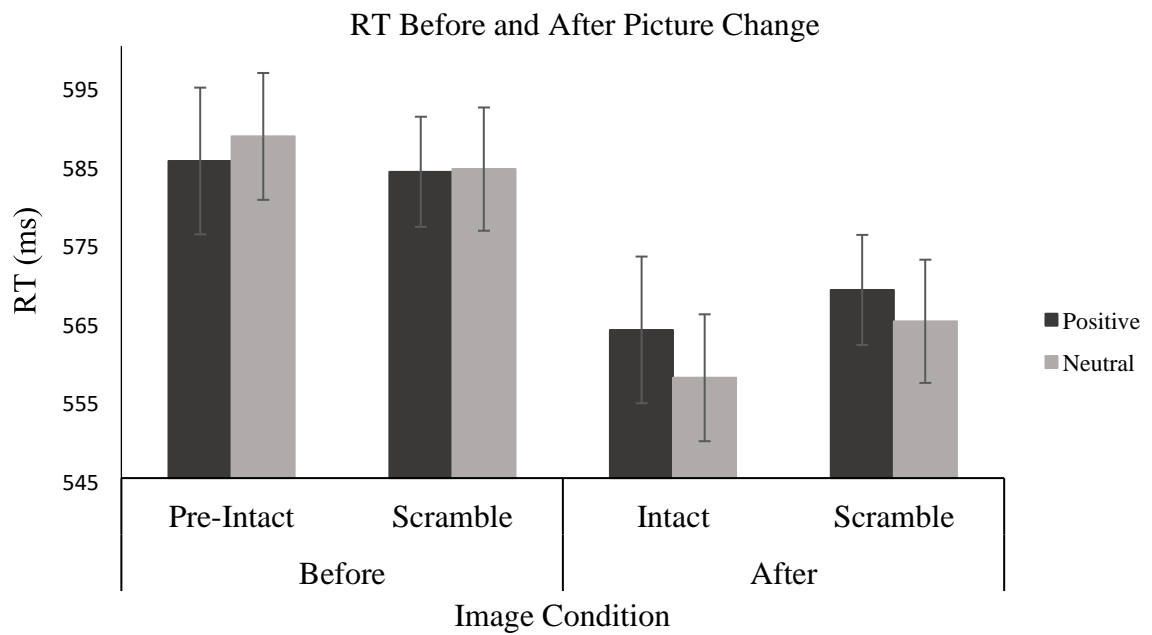


Figure 10: shows the average RT (ms) per image condition, before picture change on the left, and after picture change on the right. Error bars were calculated within subjects

## SSVEP

### Peak FFT

Mean peak FFTs were calculated for each condition see Table 3. A single peak was calculated per participant at electrode site OZ between the frequencies 6.5 - 8.5Hz to capture the highest peak value (power:  $\mu V^2$ ) of the SSVEP signal at the stimulation frequency of 7.5Hz. A 2 (valence: positive, neutral) x 2 (image type: intact, scrambled) x 2 (picture change: before, after) repeated measures ANOVA was performed to assess the effect of the emotional distractors on peak FFT before and after picture change.

A main effect of picture change was found  $F(1, 30) = 52.70, p < .001, \eta_p^2 = .637$ , demonstrating that FFT peaks were reduced after the transition to the second image. Main effects of valence  $F(1, 30) = 39.65, p < .001, \eta_p^2 = .569$ , and image type  $F(1, 30) = 44.55, p < .001, \eta_p^2 = .598$ , were also found, indicating that in the presence of

positive, and intact distractors, lower FFT peaks were found than for neutral or scrambled distractors. All two-way interactions were significant, the three-way interaction was not significant ( $p = .328$ ), see Figure 11.

A valence x image type interaction  $F(1, 30) = 5.72, p = .023, \eta_p^2 = .160$ , was found where post-hoc paired t-tests revealed that SSVEP peaks were reduced for positive compared to neutral distractors when intact ( $p < .001$ ), and when scrambled ( $p < .001$ ). The significant interaction shows that the difference between positive and neutral pictures was bigger when the images are intact, than when they are scrambled. In support with the hypothesis, the valence x image type interaction suggests that task-irrelevant high arousal distractors capture more attentional resources than neutral distractors when presented in the background of a foreground task. Replicating the findings of Experiment 1, a significant difference in SSVEP peak was found between positive and neutral scrambled distractors; suggesting that there are features of the stimulus set (e.g. colour) contributing to the reductions in SSVEP amplitude. The valence x image type interaction demonstrates that the valence difference was greater when the images were intact than when they were scrambled; demonstrating that only some of the valence effect found can be attributed to features of the stimulus sets, so the remaining difference can be attributed to the valence difference between the image sets.

