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Effect of Task-Irrelevant Emotional Faces on Attention to a Letter Search Task at High and Low Perceptual Loads

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EFFECT OF TASK-IRRELEVANT EMOTIONAL FACES ON ATTENTION TO A LETTER SEARCH TASK AT HIGH AND LOW PERCEPTUAL LOADS

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Abstract

The attentional processing of emotional faces has interested researchers over the past thirty years. However, differing methodology has led to inconsistent findings. It has been suggested that using emotional faces as task-irrelevant distractors and varying perceptual load of the primary task can create an experimental framework that will allow attentional capture by emotional face processing to be better identified and differentiated from other processes. Furthermore, the effects of time on-task on attentional processing of emotional faces are currently not well understood, in part because traditional statistical analyses, such as the ANOVA, are insufficient for finding longitudinal trends in the data. In the present study, 103 undergraduate students completed a computerized letter search task identifying one of two target letters (X or Z) from a circular arrangement of different letters (high load) or dots (low load). In 20% of trials, an emotional (happy or angry) or neutral distractor face would appear at the center of the screen. Attention was measured by the time it took for participants to identify the target letter (RT). Multilevel modeling (MLM) was used to investigate how attentional capture by distractor faces during a letter search task was affected by the emotionality of the distractor face, perceptual load, and time on-task. Results showed that emotional faces captured attention more effectively than neutral faces under low load conditions, but not at high load. Additionally, at low load, fatigue effects were found to increase the distractibility of emotional faces at low load and decrease distractibility at high load. These findings support existing theories regarding the evolutionary significance of emotional faces.

Effect of Task-Irrelevant Emotional Faces on Attention to a Letter Search Task at High and Low Perceptual Loads

Almost all activities require the use of attention. Individuals must constantly guide their attention towards the task they wish to accomplish while also directing attention away from distractions. The amount of attentional control required to maintain focus on a given task is based on a number of factors, one of which is what sort of distractor stimulus is present. A distractor that is often encountered in social settings is emotional faces. Given the role of emotion as a fundamental evolutionary adaptation, it has been suggested that the perception of emotional faces occurs through a unique process in the human brain (Öhman, 2009). As a result, emotional facial expressions are thought to attract more attention than neutral stimuli (Van Dillen & Derks, 2012).

While evolutionary theory suggests that angry faces attract focal attention more than faces displaying other emotions, scholars have found conflicting evidence. Many studies have confirmed this theory and determined that faces expressing anger seem to attract focal attention more than faces expressing positive or neutral emotions (Eastwood et al., 2001; Fenske & Eastwood, 2003; Fox et al., 2000; Hansen & Hansen, 1988; Horstmann & Bauland, 2006; Öhman et al., 2001). In contrast, other studies have found evidence of attentional biases towards happy faces as compared to angry ones (Becker et al., 2011; Bucher & Voss, 2018; Öhman et al., 2010). These seemingly inconsistent findings may be explained by considering the ongoing attentional and cognitive resource demands during facial processing.

Perceptual load theory posits that the brain has limited cognitive resources available for attention at any time. If only some of these resources are being directed toward paying attention to a given task, the remaining resources will be automatically reallocated toward perceiving any other available stimuli (Lavie, 1995; Lavie et al., 2004; Lavie & Tsal, 1994). Thus, if a person is presented with a low perceptual load task (the task displays a low visual complexity), their attention has greater potential to be captured by task-irrelevant stimuli. If, however, a person is presented with a task imposing a high perceptual load (the task displays a high visual complexity), then substantially more of their cognitive resources will be directed toward the task and it is expected that the person will effectively ignore any task-irrelevant stimuli (Lavie, 2005). Regarding the literature concerning emotional faces, it is possible that different studies used different load conditions, which may have led to inconsistent findings (Lavie, 1995). Further, it is expected that varying perceptual load within a study could provide valuable insight into the cognitive processes involved in attending to emotional faces.

The availability of cognitive resources is also dependent on time on-task. Participants expend cognitive resources as they progress through attentional tasks, which leads to cognitive fatigue (Ackerman, 2011). Cognitive fatigue has different effects on attention at high and low loads. At low load, fatigue can improve the ability of distractors to capture attention away from a primary task, while the opposite is true at high load (Csathó et al., 2012). Although the effects of time on-task on reaction time performance have been investigated in the past, there is no current research available that describes the effect of time on-task on attentional capture by emotional distractor faces at high and low loads. Multilevel modeling (MLM) can be used to analyze trial to trial differences in reaction times, which can provide information about changes in attention over time.

The current body of knowledge regarding attentional biases towards emotional faces is inconsistent and incomplete. The present study aims to contribute to the existing literature by using MLM to investigate how attentional capture by distractor faces during a letter search task is affected by 1) the emotion of the distractor face (emotional vs neutral), 2) perceptual load, and 3) time on-task. Previous research on attentional bias towards emotional faces, perceptual load theory, and how time on-task affects performance on attentional tasks will be reviewed in order to provide more background on these topics.

Literature Review

Attentional Bias Towards Emotional Faces

Facial expressions are an essential component of human communication as they facilitate social interactions and can convey information that is critical to survival. It is suspected that due to their evolutionary significance, emotional faces may be effective at capturing attention away from a primary task (Öhman, 2009). It is unclear, however, whether certain emotions are more effective at directing attention than others. This question has intrigued researchers for the past three decades and a clear answer has yet to be uncovered.

The first major work done on the subject was Hansen and Hansen's (1988) face-in-the-crowd (FiC) study. Participants were presented with a 3x3 matrix of pictures of faces. In certain trials, all the faces in the matrix portrayed the same emotion (which could be happy, angry, or neutral), while other trials contained a single discrepant face (which could be happy or angry). On each trial, participants were instructed to verbally indicate as quickly and accurately as possible whether there was a discrepant face presented. In this study, angry faces were identified more quickly and accurately than either happy or neutral faces. Hansen and Hansen's finding, often referred to as the Anger Superiority Effect (ASE), was replicated by numerous subsequent researchers using variations of the FiC paradigm (Eastwood et al., 2001; Fox et al., 2000; Öhman et al., 2001). Another well-known method used to assess attentional bias to emotional faces, flanker tasks, also confirmed this ASE (Fenske & Eastwood, 2003; Horstmann & Bauland, 2006). In the flanker task, several faces (typically three) are presented evenly spaced apart in a horizontal line. The participants are instructed to identify, as quickly and accurately as possible, the emotion of the central face (which could be happy or angry) by pressing one of two computer keys, while ignoring the two “flanking” faces (which could be happy, angry, or neutral; Fenske & Eastwood, 2003).

As the ASE became more widely researched, it was found that the stimuli used in many FiC studies presented unintended visual cues, such as light and dark patches that appear in images when photographs of faces are converted to schematic faces. These “artifacts” were shown to have biased participants to identify angry faces more quickly than other faces (Purcell et al., 1996). Studies that removed the artifacts, or used different stimuli altogether, discovered that happy faces were identified more quickly and accurately than either angry or neutral faces, lending support for a Happiness Superiority Effect (HSE) (for a review of adjusted FiC studies, see Becker et al., 2011; Bucher & Voss, 2018; Öhman, et al., 2010).

More recent research (Glickman & Lamy, 2018; Tannert & Rothermund, 2018) has brought attention to other inherent issues in the FiC paradigm and the flanker task. In both of these paradigms, the participants are instructed to identify a “target” emotion as quickly and accurately as possible while ignoring the “distractors”, or non-target faces. In the FiC paradigm, the target emotion is the discrepant emotion, and in the flanker task it is the emotion displayed by the central face. However, because both the target and the distractor stimuli consist of emotional faces, and it is necessary to process all the faces presented in order to accurately identify the target, both the target and the non-targets are considered task-relevant (Glickman & Lamy, 2018). Thus, the experimental task makes it such that participants are effectively unable to ignore distractor faces.

Unlike the studies using task-relevant distractors described above, which find either an ASE or an HSE, studies in which the distractors are task-irrelevant do not find these effects (Glickman & Lamy, 2018; Lichtenstein-Vidne et al., 2012; Tannert & Rothermund, 2018). For example, one study performed two variations of the flanker task: one in which participants were asked to indicate whether a neutrally-valenced image appeared above or below a central point while ignoring positive or negative flanking images, and one in which the central image had either a positive or negative valence (Lichtenstein-Vidne et al., 2012). When the central image was neutral (making valence a task-irrelevant factor), participants were not significantly distracted by the flankers. In contrast, tasks in which the central image was either positively or negatively valenced showed greater attentional capture by the flankers, suggesting that non-target stimuli capture attention more effectively when they share a feature, such as emotionality, with the target stimulus. Other studies have similarly adapted the flanker and FiC paradigms to compare task-relevant and task-irrelevant emotional face distractors. These studies found that emotional face distractors only capture attention when emotion is a task-relevant factor, suggesting that earlier research supporting either the ASE or HSE could be attributed to task-relevance rather than an attentional bias towards emotional faces (Glickman & Lamy, 2018; Tannert & Rothermund, 2018).

Although the aforementioned studies found that task-irrelevant stimuli do not capture attention, there is some evidence suggesting that task-irrelevant stimuli may capture attention if enough cognitive resources are available to process them (Lavie, 2005). The allocation of cognitive resources can be understood using perceptual load theory. Perceptual load theory states that visually complex tasks, referred to as high perceptual load tasks, engage all available cognitive resources and thus do not allow for attentional capture by task-irrelevant stimuli

(Lavie, 1995; Lavie et al., 2004; Lavie & Tsal, 1994). Low perceptual load tasks, on the other hand, are less visually complex and do not require the same amount of processing that high perceptual load tasks require. Since low load tasks do not use all available cognitive resources, they cause an automatic and involuntary reallocation of unused resources towards processing task-irrelevant stimuli. From this perspective, to determine the potential of different distractors in capturing attention, it is necessary to use tasks that impose a low perceptual load and compare the results to the same task at a high load. By varying the perceptual load of attentional tasks, some researchers have found that task-irrelevant distractors can, in fact, direct attention away from a task, but only if the primary task presents a low perceptual load to the participant (Forster & Lavie, 2008; Huang et al., 2011; Lavie, 2005).

The work performed by Glickman and Lamy (2018), Lichtenstein-Vidne and colleagues (2012), and Tannert and Rothermund (2018) found no significant attentional capture by task-irrelevant emotional stimuli, but these studies did not consider perceptual load in the interpretations of their results. It is possible that these studies were conducted using exclusively high perceptual load conditions, which would mean that their findings may be attributed to insufficient cognitive resources rather than to a lack of attentional capture by task-irrelevant emotional stimuli. Prior to describing the effect of perceptual load on attentional processing of task-irrelevant emotional faces, the perceptual load theory will be described in more detail.

Perceptual Load Theory

Perceptual load theory is a combination of two widely used, yet contradictory, theories of attention: the early and the late selection models. The early selection model (known early on as "Filter Theory") proposed that when asked to direct attention towards a target stimulus, the individual would construct precursory cognitive "filters" aimed at identifying the target stimulus and ignoring task-irrelevant stimuli (Broadbent, 1958). While the early selection model paints the brain as efficient and adequately explains the increase in reaction time when individuals are asked to shift their attention midway through an activity, it fails to incorporate other known phenomena. An example of such phenomena is the “cocktail party effect”, by which a person automatically directs attention to task-irrelevant, but generally important, stimuli to which they were not purposefully directing their attention (Shapiro et al., 1997). In contrast to the early selection model, the late selection model suggests that all information, regardless of whether it was task-relevant, is cognitively processed, and that the aforementioned “filter” is applied after this general processing is completed, resulting in focused attention on the target stimulus (Deutsch & Deutsch, 1963; Duncan, 1980). In this way, the late selection model resolves the “cocktail party effect” issue associated with the early selection model. However, by proposing that the brain is at all times processing all available information, the theory fails to account for the limits of cognitive capacity (Lavie, 1995).

Perceptual load theory hypothesized that target identification could occur in either the early or late stages of attentional processing, and that the stage of processing used would depend on whether the participant was presented with a high or low perceptual load (Lavie, 1995; Lavie et al., 2004; Lavie & Tsal, 1994). A high perceptual load has a high visual complexity, making it more difficult to identify a single target stimulus. As a result, nearly all available cognitive resources must be directed towards identifying the target. Since all of the available cognitive resources are engaged under high load conditions, no resources remain to be allocated towards processing other available stimuli. Thus, task-irrelevant stimuli should not be processed under high load conditions and are effectively ignored (Lavie, 2005). In contrast, a low perceptual load is less complex and therefore engages only a small portion of available cognitive resources. The remaining supply of unengaged resources are then automatically, and unconsciously, reallocated to process any task-irrelevant stimuli near the target (Lavie et al., 2004).