A valence x picture change interaction  $F(1, 30) = 48.38, p < .001, \eta_p^2 = .617$ , was found where post-hoc paired t-tests showed that SSVEP peaks were reduced for positive compared to neutral distractors, both before ( $p < .001$ ), and after ( $p < .001$ ) picture change, but the difference between positive and neutral images was larger after picture change. Supporting the hypothesis, when positive intact images were used as distractors there was a greater reduction in SSVEP peak than for neutral intact images,

suggesting that high arousal images capture more attentional resources than low arousal images when presented in the background of a foreground task. The valence x picture change interaction demonstrates that the difference between positive and neutral SSVEP peaks was stronger after picture change than before picture change; this is as expected because all images before picture change were scrambles, and only after picture change could images appear intact.

A image type x picture change interaction  $F(1, 30) = 9.13, p = .005, \eta_p^2 = .233$ , was also found where post-hoc paired t-tests demonstrated that there was no difference between intact (pre-intact) and scrambled distractors before picture change ( $p = .125$ ), but after picture change ( $p < .001$ ), intact images had significantly lower SSVEP peaks. This finding is in line with the current predictions as no intact images were shown before picture change, so differences between intact and scrambled distractors would only be predicted after picture change. The image type x picture change interaction demonstrates that attentional capture happens for any task-irrelevant intact image when presented behind a foreground task.

Overall, replicating Experiment 1, the findings from the SSVEP analysis suggest support for the hypothesis that task-irrelevant emotional information captures more attention than neutral information when presented in the same location as a foreground task. Again, there also appears to be some attentional capture by the positive scrambles, which may be the result of trial-based learning.

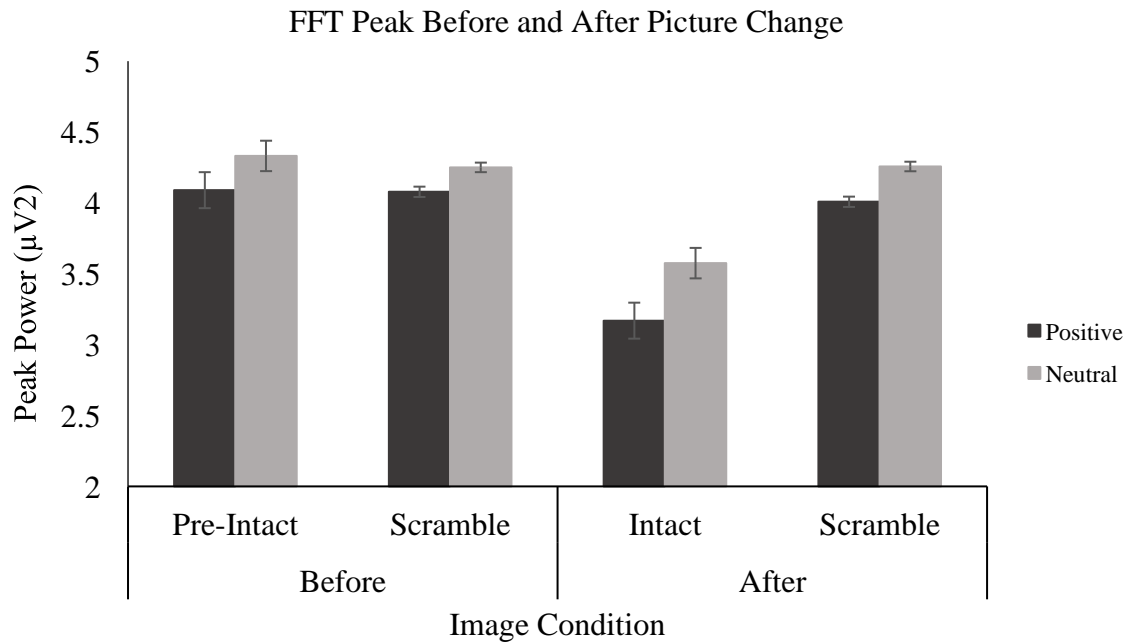


Figure 11: shows the average FFT peak ( $\mu V^2$ ) per image condition, before picture change on the left, and after picture change on the right. Error bars were calculated within subjects.