To test perceptual load theory, Lavie and Cox (1997) conducted a study using a variation of the flanker task, referred to as a letter search task. Six letters were presented arranged in a circle, with one of the six letters always being an N or X. The participant was required to identify which of these two target letters (either N or X) was present by pressing the corresponding key on a keyboard as quickly as possible. The participants were also instructed to ignore a peripheral distractor letter, appearing to the left or right of the circle of letters. The distractor letter was either compatible with the target letter (X or N, matching the target in that trial), incompatible (X or N, different from the target in that trial), or neutral (L, different from either of the possible targets and all the non-targets). High or low perceptual load was manipulated by changing the six letters in the circle. In the high load condition all six letters were different, while in the low load condition the five non-target letters were the same. In accordance with previous research, it was hypothesized that target identification would take more time in trials with incompatible distractors than with compatible distractors (Eriksen & Eriksen, 1974; Lavie & Cox, 1997). As expected, it was found that trials with incompatible distractors had significantly higher reaction times than trials with compatible distractors within the low load conditions. However, compatibility did not significantly affect reaction times in the high perceptual load conditions, suggesting that participants did not have enough cognitive resources available to process the peripheral distractor in the high load conditions. Thus, there was greater attentional capture by the distractor in the low load trials than in the high load trials, which supports the assumptions of perceptual load theory.

The Lavie and Cox (1997) study, and subsequent research, showed that participants' performance on attentional tasks under high perceptual load conditions was similar to what had been found in studies supporting the early selection model; in both cases task-irrelevant stimuli did not affect task performance. Low perceptual load conditions appeared to align with late selection findings, seeing as distractors in these conditions did receive attention (Lavie & Tsal, 1994). This pattern of observations suggests that a pre-processing filtering technique, as described by the early selection model, could be used with high perceptual loads, while a post-processing filter¸ as in the late selection model, could be used with low perceptual loads (Lavie, 1995; Lavie et al., 2004; Lavie & Tsal, 1994). Since earlier researchers had not considered the role perceptual load plays in selective attention, the load of attentional tasks may have influenced whether results from different studies supported the early or late selection model, which may have resulted in the initial split in theories (Lavie, 1995). In combining the early and late selection mechanisms, perceptual load theory allows for a more comprehensive understanding of attentional processes.

The Effect of Perceptual Load on Processing Task-Irrelevant Emotional Faces

In order to gain a better understanding of the potential attentional bias towards emotional faces, it is necessary to conduct a study that both uses task-irrelevant stimuli and varies perceptual load. Currently, only two studies have been conducted using these parameters (Gupta et al., 2016; Gupta & Srinivasan, 2015). One of these studies (Gupta et al., 2016) used the same letter search task as the one described in the Lavie and Cox (1997) study, but instead of distractor letters appearing on either side of the circle of letters it had emotional faces (happy or angry) appear in the center of the circle in 25% of the trials and no distractor appear in 75% of the trials. Since the target stimuli in this study were letters, the emotional faces are considered entirely task-irrelevant. It was found that in the low load condition, it took participants significantly more time to identify the target letter in trials with an emotional face present than in trials without an emotional face, although neither happy nor angry faces were significantly more effective at capturing attention at low loads. In the high load condition, there was no significant difference in the time it took participants to identify the target letter between trials with angry faces and trials with no faces.

These results were expected, as they follow perceptual load theory. However, unlike any other studies previously mentioned, it was also found that within the high load condition, trials with happy faces took significantly longer than trials with either angry faces or no faces. Thus, happy faces successfully captured attention regardless of whether sufficient cognitive resources were available to process them, suggesting that happy faces may hold a unique feature that make them more salient than angry faces (Gupta et al., 2016). Using a similar paradigm, a study conducted by Gupta and Srinivasan (2015) also found that happy faces captured attention in both high and low perceptual loads. In both the Gupta and colleagues (2016) and the Gupta and Srinivasan (2015) studies, comparisons were only made between positively and negatively valanced images. The present study seeks to expand on these two studies by comparing the attentional processing of neutral faces to both happy and angry faces. This will allow for a greater understanding of the potential advantages in processing of emotional faces as compared to non-emotional faces (Tannert & Rothermund, 2018).

Effects of Time On-Task on Attentional Processing

Time on-task affects attentional processing in a couple of ways. In performing a simple and repetitive task multiple times, individuals become more efficient as they progress and discover which patterns of actions lead to the quickest solutions (Crossman, 1959). Therefore, participants exhibit a decrease in reaction times (RTs) as they complete more trials and becomes more adept at attentional tasks (Mowbray & Rhoades, 1959; Teichner & Krebs, 1974). However, completing multiple trials of a task in the same sitting can drain cognitive resources, causing fatigue (Ackerman, 2011). The effect of fatigue on attentional processing differs depending on the perceptual load of the task. At high load, fatigue reduces the already limited cognitive resources that could be directed at processing distractors. This further impedes the ability of distractors to capture attention away from a primary attentional task (Csathó et al., 2012). At low load, fewer resources are necessary to complete the primary task, so participants have the cognitive capacity to process distractors even when they become fatigued. Thus, fatigue at low load can cause increasing RTs, while at high load RTs will likely decrease over time.

Both increases and decreases in RTs over time on-task could indicate reduced attention, making it difficult to understand the cognitive processes involved in completing simple choice tasks. RT data in emotional face research may also be interpreted in different ways, and because of this, comparing RT results from different studies may contribute to vastly different findings. However, there may be noticeable changes in performance from trial to trial that can offer more information about attention than aggregate RTs. For example, it is possible that RTs decrease across early trials as participants learn how to more effectively perform the task, but RTs may rise in later trials as the participants become fatigued. To identify changes in performance from trial to trial, it is necessary to use a statistical technique called Multilevel Modeling.

Multilevel modeling (MLM) is an extension of regression analyses that is uniquely suited to analyzing nested data sets (Tabachnick & Fidell, 2007). Though most commonly employed to examine the effect of individuals nested within groups, such as students nested within classrooms nested within school districts, an attentional study in which individuals are nested within experimental conditions is also a nested structure and can therefore employ MLM. “Trials” can be included as a variable that is nested within the individual participant to model changes from trial to trial.

Previous studies on attention bias towards emotional faces primarily used the repeated measures analysis of variance (ANOVA) to analyze RT data (Fenske & Eastwood, 2003; Gupta et al., 2016; O'Toole et al., 2011; Yates et al., 2010). This is likely because the ANOVA is a relatively simple analysis to perform and provides a useful summary of the differences between conditions in a data set (Whelan, 2008). Though ANOVAs are an excellent tool for making sense of many forms of data, it requires the aggregating of data across trials. As a result, the analysis eliminates changes in RT, and effects of experimental manipulations on RT, from trial to trial. Therefore, ANOVA tends to offer less information than MLM in RT studies. Another benefit of using MLM over ANOVA for analyzing attentional data is that MLM is adept at performing analyses accurately in the presence of missing data (Lachaud & Renaud, 2011; Tabachnick & Fidell, 2007). In analyzing RT data, it is necessary to separate trials in which participants performed their given task correctly from trials performed incorrectly, which guarantees that some data points will be missing from the RT set of interest. Methods of managing missing data for other analyses, such as ANOVAs, require complex extrapolation procedures, and there is a greater risk of generating unexpected statistical outcomes (Lachaud & Renaud, 2011).

Compared to ANOVA, MLM is a relatively new statistical analysis technique, and given its benefits in assessing nested data structures, several published studies in various areas of psychology have implemented MLM in analyzing RT data. For example, one study used MLM to find that trial to trial differences in RT were more sensitive indicators of cognitive issues than aggregate speed or accuracy across trials in breast cancer patients (Collins et al., 2018). Although analyzing RT data with MLM allows for greater sensitivity to small changes in performance that would otherwise have gone unnoticed, no research on attentional bias to emotional faces using MLM has been published yet. It is expected that using MLM to assess changes in performance over time would provide more information about the cognitive processes involved in completing emotional face tasks. Information of this sort could have many important research applications. For example, analyzing trial to trial changes in RTs can improve the current understanding of avoidance in patients with social anxiety disorder. Existing research proposes that patients with social anxiety disorder exhibit a hypervigilance-avoidance pattern, meaning that when presented with an emotional face, patients will first direct their attention towards it and then explicitly avoid looking at the face (Mueller et al., 2009). MLM could help identify at what point during an attentional task do patients switch from hypervigilance to avoidance strategies.

Statement of the Problem

Numerous studies comparing the effectiveness of happy, angry, and neutral faces in capturing attention have been performed over the past thirty years; however, the findings of these studies appear inconsistent. Early research supports the existence of an Anger Superiority Effect (Eastwood, et al., 2001; Fenske & Eastwood, 2003; Fox et al., 2000; Hansen & Hansen, 1988; Horstmann & Bauland, 2006; Öhman, et al., 2001), while later studies tend to find a Happiness Superiority Effect (Becker et al., 2011; Bucher & Voss, 2018; Öhman, et al., 2010). It may be possible to integrate these findings by reassessing the methodology used in previous studies. These previous studies have received criticism for using task-relevant distractor stimuli in FiC and flanker paradigms (Glickman & Lamy, 2018; Lichtenstein-Vidne et al., 2012; Tannert & Rothermund, 2018). The letter search paradigm, in contrast, ensures that all face distractors, regardless of the emotion depicted, are task-irrelevant. Therefore, the present study will use a letter search paradigm similar to those used in previous studies as a primary task (Forster & Lavie, 2007, 2008; Gupta et al., 2016; Gupta & Srinivasan, 2015; Yates et al., 2010).

It is also known that perceptual load regulates the availability of cognitive resources and thus affects whether a task-irrelevant emotional face has the potential to capture attention, yet few studies accounted for perceptual load in their procedures (Lavie, 1995; Lavie, 2005; Lavie & Cox, 1997; Lavie & Tsal, 1994; Lavie et al., 2004). The two studies that used task-irrelevant distractors and varied perceptual load conditions to study the distracting effect of emotional faces (Gupta et al., 2016; Gupta & Srinivasan, 2015). Perceptual load had a robust effect on target identification in both studies; reaction time to detect the target was longer under the high load compared to low load condition. Gupta et al. (2016) found that in low load tasks, participants took more time to identify a target when a schematically-drawn emotional (angry or happy) face was present than when there was no emotional face present, and that in high load tasks, participants took more time to identify a target only when happy faces were present, not when either angry faces or no faces were present. Gupta and Srinivasan (2015), using photographs of real people exhibiting neutral, happy, or sad expressions, found no effect of facial expression on the time to identify the target. In a surprise recognition task, happy and sad faces viewed during the low load task were recognized at a rate of over 70%. This rate was the same for happy faces during high load; however sad faces seen in the high load condition were later recognized only about 30% of the time. Across studies, these findings suggest that happy faces direct attention in both high and low load conditions, whereas previous studies have only found attentional biases in low load conditions. In order to test the replicability of this effect, further research should be conducted using a similar paradigm. Additionally, attentional processing of neutral faces should be compared to that of both happy and angry faces in order to investigate potential advantages in processing of emotional faces as compared to non-emotional faces. Research has also shown that changes in RTs over time on-task indicate differences in attentional processing (Ackerman, 2011; Crossman, 1959; Csathó et al., 2012; Mowbray & Rhoades, 1959; Teichner & Krebs, 1974), however changes in RTs from trial to trial have not been investigated in emotional face studies. The present study aims to add to the existing literature by examining fluctuations in RTs from trial to trial as participants are exposed to emotional distractor faces over time.

The objectives of the present study are to investigate how attentional capture by distractor faces is affected by: 1) the emotion depicted by the distractor faces (emotional vs neutral), 2) perceptual load, and 3) time on-task. It is hypothesized that attentional capture, as measured by reaction time, will be depend on the interactions between all three of these factors.

Method

Participants

108 undergraduate students enrolled in an Introduction to Psychology class at Virginia Commonwealth University participated in the present study. Of these 108 students, three were excluded due to low accuracy rates (lower than 60% accuracy in identifying target letter) and another four were excluded due to suspected inattention (average RTs were three standard deviations outside of the mean for that load condition; final N=103). There were no other selection criteria for participants in this study. The participants in the final sample were aged 17 to 33 (M = 19.40, SD = 2.39) and 60.2% of the participants identified as female. The sample was 39.8% White or Caucasian, 25.2% Black or African American, 15.5% Asian, and 11.7% other. Additionally, 9.7% of participants identified as Hispanic. For a complete demographic breakdown by emotion condition, see Table 1 below.