### General Discussion

Emotional distraction has been typically studied using spatially separated tasks and distractors; the current thesis examines emotional distraction using a superimposed design. Spatially separated designs allow for the assessment of attentional interactions across space, but superimposed designs allow the investigation of attentional competition between task irrelevant emotional stimuli and a foreground task, which requires feature or object-based attention to distinguish elements in common retinotopic space. Due to the differing demands on visual attention it is possible that the presence of task-irrelevant emotional stimuli in a superimposed design will have different effects than in a spatially separated design, where attentional filtering could be aided by spatial attention.

Experiment 1 aimed to replicate Hindi Attar and colleagues (2010) who have used SSVEPs to examine attentional competition between a foreground dot-motion task,

and task-irrelevant emotional background distractors. For both experiments, it was predicted that SSVEP amplitudes will be reduced in the presence of any intact image compared to a scramble. More importantly, if emotional stimuli are more distracting than neutral stimuli, then when the images are intact the drop in SSVEP amplitude will be greater for positive images than for neutral images. In both Experiments 1 and 2 the results from the SSVEP peak analysis support this prediction, demonstrated by drops in SSVEP amplitude after picture change and especially in the presence of positive intact distractors.

However, the results were not entirely consistent with predictions as valence differences were found before picture change, when all images were scrambles. Participants should not be able to tell the difference between positive and neutral scrambled images, so a valence effect was not predicted for the scrambled distractors. This finding suggests that there are some visual elements of the distractors (e.g. colour, spectral energy) contributing to the drops in SSVEP amplitudes seen for positive images. The significant valence x image type interactions found during analysis demonstrates that although there were small valences differences in the SSVEP amplitudes to the scrambles, the differences were larger between positive and neutral when distractors were intact. Finding significant differences in scrambled distractor conditions reinforces their value as a control condition to control for low level properties of the stimulus set which may influence SSVEP amplitudes. Overall, the current experiments have provided a valuable starting point from which to develop future research using SSVEPs to examine emotional distraction.

It is unclear the reason why SSVEP peaks were different between positive and neutral scrambled distractors. Efforts were made to match the stimulus sets in terms of

visual complexity and they were all run through the SHINE Toolbox together to equate them for luminance. Bekhtereva and Müller, (2017) demonstrated the influence of colour on SSVEP amplitudes during emotional visual processing where increased amplitudes were observed for colour images, and valence differences were increased with colour images. It may be the case that, because the neutral stimulus set is more varied in terms of colour than the positive set, the SSVEP to positive images was generally smaller.

Future studies examining emotional distraction using SSVEPs could investigate the extent to which participants can distinguish between positive and neutrally valenced scrambled images. It could be the case that initially, the participants cannot distinguish the image sets, but after repeated trials begin to develop an expectation of valence. If participants can develop expectations of the intact images upcoming in the trial procedure this will have implications for future experimental design using this paradigm who may want to avoid any valence expectation. Alternatively, experimenters could use this learnt expectation to investigate what happens when these expectations are disrupted. It would additionally be interesting to see if the valence effect in the scrambles translates to self-report; are participants able to categorically distinguish between positive and neutral scrambled images in a way that aligns with SSVEP peak recordings? Or does this valence effect happen outside of conscious awareness?

Behaviourally, it was predicted that performance in the dot-motion task would drop in the presence of any intact image compared to scrambles, with a further reduction in performance when comparing positive intact to neutral intact distractors. The results of Experiments 1 and 2 support this prediction, accuracy (Experiment 1), and detection sensitivity (Experiment 2) were reduced for intact positive distractors compared to

neutral distractors. The results from Experiment 2 demonstrate that while detection ability is reduced in the presence of emotional background distractors, discrimination ability is unaffected. Additionally, participants' likeliness to respond is reduced in the presence of positive intact compared to neutral intact distractors.