Table 1

Emotion Group		Angry	Happy	Total
Number of Participants		59	44	103
Sex	Female	34	28	62
	Male	25	16	41
Age	Age Range	17-33	17-25	17-33
	Mean Age	19.53	19.27	19.40
Race/Ethnicity	Asian	10	6	16
	Black/African American	11	15	26
	Hispanic	5	5	10
	White/Caucasian	28	13	41
	Other	6	6	12

Procedure

After providing informed consent, participants completed the Social Phobia and Anxiety Inventory-23 (SPAI-23; Roberson-Nay et al., 2007), an abridged version of the SPAI (Turner et al., 1989), which is a 23-item self-report inventory assessing social phobia. Questionnaire data are not relevant to this study and will not be discussed further. Participants were then administered a letter search task similar to tasks used in previous studies, via computer (Forster & Lavie, 2007, 2008; Gupta et al., 2016; Gupta & Srinivasan, 2015; Yates et al., 2010). In this task, participants were instructed to identify a target letter from among a circular array of letters as quickly and accurately as possible by pressing the corresponding key on their keyboard. Participants' reaction times were recorded in milliseconds by the computer as they responded. These reaction times were the dependent variable used for data analysis, discussed in a later section.

Each participant completed 640 trials of the letter search task. These trials were presented in four 160-trial blocks with a brief break between blocks. Within each 160-trial block, a quasi-random 20% of the trials had a face appear in the center of the circular letter array (see Appendix A). 80% of the trials did not include a face so as to maintain the novelty of distractor presence and avoid habituation (Forster & Lavie, 2007, 2008; Yates et al., 2010). These faces could demonstrate either an emotional expression or a non-emotional (neutral) expression.

In each trial, the screen displayed an array of six letters arranged in a circle against a black background. The circular array would contain one target letter, which would be randomly selected as either “X” or “Z” (with 50% of the distractor trials using “X” and 50% using “Z”), and five nontarget letters. In the high perceptual load condition, the nontarget letters consisted of five different letters (H, J, L, W, and Y) in a random order, whereas in the low perceptual load condition the nontargets were all the same (five dots). The location of the target and nontarget letters was randomized with an equal probability of appearing in any of six positions within the circle. The letters appeared for 100ms, after which they disappeared and the participants were given two seconds to identify which of these two target letters (either X or Z) was present by pressing the “1” key to indicate they had seen an “X” and the “2” key to indicate they had seen a “Z”. The participants were instructed to enter their responses as quickly as possible while ignoring the images of faces if they were present (see Appendix B for participant instruction sheet). The experimental session took approximately 40 minutes to complete in total.

Within each block of trials only one type of face (emotional or non-emotional) was presented, and within each block, all trials were presented with the same perceptual load. Each participant completed one 160-trial block of each combination of emotionality and load (i.e. high load and emotional face, high load and neutral face, low load and emotional face, low load and neutral face). The order in which blocks were completed was counterbalanced across participants. Two separate experiments were conducted using these procedures; in one the emotional faces depicted angry expressions (N = 59) and in one the emotional faces depicted happy expressions (N = 44).

Materials

Emotional distractors were obtained from the Pert-96 database, which supplies high quality photographs of male and female actors of a variety of ages and races that have been shown to clearly demonstrate specific emotions (Gur et al., 2002). 16 unique pictures of happy, angry, and neutral faces (48 faces total) were used in this study. Each of the 16 neutral faces and 16 emotional faces (either happy or angry, depending on which condition the participant was in) was presented four times during the experiment, once per each 160-trial block. Half of the faces used were male and half were female, and the majority of the faces were non-white (86.3%). The order in which faces were presented was randomized.

Data Analysis Strategy

Multilevel modeling, using two-level multilevel growth models, was used to assess change in participants' reaction times as a function of the independent variables. The two-level models were set up with trials within blocks (1-160) at level 1 and participants at level 2. Predictors (fixed effects) at the trial level included perceptual load (high or low), face presence (present or absent), face emotionality (emotional or neutral), block number (1-4), trial number (1-160), and trial number squared. The last two variables were included in the model to account for linear and quadratic effects of task experience on RT. The level 2 predictor was emotion group (happy or angry). Furthermore, the inclusion of level 2 allowed for the models to account for individual variance in RT. Block numbers were mean-centered and trial numbers were mean-centered and then divided by 79 (to help with convergence)[1]. The "as.factor" function in R was used to dummy code the categorical predictors, including perceptual load (reference level = low

[1] When conducting MLM analyses using a large predictor variable (such as trial numbers, which ranged from 1-160), it is standard procedure to transform the variable such that it has an approximate range of -1-1. This transformation was not necessary with block numbers since the range was fairly small to begin with (1-4).

load), face presence (reference level = no face), face emotionality (reference level = neutral), and emotion group (reference level = happy group). The models allowed intercepts to vary by participant (random intercepts), and in the final model the effect of trials on reaction time was allowed to vary by participants as well (random slopes). MLM analyses were conducted using the ‘lme4’ package (Bates et al., 2015) in R version 4.0.0 (R Core Team, 2020). The models were assessed for linearity, normality of the residuals, homoscedasticity, and multicollinearity prior to the analysis. Maximum likelihood estimations were used for all analyses. A total of 49134 trials were analyzed across 103 participants, lending sizeable power to the models created (Gelman & Hill, 2006).

A four-step MLM approach was used to assess the effects of the predictors on participants’ reaction times on the letter search task. In the first step, a Baseline was established using random intercepts and no fixed effects:

Baseline, Level 1:

$$\mathrm{RT}_{ij} = \beta_{0j} + e_{ij}$$

Baseline, Level 2:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

where RT_{ij} represents the reaction time of participant *j* for trial *i;* β_{0j} represents participant *j*’s average reaction time; e_{ij} represents random error at the trial level, or the difference in reaction time between trial *i* and participant *j*’s mean reaction time across trials; γ_{00} represents the grand mean of reaction times across all participants; u_{0j} represents the random error for participant *j*, which can be interpreted as the individual variation.

In the second step, load was added as a predictor to the Baseline to create Model 1. Model 1 served to test the effectiveness of the experimental design by assessing the relationship between perceptual load and RT. Model 1 can be defined by the following equation:

Model 1, Level 1:

$$RT_{ij} = \beta_{0j} + \beta_{1}*(LOAD_{ij}) + e_{ij}$$

Model 1, Level 2:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_{1} = \gamma_{10}$$

where β_{0j} represents participant *j*'s average reaction time when all the predictors are in the "control" condition (in this case, referring to the low load condition); β_{1} represents the difference in the reaction time of participant *j* between the mean reaction time across all load conditions (γ_{10}) and the mean reaction time for the load specified in trial *i* (represented by $LOAD_{ij}$), which can be interpreted as the main effect of load. In this model it will be assumed that the slope for the relationship between load and reaction time for participant *j* (β_{1}) will be the same as the overall slope for the relationship between load and reaction time across participants (γ_{10}).

In the third step, face presence, face emotionality, emotion group, and all of the interactions between them were added to Model 1 to create Model 2, which was meant to account for all emotional face conditions at high and low load. Typically, in multilevel modeling variables and interactions are added to models one at a time. In the case of the present study, it is appropriate to add these variables simultaneously because the variables are not manipulated independently; for example, face emotionality can only be manipulated when a face is present. The three-way interaction between these predictors represents what sort of face (happy, angry, neutral, or no face) the participant was shown during a given trial while the main effects of the predictors represent the conceptual factors that comprise the face. Model 2 can be defined by the following equation:

Model 2, Level 1:

$$RT_{ij} = \beta_{0j} + \beta_{1}*(PRES_{ij}) + \beta_{2}*(EMOTION_{ij}) + \beta_{3}*(LOAD_{ij}) + \beta_{4}*(PRES_{ij}*EMOTION_{ij}) + \beta_{5}*(PRES_{ij}*LOAD_{ij}) + \beta_{6}*(LOAD_{ij}*EMOTION_{ij}) + \beta_{7}*(GROUP_{j}*PRES_{ij}) + \beta_{8}*(GROUP_{j}*EMOTION_{ij}) + \beta_{9}*(GROUP_{j}*LOAD_{ij}) + \beta_{10}*(GROUP_{j}*PRES_{ij}*EMOTION_{ij}) + \beta_{11}*(GROUP_{j}*PRES_{ij}*LOAD_{ij}) + \beta_{12}*(GROUP_{j}*LOAD_{ij}*EMOTION_{ij}) + \beta_{13}*(LOAD_{ij}*PRES_{ij}*EMOTION_{ij}) + \beta_{14}*(GROUP_{j}*PRES_{ij}*EMOTION_{ij}*LOAD_{ij}) + e_{ij}$$

Model 2, Level 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}*(GROUP_{j}) + u_{0j}$$

$$\beta_{1} = \gamma_{10}$$

$$\beta_{2} = \gamma_{20}$$

$$\beta_{3} = \gamma_{30}$$

.
.
.

$$\beta_{14} = \gamma_{140}$$

where the interaction terms β_{3}, β_{4}, β_{5}, and β_{6} (as well as the overall regression coefficients γ_{10}, γ_{20}, γ_{30}, γ_{40}, γ_{50}, and γ_{60}, which are considered equal to the interaction terms in this model) represent the change in reaction time between the levels within face presence, face emotionality, and emotion group (PRES, EMOTION, and GROUP, respectively). Also, γ_{01} refers to the difference in the grand mean of reaction time and the mean for participant *j*'s emotion group (represented by $GROUP_{j}$).

In the fourth and final step, Model 3 was created by adding trial number (as linear and quadratic variables) and block number as fixed effects and trial number (only as a linear variable) as a random slope to Model 2. Trial number was used to assess changes in RT within sets of 160 trials averaged across 4 blocks, block number was used to assess changes in RT between 4 blocks averaged across 160 sets trials, and the interaction between trials and blocks was used to assess whether the effect of trials within blocks changed as participants continued the session. Similar to previous paragraph, multiple variables were added simultaneously in this step due to their combined conceptual representation of time on task. Please refer to Appendix C to see the equation used for Model 3.

Model 3 is structured similarly to Model 2 except that it also includes a random slope. Model 3 allows the change in reaction time across trials to vary within participants by adding to the overall slope for the relationship between trial and reaction time across participants (γ_{50}) an error term representing participant *j*'s deviation from the overall slope (u_{5j}). The combined overall slope and error term is represented as β_{5j}.

Model 3 produced complex outputs with statistically significant interactions, involving as many as five variables. In order to assist in interpretation of these interactions, Model 3 was rerun on high load data and low load data separately after removing the load predictor from the equation. The results of the post hoc analyses will be discussed alongside the results of Model 3.

Results

The relative utility of Models 1-3 was investigated by calculating the chi-square distributions for the -2 log likelihood change when performing the following comparisons: Model 1 was compared to the Baseline, Model 2 was compared to Model 1, and Model 3 was compared to Model 2 (see Appendix D for a full comparison of fit statistics). Model 1 accounted for significantly more variance than the Baseline did, $\chi^2(1) = 17638.58$, $p < 0.001$, suggesting that adding load as a predictor to the unconditional model enabled it to better fit the data. Furthermore, load was found to have a significant effect on RT, $b = 184.26$, SE = 1.26, $t(49044.82) = 145.72$, $p < 0.001$, indicating that participants were slower to react in high load trials than in low load trials. This suggests that the study's perceptual load manipulation was successfully implemented.

Model 2 was then compared to Model 1 and it was determined that the combined fixed effects of face presence, emotionality, emotion group, and all their interactions significantly improved model fit, $\chi^2(14) = 214.75$, $p < 0.001$. Trial number, trial number squared, and block were added to Model 2 as fixed effects, and trial number was also included as a random slope, to create Model 3, and then the two models were compared. Model 3 accounted for significantly more variance than Model 2 did, $\chi^2(82) = 1577.86$, $p < 0.001$, indicating that adding time effects to Model 2 improved model fit. In sum, after comparing the models, Model 3 was determined to best fit the data. Thus, only results from Model 3 are discussed below (see Appendix E for tables of fixed and random effects).

Main Effects

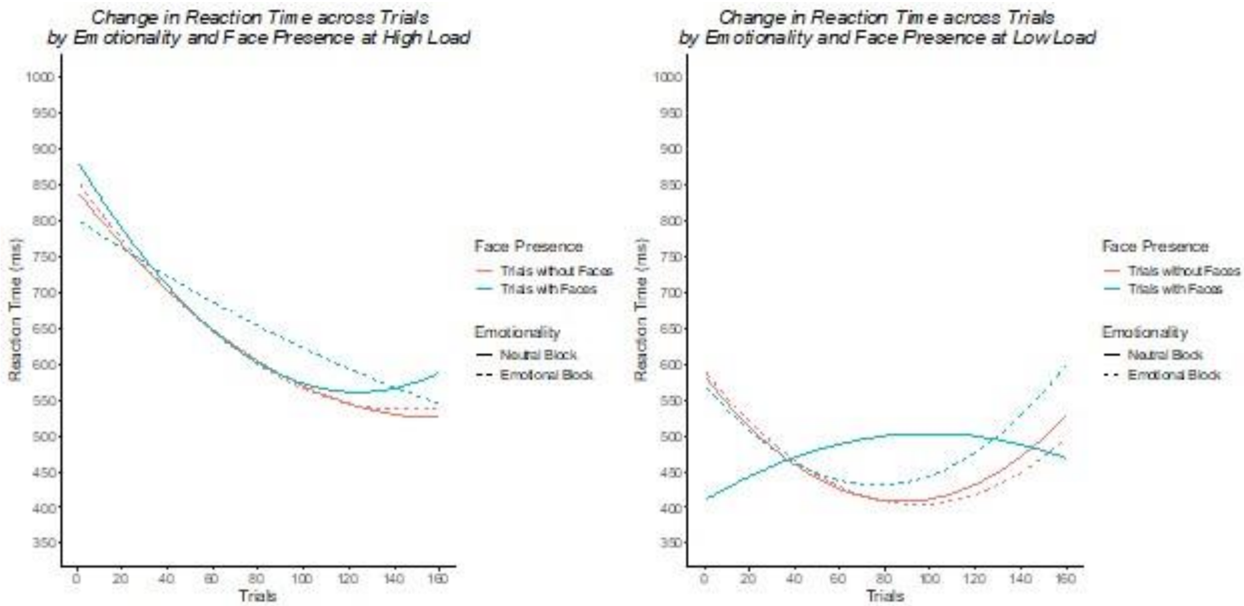
RTs were longer during high load than low load blocks, main effect of load, $b = 178.73$, SE = 2.60, $t(48979.42) = 68.66$, $p < 0.001$, and participants took longer to react in trials with distractor faces than in trials without distractor faces, main effect of face presence, $b = 21.29$, SE = 3.71, $t(48936.98) = 5.73$, $p < 0.001$. These beta-weights indicate that reaction time during high load trials was on average about 178 msec slower than low load trials, and reaction time on trials with a face present was on average about 21 msec slower than when no distracting face was presented. Reaction time also changed over the course of the experiment, as revealed by main effects of quadratic trial number, $b = 1466.83$, SE = 366.97, $t(48946.38) = 4.00$, $p < 0.001$, and block number, $b = -9.10$, SE = 2.04, $t(41888.00) = -4.46$, $p < 0.001$. The quadratic trial number effect indicates that, on average, RTs decreased as participants completed more trials near the beginning of the block, and then gradually increase towards the end of the block. The beta-weight for block indicates that across the four blocks, RTs were, on average, about 9 msec faster compared to the previous block. These main effects of load, face presence, quadratic trial number, and block were qualified by several interactions, described below, that provide more information about the ways by which these variables affect each other.

Effects of Emotional Faces

Distractor faces were included in 20% of the letter search task trials and either depicted emotional or neutral expressions, depending on the block in which they were presented. The effect of emotional faces on RT was used to investigate whether emotional faces captured attention more successfully than neutral faces. Results showed that emotional faces did differ from neutral faces in their ability to capture attention; however, this effect was dependent on cognitive load and practice with the task, as indicated by a Face Presence x Emotionality x Trials^2 x Load interaction, $b = -4015.94$, SE = 1812.62, $t(48956.35) = -2.22$, $p = 0.027$. This effect can be seen in Figure 1. To help disentangle this interaction, Model 3 was analyzed separately for high load and low load blocks. As the left panel in Figure 1 suggests, at high load, RTs in both emotional (dotted lines) and neutral (solid lines) blocks decreased over time across the entire 160-trial block. Further, the presence (blue lines) and absence (red lines) of distractor faces did not significantly affect the rate at which RTs decreased in the high load condition. Thus, emotional and neutral faces were equally effective at attentional capture in the high load condition, Face Presence x Emotionality x Trial^2 $p = 0.34$.

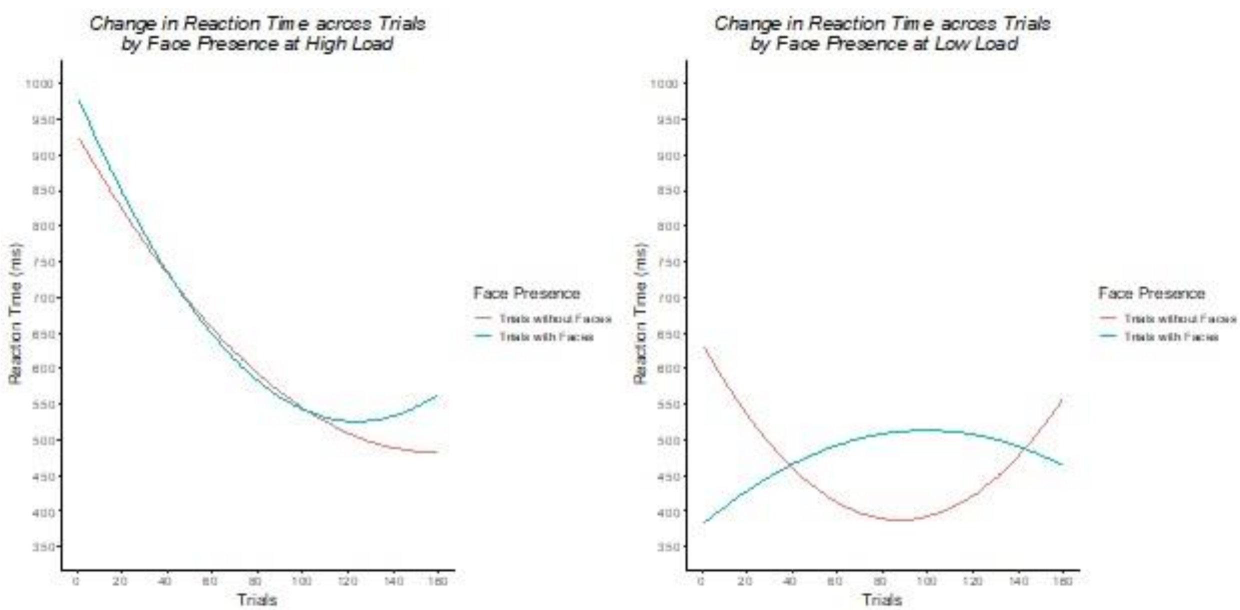
At low load, emotional faces appeared to capture attention more effectively than either neutral faces or no faces. Specifically, in the low load conditions (the right panel of Figure 1), it is apparent that trials with emotional faces (dotted blue line) were more distracting than trials with neutral faces (solid blue line) during trials early in the block and late in the block, whereas there is a slight effect in the opposite direction during middle trials. On the other hand, for trials in which no distracting face was present, the pattern of reaction time over trials was the same for blocks with emotional faces (dotted red line) and blocks with neutral faces (solid red line). This pattern resulted in a Face Presence x Emotionality x $Trial^2$ interaction, $b = 1692.20$, SE = 689.79, $t(29000.32) = 2.45$, $p = 0.014$ for low load blocks. The reaction time results also indicated that mere face presence (regardless of whether the face depicted an emotional or neutral expression) also significantly affects RT over trials during low, but not high, perceptual load (see Figure 2), Model 3 interactions of Face Presence x Load x $Trial^2$, $b = 2831.37$, SE = 1286.70, $t(48956.10) = 2.20$, $p = 0.028$, and Face Presence x $Trial^2$, $b = -2092.77$, SE = 810.77, $t(48941.23) = -2.58$, $p = 0.010$.

Figure 1



Note. The Face Presence x Emotionality x $Trial^2$ interaction was significant at the 0.05 level at low load (right) but not at high load (left).

Figure 2



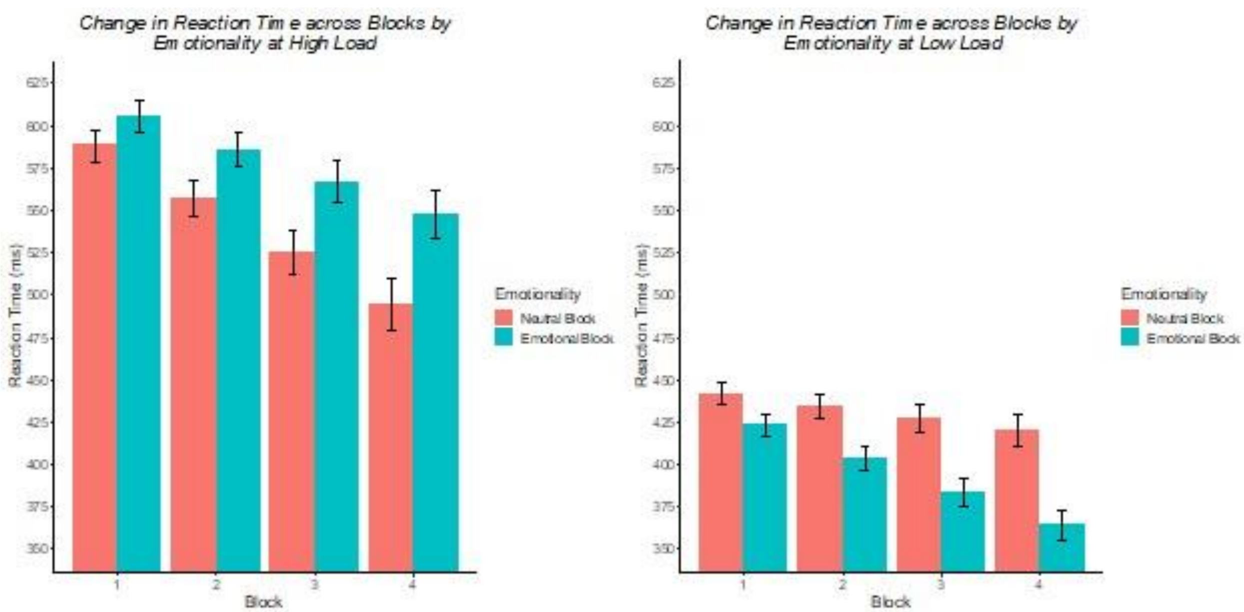
Note. The Face Presence x $Trial^2$ interaction was significant at the 0.05 level at low load (right) but not at high load (left).

Effects of Emotional Blocks

The effects in Figure 1 indicate that the presence of emotional faces was distracting; trials with emotional faces present generally produced higher RTs than trials without distractor faces or with neutral distractor faces. In addition, there was a difference in reaction times between blocks of trials with emotional and neutral faces that occurred on all trials of a block (i.e., even on trials in which the face was not present). This can be seen in the marginally significant main effect of emotionality, $b = -4.50$, SE = 2.32, $t(48953.81) = -1.94$, $p = 0.053$), indicating that reaction times were slightly (4.5 msec) faster in blocks during which an emotional face was shown on 20% of the trials, compared to blocks during which a neutral face was shown on 20% of the trials.

However, this effect differed depending on perceptual load, and changed over the course of the study, as indicated in Figure 3, which depicts a significant Block x Load x Emotionality interaction, $b = 28.62$, SE = 6.51, $t(33476.50) = 4.40$, $p < 0.001$. The model was analyzed separately for high and low load blocks to better understand these results. At high load, RTs in neutral blocks did not significantly differ from RTs in emotional blocks overall (Emotionality $p = .49$) or over time (Emotionality x Block, $p = 0.68$). At low load, not only were RTs in emotional blocks faster than RTs in neutral blocks, Emotionality, $b = -3.87$, SE = 1.82, $t(29014.61) = -2.13$, $p = 0.034$, but this difference became greater toward the end of the session, when participants had more experience with the task, resulting in a Block x Emotionality interaction ($b = -20.46$, SE = 3.29, $t(22861.65) = -6.22$, $p < 0.001$) at low load. In Figure 3, the effect can be identified by noting the increasing differences between the bars representing neutral (red) and emotional (blue) blocks as participants progress in the study. This pattern of results also produced significant Block x Load, $b = -19.01$, SE = 3.69, $t(38649.79) = -5.16$, $p < 0.001$, and Block x Emotionality interactions, b = -8.54, SE = 3.50, t(36515.10) = -2.44, p = 0.015 in Model 3. It is important to note again that the interactions described in this paragraph did not include the variable of face presence. Thus, although there was a difference in RTs across emotional *blocks* as compared to neutral ones, this effect occurred across all trials in the block, including the 20% of trials with faces and the 80% without faces as distractors. It is unclear how these interactions can be used to interpret the effect of emotional face presence on RTs. These results are therefore not relevant to the goals of the present study and they will not be discussed further.