Together the behavioural results suggest evidence for emotional distraction during the presentation of positive intact distractors. There was no evidence of a valence effect for the scrambled image conditions which suggests that the valence effect found in the SSVEPs during scrambled distractor presentation reflects a difference in neural processing rather than a measure of emotional distraction. The current thesis demonstrates the importance of a sensitive behavioural measure when investigating emotional distraction. If behavioural distraction is not demonstrated between different image conditions, then differences in neural signals require a different interpretation.

In comparison to Hindi Attar et al., (2010), the current study provided a partial replication of their results. Both studies found reductions in SSVEP amplitudes and behavioural performance after transitioning to a positive intact distractor, but the current study found significant valence effects in the scrambles, inconsistent with Hindi Attar and colleagues. Significant methodological differences between Hindi Attar et al., (2010) and the current experiments may have contributed to the differences in results. The frequency of intact distractors used differed; on 50% of trials for Hindi Attar and colleagues, and on 33% of trials in the current experiments. If the valence difference found in the current experiment for scrambled distractors has developed from trial-based learning it may have appeared here and not previously because of the increased presentation proportion of scrambled images, thus more exposure to the scrambles may have led to a learned ability to distinguish between positive and neutral scrambles.

Another way the current study differs from Hindi Attar (2010) is in the proportion of motion-coherence chosen for the dot-motion task. Hindi attar used a motion-coherence proportion of 35%, meaning that during motion-targets, 35% of the dots in the stimulus array moved in the same direction, in the current experiments the motion-coherence proportion chosen was 50%. This percentage was chosen for the current experiments because after some behavioural piloting, participants felt like they were just guessing at 35% and the ambiguity of the task was making them uncomfortable, so the motion coherence was increased to 50%. Participants still reported that the task was challenging. Hindi Attar and Müller, (2012) have previously demonstrated that valence effects in the dot-motion task were unaffected by perceptual load, so the increase in motion coherence was a justified modification for the comfort of participants. In support of the literature on negative priming, participants in the current experiment demonstrated the ability to select and ignore stimuli based on depth. The results from both the detection and discrimination performance of participants in Experiment 2 demonstrate that they were generally quite accurate at the task.

## **Summary and Conclusion**

The aim of the current thesis was to replicate the experimental design used by Hindi Attar and colleagues (2010) to investigate competitive emotion-attention interactions between a foreground task, and task-irrelevant, emotional background distractors. Steady-State-Visual-Evoked-Potentials (SSVEPs) were used as a measure of attentional resource allocation to the flickering foreground dot-motion task.

In Experiment 1 participants' task was to detect short incidents of coherent motion in an otherwise randomly moving dot array, while distractors were shown in the background. At the start of a trial the background distractors were always scrambled

images, but then transition into either another scramble of the same original image (66% of trials), or an intact version of the image (33% of trials). Participants were found to have reduced SSVEP amplitudes in the presence of positive, intact distractors when compared to neutral intact distractors. Additionally, behavioural performance in the dot-motion task was also reduced in the presence of positive intact distractors.

Unexpectedly, there were also valence differences in SSVEP amplitudes for the scrambled images which suggests that some properties of the stimulus set (e.g. colour) are contributing to the drop in SSVEP amplitude. Alternatively, there may be trial-based learning occurring for the participants as a positive scramble will be shown before each intact image, participants could come to distinguish the colour palettes between the positive and neutral stimulus sets.

In Experiment 2 the same trial procedure was implemented with a change in the behavioural task. Participants' task in Experiment 2 was to discriminate between horizontal and vertical targets by a key press. SSVEP results from Experiment 2 replicated the results from Experiment 1 with significant effects of valence found, where the presentation of positive distractors resulted in reduced SSVEP peaks. The significant valence effect found in the scrambles in Experiment 1 was again found in Experiment 2; importantly in both experiments there was the presence of a significant valence x image type interaction where the valence differences observed for scrambled distractors were stronger for intact distractors. Behavioural performance in Experiment 2 demonstrated that while motion-target detection ability is impaired by the presence of task-irrelevant emotional distractors, discrimination ability is unaffected. Additionally, participants showed a response bias where they were less likely to respond at all, in the presence of positive intact background distractors. The findings of the current thesis show support for the hypothesis that emotional information is more distracting than neutral

information; this effect can be seen in both the neural and behavioural measures of the task.