Figure 3

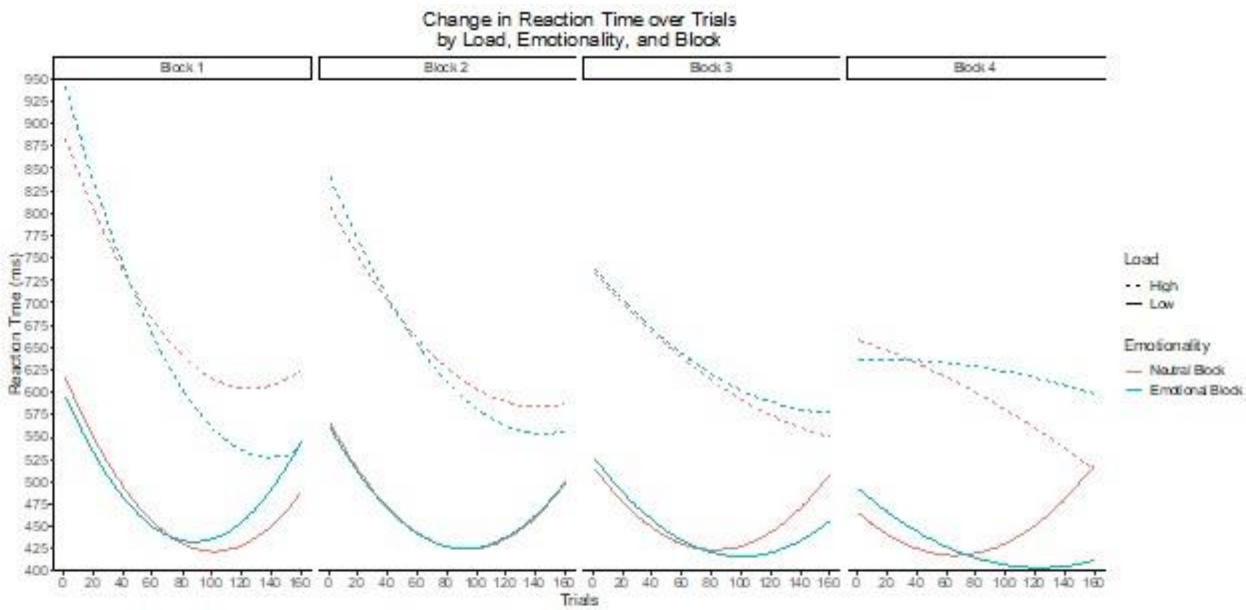


Note. The Emotionality x Blocks interaction was significant at the 0.05 level at low load (right) but not at high load (left).

The effect described in the previous paragraph was further complicated in that it differed across trials, producing a significant Trial x Block x Load x Emotionality interaction, b = 2274.68, SE = 1010.21, t(407.30) = 2.25, p = 0.024. When the model was analyzed separately by load, the Trial x Block x Emotionality interaction was not statistically significant for low load (p

= 0.06) nor high load (p = 0.11). However, as depicted by Figure 4, the two load conditions produced opposing patterns across the latter trials in each block, which led to the complicated interaction.

Figure 4



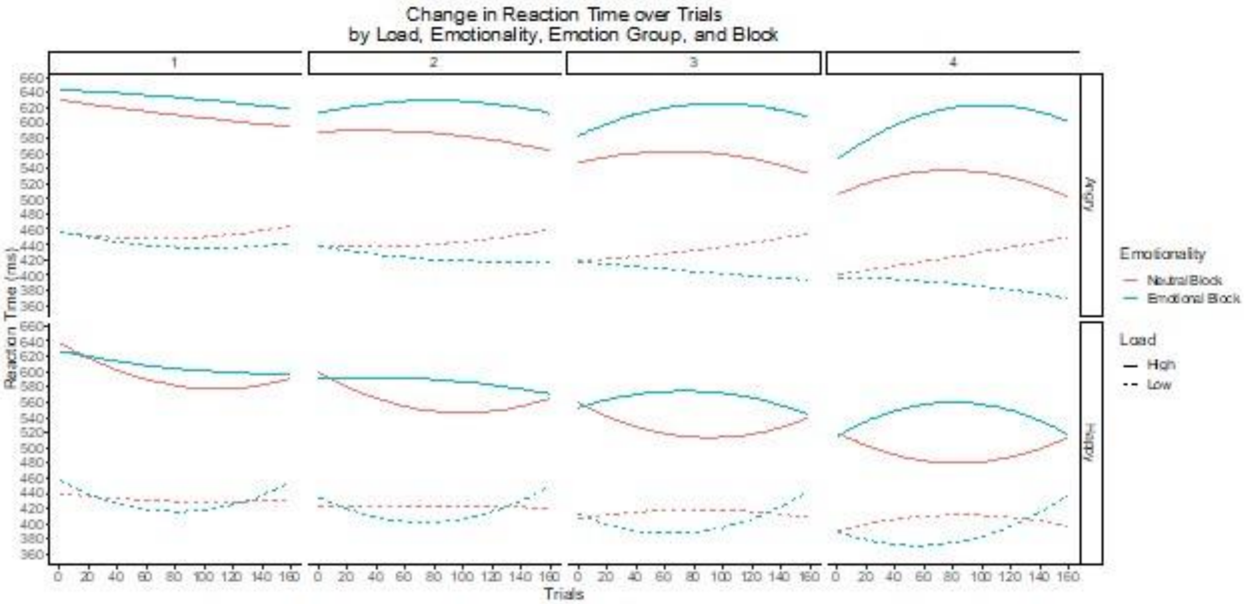
For the high load condition in the first block, RTs in the later trials of neutral blocks are slower than RTs in later trials of emotional blocks; however, by block 4 this has reversed and RTs in later trials of neutral blocks are faster than RTs in later trials of emotional blocks. The opposite is true of low load blocks, such that in block 1 RTs in the later trials of neutral blocks are faster than RTs in later trials of emotional blocks but in block 4 RTs in later trials of neutral blocks are slower than RTs in later trials of emotional blocks. These trends suggest that at high loads emotional blocks require more cognitive resources than neutral blocks over time, and at low loads neutral blocks require more cognitive resources than emotional blocks over time. These patterns of data also resulted in Trial x Load, b = -2415.14, SE = 577.55, t(49011.42) = -4.18, p < 0.001, and Trial x Block interactions, b = 895.48, SE = 371.64, t(1734.10) = 2.41, p =

0.016. As noted in the previous paragraph, these results demonstrate differences between emotional and neutral blocks, but not necessarily between emotional and neutral faces since the blocks being compared contained 20% trials with distractor faces and 80% trials without distractor faces, and there was no significant interaction with face presence.

Effects of Happy vs. Angry Faces

To compare the effectiveness of attentional capture between happy and angry faces, emotional blocks featured either a happy or an angry face, depending on the emotion group to which participants were assigned. There were no effects indicating that angry faces were more, or less, distracting than happy faces; that is, there were no significant interactions involving both face presence and group (all interactions involving these two variables were $p > .20$). The model identified a complex effect of emotion group on RT, described by a Group x Emotionality x $Trial^2$ x Block x Load interaction, $b = -2421.79$, SE = 1103.29, $t(48964.06) = -2.20$, $p = 0.028$. Figure 5 illustrates the differences in the patterns of RT changes across trials and blocks between happy and angry face groups presented with neutral and emotional blocks. However, since face presence was not one of the variables included in this interaction, the differences in RT patterns do not necessarily represent differences in the distracting effect of happy and angry faces. Thus, these findings are not relevant to the objectives of the present study and will not be discussed further. Additional significant interactions involving the emotion group variable include: Group x Load x $Trial^2$ x Block, $b = 1581.95$, SE = 805.38, $t(48967.77) = 1.96$, $p = 0.0495$, Group x Emotionality x $Trial^2$, $b = 1820.25$, SE = 790.00, $t(48942.90) = 2.30$, $p = 0.021$, Group x Load, $b = 10.84$, SE = 4.00, $t(48983.86) = 2.71$, $p = 0.007$, and Group x Load x $Trial^2$, $b = 1742.45$, SE = 887.76, $t(48969.38) = 1.96$, $p = 0.0497$.

Figure 5



Discussion

The present study investigated the attentional biases towards emotional faces by analyzing how effectively distractor faces capture attention in a letter search task. The first objective was to compare the effectiveness of attentional capture by emotional compared to neutral faces. The second objective was to evaluate the effect of varying perceptual load in the primary letter search task on the attentional capture of distractor faces. The third objective investigates the effect of time on-task on attentional capture by distractor faces. The distractibility of emotional distractor faces was compared to neutral faces, and the distractibility of happy faces was compared to angry faces. Multilevel modeling was used to identify trial to trial fluctuations in reaction times, which were predicted to reveal more about changes in attentional processing over time than simply comparing means across blocks. The results of the present study showed a significant interaction effect between the factors highlighted in all three objectives, suggesting that attentional capture by distractor faces cannot be predicted by any one of these factors alone. As hypothesized, emotional expression, perceptual load, and time on-task must be considered simultaneously in order to understand how focal attention will be directed.

Previous research found that emotional faces are more successful at capturing attention than neutral faces when participants have enough available cognitive resources to allocate towards processing the distractor stimuli. Thus, it was expected that the difference in attentional capture would be evident in low load trials, when cognitive resources would be more available, compared to high load trials (Lavie, 1995; Lavie et al., 2004; Lavie & Tsal, 1994). The present study was consistent with these predictions, and thus with load theory, in that distractor faces were generally more successful at attentional capture at low load than at high load. Results were also consistent with much of the existing literature on attentional capture by emotional and neutral faces as it found that emotional faces were generally more successful at capturing attention away from a primary task than neutral faces at low load.

The present study found that high load trials had significantly slower RTs than low load trials, suggesting that the load manipulation was effective. Perceptual load theory states that identifying a target stimulus set in a highly complex visual environment (high load) would demand more cognitive resources than identifying a target set in a less complex environment (low load; Lavie, 1995; Lavie et al., 2004; Lavie & Tsal, 1994). Since high load tasks are more cognitively demanding than low load tasks, it follows that more resources would be required to complete the same task at high load than at low load. Each of these effects will be discussed in more detail in the following sections.

Faces as Distractors

Trials with distractor faces had significantly slower RTs than trials without distractor faces, suggesting that the faces were effective at capturing attention from the primary task.

Although these findings were expected at low load, participants were also distracted at high load. According to load theory, performing a primary task with a low load will only engage a small portion of an individual's cognitive resources, leaving the remaining resources to be automatically reallocated towards processing task-irrelevant stimuli, such as distractor faces (Lavie et al., 2004; Lavie & Tsal, 1994). The finding of distractor face trials having slower RTs than trials without distractor faces during low load blocks (Figure 2) is consistent with perceptual load theory.

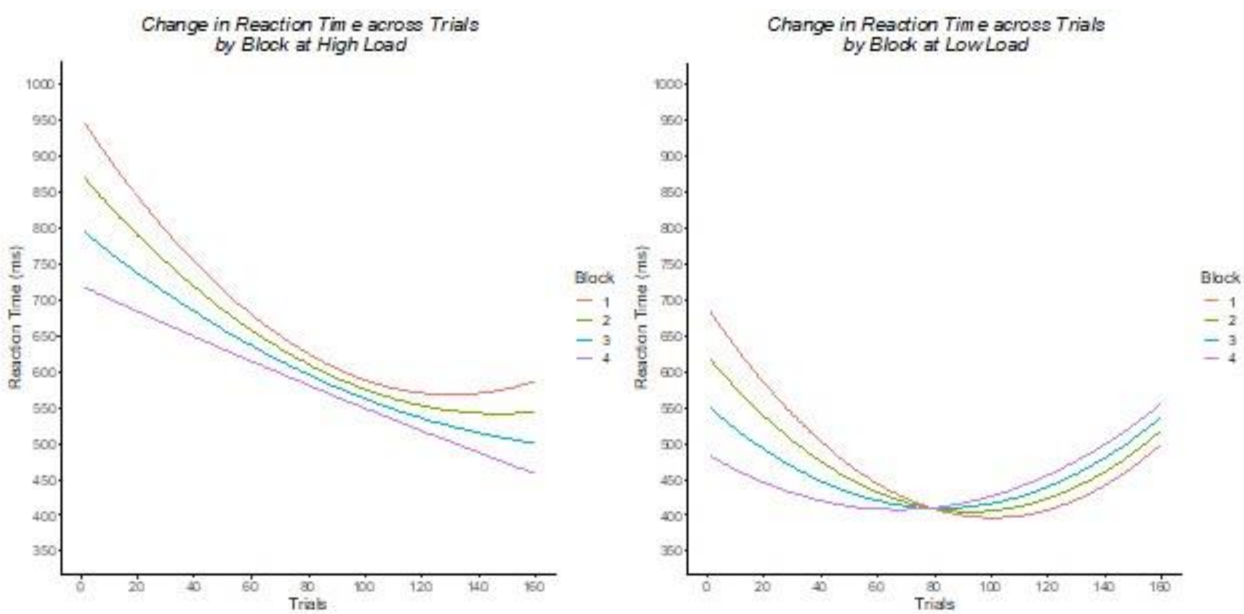
The high load condition was designed to direct all or nearly all available cognitive resources towards completing the primary task. This would leave little processing capacity available for attentional capture by task-irrelevant stimuli, so task-irrelevant distractors should not be able to direct attention away from a primary task (Forster & Lavie, 2008; Huang et al., 2011; Lavie, 2005). Results demonstrated a smaller difference between trials with faces and trials without faces at high load than at low load, indicating that fewer cognitive resources were available to be directed at processing task-irrelevant distractors in the high load condition. These findings are consistent with perceptual load theory.

Practice Effects

Participants demonstrated improvements in RTs from block to block, indicating an overall practice effect across the entire session. Greater practice with a simple and repetitive task, like the letter search task, enables participants to learn ways to improve efficiency, thereby reducing RTs (Mowbray & Rhoades, 1959; Teichner & Krebs, 1974). Within blocks, however, analyses revealed that patterns of trial to trial changes on RT differed depending on load (Figure

6)[2]. At high load, participants demonstrated consistent reductions in RT as they completed trials. The reductions in RT across blocks and across trials within blocks suggests that participants were continuously improving their performance in high perceptual load tasks. At low load, participants reacted more slowly at the beginning and end of each block and reacted more quickly in the middle trials. Furthermore, in later blocks, RTs started faster and ended more slowly in later trials than in earlier blocks. The RT reductions from the beginning to the middle of each block can indicate learning in the same way that was noted with high load trials. RT increases from the middle of each block to the end can be explained by cognitive fatigue; as participants complete more trials, they are likely to experience a depletion in the total quantity of cognitive resources available to them, which hinders performance (Ackerman, 2011).

Figure 6



Note. The Block x Trial interaction was significant at the 0.05 level at low load (right) but not at high load (left), $p = .60$. Main effects of Trial and Block were found for high load (both $p < .001$).

[2] The practice effects illustrated in Figure 6 are clear and systematic and help to contextualize the effects of emotional faces. However, it should be noted that the overall Load x Block x Trial interaction depicted in the figure is not significant in Model 3 ($p = .60$).

Emotionality Effects

The consensus in the existing literature is that emotional faces are more effective at directing attention than neutral faces (Becker et al., 2011; Bucher & Voss, 2018; Eastwood et al. 2001; Fenske & Eastwood, 2003; Fox et al., 2000; Glickman & Lamy, 2018; Gupta et al., 2016; Gupta & Srinivasan, 2015; Hansen & Hansen, 1988; Öhman et al. 2001; Öhman, et al., 2010; Tannert & Rothermund, 2018). In the present study, attentional bias towards emotional faces was investigated by comparing differences in RTs between emotional and neutral trials that displayed distractor faces at high and low load. Consistent with load theory's proposition that when cognitive resources are highly occupied, resources will not be available to process distracting information, there was no difference in RTs between emotional and neutral trials at high load. At low load, participants exhibited slower RTs in emotional face trials than in neutral face trials during the beginning and near the ends of blocks (Figure 1). Thus, the present study is consistent with load theory in finding that emotional faces are more effective at capturing attention than neutral faces when sufficient cognitive resources are available to process distractors.

The present study is inconsistent with the study conducted by Gupta and Srinivasan (2015), which did not report a significant difference in RT between trials with emotional faces and trials with neutral faces at low load. Several methodological differences could have led to these contrasting results. Gupta and Srinivasan (2015) used distractor faces in each trial of their study whereas the present study only used distractor faces in 20% of trials. Seeing distractor faces in every trial reduces their novelty, which could have decreased the distractibility of the faces and therefore the extent to which the emotions of the faces were processed, which could make it seem as though emotional and neutral faces have the same effect on RT. The Gupta and Srinivasan (2015) study also used happy and sad faces as their emotional distractors while the present study used happy and angry faces. It is possible that different emotions have different effects on RT. While the higher RTs found in the emotional face trials of the present study indicate that happy and angry faces attract attention, Gupta and Srinivasan (2015) suggested that sad faces may *inhibit* attentional processing, which would likely result in faster RTs. The present study also grouped emotions into blocks of 160 trials, within which distractor faces would only show one type of emotion (either happy, angry, or neutral). Since happy, sad, and neutral face trials in the Gupta and Srinivasan (2015) study were not divided into different blocks, this could mean that there was a carryover effect, with each trial affecting the way the next one is processed. In addition to methodological differences, the statistical analyses employed by the two studies were different. Gupta and Srinivasan (2015) used an ANOVA to average RTs across all trials, which eliminates the effects of time on-task. By using MLM, the present study may have been more sensitive to subtle variations in RT over time and different conditions.

The present study also revealed a couple of important patterns of trial-to-trial differences in RTs when comparing trials with faces to trials without faces at high and low load. At high load, RTs decreased steadily over time regardless of face presence (as seen in Figure 2), suggesting that the distractor faces did not interfere with participants' learning on the letter search task. Similar improvements in RT were identified in low load trials without distractor faces, indicating a learning effect. However, low load trials *with* distractor faces show evidence of fatigue, as RTs worsen with more trials completed. Since fewer resources are necessary to complete the primary task at low load, even when participants become fatigued, they still have the cognitive capacity to process distractors. Thus, fatigue at low load can cause distractors to become even more distracting (Csathó et al., 2012). The same does not hold true for high load conditions because at high load fatigue reduces the already limited portion of a participant's attention that could be directed at processing distractors, which further impedes the ability of distractors to capture attention away from a primary task. In this way, distractors become less distracting at high load.

Although not specified as an objective of the present study, the effectiveness of attentional capture by happy faces was compared to angry faces since this was discussed in much of the emotional face literature. Some researchers in this field argued that angry faces were more effective at attentional capture than either happy or neutral faces (Eastwood et al. 2001; Fenske & Eastwood, 2003; Fox et al., 2000; Hansen & Hansen, 1988; Horstmann & Bauland, 2006; Öhman et al. 2001) while other studies found happy faces to be more effective (Becker et al., 2011; Bucher & Voss, 2018; Gupta et al., 2016; Öhman et al., 2010). The current study found no differences in RT patterns between happy and angry face trials at either high or low load. These results are consistent with more recent research finding that happy and angry faces are equally effective at attentional capture (Glickman & Lamy, 2018; Lichtenstein-Vidne et al., 2012; Tannert & Rothermund, 2018). Thus, on balance the literature supports neither an Anger Superiority Effect nor a Happy Superiority Effect, though given the discrepant findings and the disparate methodologies and stimuli employed in this area, it is still possible that there are some conditions in which one or the other emotion is more attention-engaging.

Effects of Emotion Group

The present study found a very complicated significant five-way interaction involving the between-subjects variable of Group (Anger vs Happy faces) and the within-subjects variables of Emotionality (Neutral vs. Emotional faces), Trial[2], Block, and Perceptual Load, as well as two-, three-, and four-way interactions involving Group and various combinations of these variables. These interactions were not predicted, and because none of the interactions included the variable of Face Presence, these effects are not relevant to the objectives of this study, which all involve assessing the conditions under which emotional faces serve as a distraction when processing a primary task. These significant findings may suggest an interesting contextual or preparedness effect. That is, the possibility of viewing anger or happy faces may set up a different context that affects processing of the primary task, resulting in reaction time differences whether or not the face actually appears. On the other hand, this may be a chance finding, or represent sampling differences (viewing angry or happy faces was manipulated between-subjects). Thus, any interpretation of these effects would be extremely speculative.

Limitations

It is possible that the results may not reflect the differences in attentional capture between emotional and neutral faces due to insufficient statistical power, or insufficient data to stably estimate the distracting effect of emotional faces. In the current study only 20% of the trials presented during the letter search task contained faces in order to avoid habituation to the distractors. As a result, there are relatively few datapoints available to estimate RT on trials with distractor faces compared to trials without distractors. This may have resulted in lower power to detect effects of distractors, and/or less stable estimates of distractor effects. In the future, the percentage of trials containing faces should be increased in order to provide more datapoints for trials that include distractors. A subsequent study employing these experimental methods has shown that even with 50% of trials containing faces, the faces continue to have the same distracting effects as found in the current study (Panayiotou et al., 2018). With more face-containing trials, the effect of face presence will be able to be examined with greater power, and it will be possible to evaluate the differences in attentional capture between emotional and neutral faces more effectively.

Another limitation of the present study was that RTs in happy and angry face trials were only compared on a between-subject level, possibly increasing group-level variability. It is recommended that future researchers consider presenting the same participants with both happy and angry faces to reduce group-level variability. Gupta and colleagues (2016) presented their subjects with both happy and angry faces in their study and found that happy faces were more effective than angry faces at directing attention away from a primary letter search task at high load. It is possible that the variation in methodology may explain this different finding from the results of the present study, although Gupta and colleagues' (2016) use of schematic faces rather than pictures of real facial expressions may have also contributed to this difference, as previously discussed.

It should also be noted that the present study sampled exclusively college students at Virginia Commonwealth University. This limits the generalizability of the results, seeing as the college sample has little diversity in age, educational background, and geographic location. Future research should expand sampling to more accurately describe the cognitive processes of people with more varied life experiences.

Summary and Future Directions

The present study employed multilevel modeling to investigate the changes in attentional capture by emotional faces over time. Results showed that faces were effective at capturing attention away from the primary letter search task throughout the study. Attentional capture by distractor faces was more effective at low load than at high load, supporting Perceptual Load Theory. At low load, it was found that emotional faces captured attention more successfully than neutral faces, which lends support to the theory that emotional faces hold an evolutionary significance. This would prioritize their processing over other stimuli that contain information that is less relevant to survival, such as neutral faces (Öhman, 2009).

Trial to trial differences revealed evidence of both learning effects and fatigue effects. At high load, participants demonstrated a steady improvement in RTs across trials both with and without faces, indicating a learning effect. The same was true of low load trials without faces. Low load trials with faces exhibited a different trend, with participants' performance worsening as they completed more trials. Their performance on the low load trials with faces indicate that participants were experiencing cognitive fatigue. It may seem counterintuitive to find RTs worsening at low load but not at high load, however low perceptual loads require fewer resources to complete the primary task, so even when participants become fatigued, they have the cognitive capacity to process distractors (Csathó et al., 2012). Since comparatively more cognitive resources are required to process high perceptual loads, high load tasks reduce the already limited portion of a participant's attention that could be directed at processing distractors, further impeding the ability of distractors to capture attention away from a primary task. Thus, fatigue at low load can cause distractors to become even more distracting, while at high load they become less distracting.

To this author's knowledge, no previous studies have used MLM to compare the effectiveness of attentional capture between happy and angry faces at high and low loads. In the present study, MLM made it possible to identify dynamic changes in RTs over time, which allowed for attentional capture to be investigated in the context of time on-task. However, the statistical results were complex and difficult to interpret. Additional research employing task-irrelevant distractors, high and low perceptual load conditions, and MLM is needed to test the replicability of these effects. The present study found no difference in the effectiveness of attentional capture between happy and angry faces, consistent with other recent research that has not found evidence for Anger Superiority or Happiness Superiority effects. While it is possible that the lack of significant differences between happy and angry face trials could indicate that both types of emotions are equally distracting, it is also possible that no difference was found due to a small number of trials containing distractor faces. Thus, it is recommended that future studies include a greater percentage of distractor faces to increase the statistical power to detect differences in RTs between emotional and neutral face trials. It is also recommended that future researchers consider presenting the same participants with both happy and angry faces to reduce group-level variability.

The present study used RTs as a measure of attention, however other variables, particularly accuracy, can also be used to measure attention. Furthermore, measures of participants' confidence in their performance on the primary task can provide useful information about focused attention and conscious processes (Kunimoto et al., 2001). Future studies should consider running multiple models interchanging RT, accuracy, and confidence as the dependent variables to capture more dimensions of cognitive processing involved in attentional capture.