The findings from this thesis contribute to the understanding of attentional competition between a primary foreground task and irrelevant emotional background distractors. The SSVEP paradigm developed here will serve as the starting point to examine emotion-attention interactions and feature-based attention in our own lab. In our complex visual environment, the current results suggest that perceivers can both ignore and select objects based on depth, but that perceptual biases toward task-irrelevant emotional stimuli are still able to influence the allocation of attention. Akin to results from spatially separated designs, emotional information in a superimposed design draws attentional resources away from the current task towards the irrelevant distractor.

The employment of SSVEP techniques allows for the assessment of complex 3D scenes which better mimics the visual selection challenges we are faced with in everyday life. In this way lab-based paradigms can get closer to externally valid emotional distraction that can be easily translated into practical applications in mental health therapies, education, and traffic safety policies. In the current paradigm it is yet to be seen if participants can discriminate between positive and neutrally valenced scrambles. It may be the case that future iterations of this experiment may want to avoid perceptual learning of this type, or alternatively capitalise on the differential entrainment of the SSVEP signal between positive and neutral scrambles and see if it relates to self-reported valence discriminations. The results from the current thesis demonstrate the value of employing SSVEP in the future investigation of superimposed emotional distraction.

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## Appendix A

List of the IAPS images used with their corresponding valence category, valence rating, and arousal rating. The whole image set was used in Experiment 1, while everything but the anticipation trials was used in Experiment 2.

IAPS Image Number	Valence condition	Valence rating	Arousal rating
2026	Neutral	4.82	3.40
2191	Neutral	5.30	3.61
2272	Neutral	4.50	3.74
2273	Neutral	5.41	3.52
2308	Neutral	5.22	3.82
2309	Neutral	4.89	4.33
2377	Neutral	5.19	3.50
2383	Neutral	4.72	3.41
2390	Neutral	5.40	3.57
2393	Neutral	4.87	2.93
2396	Neutral	4.91	3.34
2400	Neutral	4.21	4.20
2410	Neutral	4.62	4.13
2411	Neutral	5.07	2.86
2480	Neutral	4.77	2.66
2575	Neutral	5.46	4.16
2595	Neutral	4.88	3.71
27451	Neutral	5.31	3.26
2749	Neutral	5.04	3.76

2870	Neutral	5.31	3.01
7493	Neutral	5.35	3.39
7497	Neutral	5.19	4.97
7506	Neutral	5.34	4.25
7550	Neutral	5.27	3.95
8010	Neutral	4.38	4.12
8312	Neutral	5.37	3.32
9210	Neutral	4.53	3.08
4232	Positive	5.95	6.28
4290	Positive	7.61	7.20
4311	Positive	6.66	6.67
4490	Positive	6.27	6.06
4530	Positive	6.19	5.31
4604	Positive	5.98	6.09
4611	Positive	6.62	6.04
4647	Positive	5.89	6.21
4650	Positive	6.96	5.67
4651	Positive	6.32	6.34
4658	Positive	6.62	6.47
4659	Positive	6.87	6.93
4664	Positive	6.61	6.72
4666	Positive	6.24	6.10
4668	Positive	6.67	7.13
4669	Positive	5.97	6.11

4670	Positive	6.99	6.74
4672	Positive	6.00	6.29
4676	Positive	6.81	6.07
4680	Positive	7.25	6.02
4690	Positive	6.83	6.06
4692	Positive	5.87	6.39
4693	Positive	6.16	6.57
4694	Positive	6.69	6.42
4695	Positive	6.84	6.61
4697	Positive	6.22	6.62
4698	Positive	6.50	6.72
4800	Positive	6.44	7.07
2357	Neutral Anticipation trial	5.41	3.33
7033	Neutral Anticipation trial	5.40	3.99
7036	Neutral Anticipation trial	4.88	3.32
7130	Neutral Anticipation trial	4.77	3.35
7512	Neutral Anticipation trial	5.38	3.72
7513	Neutral Anticipation trial	5.45	3.72
7560	Neutral Anticipation trial	4.47	5.24
4220	Positive Anticipation trial	8.02	7.17
4520	Positive Anticipation trial	6.16	4.80
4607	Positive Anticipation trial	7.03	6.34
4645	Positive Anticipation trial	6.73	5.69
4653	Positive Anticipation trial	6.56	5.83

4677	Positive Anticipation trial	6.58	6.19
4687	Positive Anticipation trial	6.87	6.51