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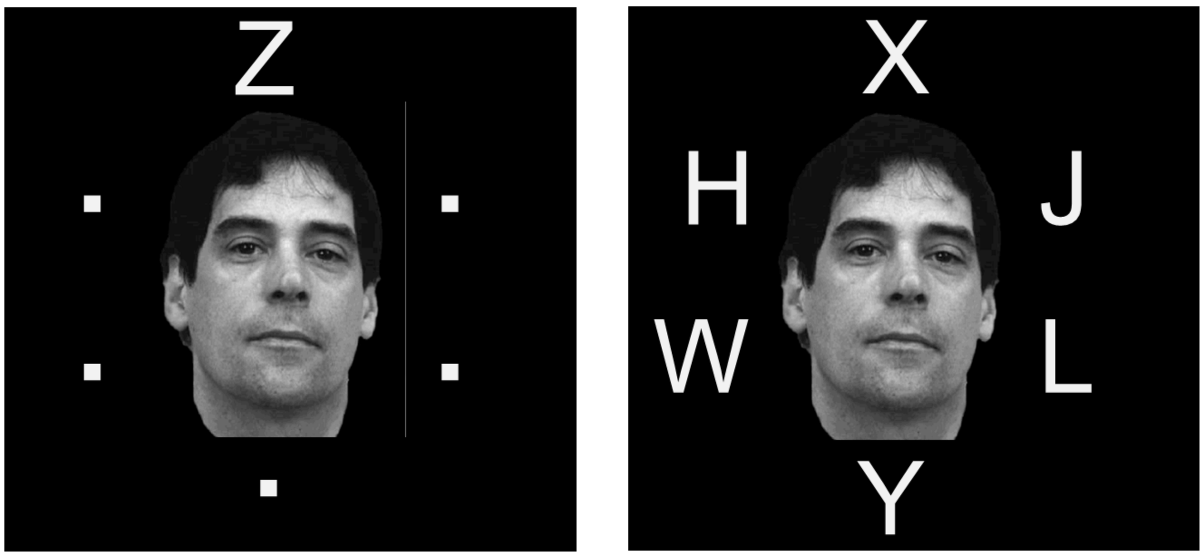
Appendix A

Example Stimuli



Example neutral face stimuli. The picture on the left represents an example of a low load condition in which the participant is meant to find the letter Z. The picture on the right represents an example of a high load condition in which the participant is meant to find the letter X.

Appendix B

Participant Instructions

Welcome to the experiment!

This is an experiment on reaction time. Your task is to respond as QUICKLY and ACCURATELY as possible to brief displays.

You will perform on a visual search task. On each of several trials, you will see a display with one letter (target letter X or Z; Example 1) or six letters (X or Z plus five other non-target letters; Example 2) appearing in a circular arrangement around the centre of the screen. Your task is to press a button as QUICKLY and as ACCURATELY as possible identifying which of the two target letters (X or Z) was present in each trial.

Note that in some trials a face will appear at the center of the screen, inside the letter circle. The purpose of the face is to slow you down. Please try to ignore it and respond to the target letter as quickly as possible.

Example 1

Example 2

The letters will appear for 100 ms (very briefly). You will next be given 2 seconds to respond as quickly and accurately as possible. Use the numeric keypad to indicate which target letter appeared:

"1" for "X" using your right hand INDEX finger

"2" for "Z" using your right hand MIDDLE finger

Please guess when not sure. Try to ALWAYS give a response even if not sure.

To continue to the next trail press any key.

It is important that you work as fast as possible while also being as accurate as possible. This is the main purpose of the experiment. We will be recording your reaction time and accuracy scores. Be aware that all displays appear very quickly, so you will need to concentrate.

You will now have some practice blocks (for each possible kind of display) to help familiarize yourself with these instructions.

KEY POINTS:

- **Find the "X" or "Z" in the task.**
- **Ignore the face at the center of the screen when it appears.**
- **Be as fast as you can while also being as accurate as you can.**

Appendix C

Model 3 Equation

Model 3, Level 1:			
RTij = β0j +	*β1*(PRESij) + β2*(EMOTIONij) +*	*β3*(LOADij) + β4*(BLOCKij) +*	*β5j*(TRIALij) + β6*(TRIAL^2ij) +*
	β7(PRESij*EMOTIONij) +*	*β8*(GROUPj*PRESij) +*	*β9*(GROUPj*EMOTIONij) +*
	β10(PRESij*LOADij) +*	*β11*(LOADij*EMOTIONij) +*	*β12*(GROUPj*LOADij) +*
	β13(PRESij*BLOCKij) +*	*β14*(EMOTIONij* BLOCKij) +*	*β15*(GROUPj*BLOCKij) +*
	β16(LOADij*BLOCKij) +*	*β17*(PRESij*TRIALij) +*	*β18*(PRESij*TRIAL^2ij) +*
	β19(EMOTIONij*TRIALij) +*	*β20*(EMOTIONij*TRIAL^2ij) +*	*β21*(GROUPj*TRIALij) +*
	β22(GROUPj*TRIAL^2ij) +*	*β23*(LOADij*TRIALij) +*	*β24*(LOADij*TRIAL^2ij) +*
	β25(BLOCKij*TRIALij) +*	*β26*(BLOCKij*TRIAL^2ij) +*	*β27*(PRESij*EMOTIONij*GROUPj) +*
	β28(PRESij*EMOTIONij*LOADij) +*	*β29*(PRESij*GROUPj*LOADij) +*	*β30*(EMOTIONij*GROUPj*LOADij) +*
	β31(PRESij*EMOTIONij*BLOCKij) +*	*β32*(PRESij*GROUPj*BLOCKij) +*	*β33*(EMOTIONij*GROUPj*BLOCKij) +*
	β34(PRESij*LOADij*BLOCKij) +*	*β35*(EMOTIONij*LOADij*BLOCKij) +*	*β36*(GROUPj*LOADij*BLOCKij) +*
	B37(PRESij*EMOTIONij*TRIALij) +*	*β38*(PRESij*EMOTIONij*TRAIL^2ij) +*	*β39*(PRESij*GROUPj*TRIALij) +*
	β40(PRESij*GROUPj*TRIAL^2ij) +*	*β41*(EMOTIONij*GROUPj*TRIALij) +*	*β42*(EMOTIONij*GROUPj*TRIAL^2ij) +*
	β43(PRESij*LOADij*TRIALij) +*	*β44*(PRESij*LOADij*TRIAL^2ij) +*	*β45*(EMOTIONij*LOADij*TRIALij) +*
	β46(EMOTIONij*LOADij*TRIAL^2ij) +*	*β47*(GROUPj*LOADij*TRIALij) +*	*β48*(GROUPj*LOADij*TRIAL^2ij) +*
	β49(PRESij*BLOCKij*TRIALij) +*	*β50*(PRESij*BLOCKij*TRIAL^2ij) +*	*β51*(EMOTIONij*BLOCKij*TRIALij) +*
	β52(EMOTIONij*BLOCKij*TRIAL^2ij) +*	*β53*(GROUPj*BLOCKij*TRIALij) +*	*β54*(GROUPj*BLOCKij*TRIAL^2ij) +*
	β55(LOADij*BLOCKij*TRIALij) +*	*β56*(LOADij*BLOCKij*TRIAL^2ij) +*	
	β57(PRESij*EMOTIONij*GROUPj*LOADij) +*	*β58*(PRESij*EMOTIONij*GROUPj*BLOCKij) +*	
	β59(PRESij*EMOTIONij*LOADij*BLOCKij) +*	*β60*(PRESij*GROUPj*LOADij*BLOCKij) +*	
	β61(EMOTIONij*GROUPj*LOADij*BLOCKij) +*	*β62*(PRESij*EMOTIONij*GROUPj*TRIALij) +*	
	β63(PRESij*EMOTIONij*GROUPj*TRIAL^2ij) +*	*β64*(PRESij*EMOTIONij*LOADij*TRIALij) +*	
	β65(PRESij*EMOTIONij*LOADij*TRIAL^2ij) +*	*β66*(PRESij*GROUPj*LOADij*TRIALij) +*	
	β67(PRESij*GROUPj*LOADij*TRIAL^2ij) +*	*β68*(EMOTIONij*GROUPj*LOADij*TRIALij) +*	
	β69(EMOTIONij*GROUPj*LOADij*TRIAL^2ij) +*	*β70*(PRESij*EMOTIONij*BLOCKij*TRIALij) +*	
	β71(PRESij*EMOTIONij*BLOCKij*TRIAL^2ij) +*	*β72*(PRESij*GROUPj*BLOCKij*TRIALij) +*	
	β73(PRESij*GROUPj*BLOCKij*TRIAL^2ij) +*	*β74*(EMOTIONij*GROUPj*BLOCKij*TRIALij) +*	
	β75(EMOTIONij*GROUPj*BLOCKij*TRIAL^2ij) +*	*β76*(PRESij*LOADij*BLOCKij*TRIALij) +*	
	β77(PRESij*LOADij*BLOCKij*TRIAL^2ij) +*	*β78*(EMOTIONij*LOADij*BLOCKij*TRIALij) +*	
	β79(EMOTIONij*LOADij*BLOCKij*TRIAL^2ij) +*	*β80*(GROUPj*LOADij*BLOCKij*TRIALij) +*	
	β81(GROUPj*LOADij*BLOCKij*TRIAL^2ij) +*	*β82*(PRESij*EMOTIONij*GROUPj*LOADij*BLOCKij) +*	
	β83(PRESij*EMOTIONij*GROUPj*LOADij*TRIALij) +*	*β84*(PRESij*EMOTIONij*GROUPj*LOADij*TRIAL^2ij) +*	
	β85(PRESij*EMOTIONij*GROUPj*BLOCKij*TRIALij) +*	*β86*(PRESij*EMOTIONij*GROUPj*BLOCKij*TRIAL^2ij) +*	
	β87(PRESij*EMOTIONij*LOADij*BLOCKij*TRIALij) +*	*β88*(PRESij*EMOTIONij*LOADij*BLOCKij*TRIAL^2ij) +*	
	β89(PRESij*GROUPj*LOADij*BLOCKij*TRIALij) +*	*β90*(PRESij*GROUPj*LOADij*BLOCKij*TRIAL^2ij) +*	
	β91(EMOTIONij*GROUPj*LOADij*BLOCKij*TRIALij) +*	*β92*(EMOTIONij*GROUPj*LOADij*BLOCKij*TRIAL^2ij) +*	
	β93(PRESij*EMOTIONij*GROUPj*LOADij*BLOCKij*TRIALij) +*		
	β94(PRESij*EMOTIONij*GROUPj*LOADij*BLOCKij*TRIAL^2ij) + eij*		

Model 3, Level 2:
$\beta_{0j} = \gamma_{00} + \gamma_{01}*(GROUP_j) + u_{0j}$
$\beta_1 = \gamma_{10}$
$\beta_2 = \gamma_{20}$
$\beta_3 = \gamma_{30}$
$\beta_4 = \gamma_{40}$
$\beta_{5j} = \gamma_{50} + u_{5j}$
$\beta_6 = \gamma_{60}$
.
.
.
$\beta_{94} = \gamma_{940}$

Appendix D

Model Comparisons					
Comparison	**Parameters**	**-2LL**	**Chi-squared**	**df**	**p-value**
Baseline	3	-320402			
Model 1 vs Baseline	4	-311583	17638.58	1	**<0.001**
Model 2 vs Model 1	18	-311476	214.75	14	**<0.001**
Model 3 vs Model 2	100	-310687	1577.86	82	**<0.001**

Appendix E

Summary of Fixed and Random Effects in Model 3

Model 3 - Fixed Effects	b-Value	Std. Error	df	t-value	p-value
(Intercept)	457.92	8.60	108.86	53.23	<0.001
PRES	21.29	3.72	48936.98	5.73	<0.001
EMOTION	-4.50	2.32	48953.81	-1.94	0.053
GROUP	-21.74	13.17	108.97	-1.65	0.10
LOAD	178.73	2.60	48979.42	68.66	<0.001
BLOCK	-9.10	2.04	41888.01	-4.46	<0.001
TRIAL	-551.21	453.06	396.17	-1.22	0.22
TRIAL^2	1466.83	366.97	48946.38	4.00	<0.001
PRES * EMOTION	7.89	5.22	48935.61	1.51	0.13
PRES * GROUP	-0.61	5.73	48947.06	-0.11	0.92
EMOTION * GROUP	5.60	3.57	48960.21	1.57	0.12
PRES * LOAD	-6.39	5.94	48942.64	-1.08	0.28
EMOTION * LOAD	4.61	3.64	48968.48	1.27	0.21
GROUP * LOAD	10.84	4.00	48983.86	2.71	0.007
PRES * BLOCK	-1.75	3.29	48933.08	-0.53	0.60
EMOTION * BLOCK	-8.54	3.50	36515.10	-2.44	0.015
GROUP * BLOCK	-0.39	3.24	41720.85	-0.12	0.90
LOAD * BLOCK	-19.01	3.69	38649.79	-5.16	<0.001
PRES * TRIAL	992.92	820.21	48946.83	1.21	0.23
PRES * TRIAL^2	-2092.77	810.77	48941.23	-2.58	0.010
EMOTION * TRIAL	-416.02	515.91	49023.68	-0.81	0.42
EMOTION * TRIAL^2	-145.40	516.24	48944.57	-0.28	0.78
GROUP * TRIAL	-116.01	696.86	402.60	-0.17	0.87
GROUP * TRIAL^2	-247.79	562.46	48947.99	-0.44	0.66
LOAD * TRIAL	-2415.14	577.55	49011.42	-4.18	<0.001
LOAD * TRIAL^2	-703.72	578.22	48974.36	-1.22	0.22
BLOCK * TRIAL	895.48	371.64	1734.10	2.41	0.016
BLOCK * TRIAL^2	-252.99	322.03	48941.30	-0.79	0.43
PRES * EMOTION * GROUP	-0.25	8.04	48945.46	-0.03	0.98
PRES * EMOTION * LOAD	3.10	8.33	48945.13	0.37	0.71
PRES * GROUP * LOAD	-11.32	9.11	48943.65	-1.24	0.21
EMOTION * GROUP * LOAD	-6.62	5.59	48972.39	-1.18	0.24
PRES * EMOTION * BLOCK	-0.24	4.67	48931.29	-0.05	0.96
PRES * GROUP * BLOCK	6.22	5.22	48938.63	1.19	0.23
EMOTION * GROUP * BLOCK	5.02	5.38	36412.66	0.93	0.35
PRES * LOAD * BLOCK	1.15	5.29	48943.99	0.22	0.83

EMOTION * LOAD * BLOCK	28.62	6.51	33476.50	4.40	<0.001
GROUP * LOAD * BLOCK	-5.07	5.87	38435.31	-0.86	0.39
PRES * EMOTION * TRIAL	168.92	1156.97	48944.42	0.15	0.88
PRES * EMOTION * TRIAL^2	2122.62	1142.00	48939.78	1.86	0.063
PRES * GROUP * TRIAL	-1607.96	1244.14	48947.97	-1.29	0.20
PRES * GROUP * TRIAL^2	723.98	1255.48	48955.42	0.58	0.56
EMOTION * GROUP * TRIAL	94.37	794.50	49031.09	0.12	0.91
EMOTION * GROUP * TRIAL^2	1820.25	790.00	48942.90	2.30	0.021
PRES * LOAD * TRIAL	-662.42	1297.92	48951.12	-0.51	0.61
PRES * LOAD * TRIAL^2	2831.37	1286.70	48956.10	2.20	0.028
EMOTION * LOAD * TRIAL	111.39	807.10	49020.13	0.14	0.89
EMOTION * LOAD * TRIAL^2	344.09	810.17	48968.00	0.43	0.67
GROUP * LOAD * TRIAL	-844.48	893.37	49005.65	-0.95	0.34
GROUP * LOAD * TRIAL^2	1742.45	887.76	48969.38	1.96	0.0497
PRES * BLOCK * TRIAL	-55.50	725.79	48945.99	-0.08	0.94
PRES * BLOCK * TRIAL^2	12.48	716.98	48935.70	0.02	0.99
EMOTION * BLOCK * TRIAL	-1031.66	580.49	708.16	-1.78	0.076
EMOTION * BLOCK * TRIAL^2	-249.37	459.67	48944.84	-0.54	0.59
GROUP * BLOCK * TRIAL	-383.67	587.81	1708.95	-0.65	0.51
GROUP * BLOCK * TRIAL^2	-323.91	506.41	48938.86	-0.64	0.52
LOAD * BLOCK * TRIAL	-335.52	632.90	907.08	-0.53	0.60
LOAD * BLOCK * TRIAL^2	-396.53	510.50	48982.40	-0.78	0.44
PRES * EMOTION * GROUP * LOAD	-0.37	12.77	48945.40	-0.03	0.98
PRES * EMOTION * GROUP * BLOCK	-7.55	7.18	48935.42	-1.05	0.29
PRES * EMOTION * LOAD * BLOCK	-4.05	7.47	48945.58	-0.54	0.59
PRES * GROUP * LOAD * BLOCK	-5.56	8.37	48947.24	-0.67	0.51
EMOTION * GROUP * LOAD * BLOCK	-12.09	10.03	33392.34	-1.21	0.23
PRES * EMOTION * GROUP * TRIAL	-694.33	1749.12	48953.02	-0.40	0.69
PRES * EMOTION * GROUP * TRIAL^2	-1601.14	1765.69	48953.00	-0.91	0.36
PRES * EMOTION * LOAD * TRIAL	-149.92	1831.97	48951.68	-0.08	0.93
PRES * EMOTION * LOAD * TRIAL^2	-4015.94	1812.62	48956.35	-2.22	0.027
PRES * GROUP * LOAD * TRIAL	1061.02	1975.80	48949.50	0.54	0.59
PRES * GROUP * LOAD * TRIAL^2	-2444.46	1987.72	48967.26	-1.23	0.22
EMOTION * GROUP * LOAD * TRIAL	1495.91	1247.45	49026.62	1.20	0.23
EMOTION * GROUP * LOAD * TRIAL^2	-2305.18	1241.49	48961.85	-1.86	0.063
PRES * EMOTION * BLOCK * TRIAL	-625.93	1034.87	48942.94	-0.61	0.55
PRES * EMOTION * BLOCK * TRIAL^2	381.98	1021.95	48933.18	0.37	0.71
PRES * GROUP * BLOCK * TRIAL	-1115.81	1143.44	48946.35	-0.98	0.33
PRES * GROUP * BLOCK * TRIAL^2	201.76	1153.68	48937.57	0.18	0.86
EMOTION * GROUP * BLOCK * TRIAL	1699.16	888.59	707.12	1.91	0.056

EMOTION * GROUP * BLOCK * TRIAL^2	774.67	700.74	48940.22	1.11	0.27
PRES * LOAD * BLOCK * TRIAL	567.04	1158.33	48951.33	0.49	0.62
PRES * LOAD * BLOCK * TRIAL^2	-705.89	1145.82	48950.21	-0.62	0.54
EMOTION * LOAD * BLOCK * TRIAL	2274.68	1010.21	407.30	2.25	0.025
EMOTION * LOAD * BLOCK * TRIAL^2	144.84	721.23	48975.16	0.20	0.84
GROUP * LOAD * BLOCK * TRIAL	570.10	1004.06	898.63	0.57	0.57
GROUP * LOAD * BLOCK * TRIAL^2	1581.95	805.38	48967.77	1.96	0.0495
PRES * EMOTION * GROUP * LOAD * BLOCK	11.54	11.45	48946.23	1.01	0.31
PRES * EMOTION * GROUP * LOAD * TRIAL	1380.48	2777.39	48950.47	0.50	0.62
PRES * EMOTION * GROUP * LOAD * TRIAL^2	3170.59	2794.99	48965.55	1.13	0.26
PRES * EMOTION * GROUP * BLOCK * TRIAL	1243.29	1576.47	48944.20	0.79	0.43
PRES * EMOTION * GROUP * BLOCK * TRIAL^2	-522.87	1591.22	48935.05	-0.33	0.74
PRES * EMOTION * LOAD * BLOCK * TRIAL	-1001.24	1648.60	48964.48	-0.61	0.54
PRES * EMOTION * LOAD * BLOCK * TRIAL^2	-440.23	1627.89	48949.81	-0.27	0.79
PRES * GROUP * LOAD * BLOCK * TRIAL	1422.26	1835.42	48965.95	0.78	0.44
PRES * GROUP * LOAD * BLOCK * TRIAL^2	-2147.26	1837.00	48945.89	-1.17	0.24
EMOTION * GROUP * LOAD * BLOCK * TRIAL	-2980.12	1552.42	409.58	-1.92	0.056
EMOTION * GROUP * LOAD * BLOCK * TRIAL^2	-2421.79	1103.29	48964.06	-2.20	0.028
PRES * EMOTION * GROUP * LOAD * BLOCK * TRIAL	-690.83	2520.53	48963.36	-0.27	0.78
PRES * EMOTION * GROUP * LOAD * BLOCK * TRIAL^2	3174.82	2527.10	48949.56	1.26	0.21
Model 3 - Random Effects					
σ2	17967.18				
τ00 Participants	4205.11				
τ11 Participants*TRIAL	4180098.12				
ρ01 Participants	-0.12				
ICC	0.19				
N Participants	103.00				
Observations	49134.00				
Marginal R2 / Conditional R2	0.287 / 0.422				
Model 3, Low Load Only - Fixed Effects	**b-Value**	**Std. Error**	**df**	**t-value**	**p-value**
(Intercept)	458.73	8.53	105.52	53.80	<0.001

PRES	21.32	2.91	28998.14	7.32	<0.001
EMOTION	-3.87	1.82	29014.61	-2.13	0.034
GROUP	-21.75	13.05	105.61	-1.67	0.10
BLOCK	-7.49	1.84	25180.15	-4.07	<0.001
TRIAL	-406.72	325.93	195.68	-1.25	0.21
TRIAL^2	1115.62	221.67	29005.95	5.03	<0.001
PRES * EMOTION	7.95	4.09	28996.78	1.94	0.052
PRES * GROUP	-0.70	4.49	29006.27	-0.16	0.88
EMOTION * GROUP	4.46	2.80	29022.24	1.59	0.11
PRES * BLOCK	-1.35	2.58	28995.02	-0.52	0.60
EMOTION * BLOCK	-20.46	3.29	22861.65	-6.22	<0.001
GROUP * BLOCK	-3.74	2.93	25082.19	-1.28	0.20
PRES * TRIAL	804.42	495.18	29006.53	1.63	0.10
PRES * TRIAL^2	-1569.83	489.75	29001.84	-3.21	0.0014
EMOTION * TRIAL	-260.12	311.63	29083.30	-0.84	0.40
EMOTION * TRIAL^2	-71.76	311.84	29004.58	-0.23	0.82
GROUP * TRIAL	-161.20	500.73	198.11	-0.32	0.75
GROUP * TRIAL^2	-215.10	339.78	29007.17	-0.63	0.53
BLOCK * TRIAL	631.78	250.90	995.73	2.52	0.012
BLOCK * TRIAL^2	-192.65	194.51	29000.45	-0.99	0.32
PRES * EMOTION * GROUP	-0.19	6.30	29006.08	-0.03	0.98
PRES * EMOTION * BLOCK	-0.83	3.66	28993.61	-0.23	0.82
PRES * GROUP * BLOCK	5.93	4.09	28998.69	1.45	0.15
EMOTION * GROUP * BLOCK	20.68	5.05	22812.78	4.10	<0.001
PRES * EMOTION * TRIAL	127.37	698.44	29004.27	0.18	0.86
PRES * EMOTION * TRIAL^2	1692.20	689.79	29000.32	2.45	0.014
PRES * GROUP * TRIAL	-1238.90	751.22	29006.16	-1.65	0.10
PRES * GROUP * TRIAL^2	622.97	758.45	29014.50	0.82	0.41
EMOTION * GROUP * TRIAL	24.76	480.04	29090.69	0.05	0.96
EMOTION * GROUP * TRIAL^2	1380.32	477.21	29003.41	2.89	0.0038
PRES * BLOCK * TRIAL	-110.27	438.18	29005.88	-0.25	0.80
PRES * BLOCK * TRIAL^2	63.45	433.06	28996.85	0.15	0.88
EMOTION * BLOCK * TRIAL	-772.32	411.94	479.40	-1.88	0.06
EMOTION * BLOCK * TRIAL^2	-219.27	277.68	29003.88	-0.79	0.43
GROUP * BLOCK * TRIAL	45.31	396.70	987.13	0.11	0.91
GROUP * BLOCK * TRIAL^2	-228.19	305.88	28998.81	-0.75	0.46
PRES * EMOTION * GROUP * BLOCK	-6.50	5.63	28996.56	-1.16	0.25
PRES * EMOTION * GROUP * TRIAL	-497.02	1056.20	29010.66	-0.47	0.64
PRES * EMOTION * GROUP * TRIAL^2	-1342.74	1066.70	29013.29	-1.26	0.21
PRES * EMOTION * BLOCK * TRIAL	-405.44	624.71	29003.85	-0.65	0.52

PRES * EMOTION * BLOCK * TRIAL^2	273.31	617.24	28994.95	0.44	0.66
PRES * GROUP * BLOCK * TRIAL	-876.48	690.42	29005.61	-1.27	0.20
PRES * GROUP * BLOCK * TRIAL^2	102.16	696.85	28998.04	0.15	0.88
EMOTION * GROUP * BLOCK * TRIAL	1180.30	629.98	480.11	1.87	0.06
EMOTION * GROUP * BLOCK * TRIAL^2	586.30	423.28	29000.12	1.39	0.17
PRES * EMOTION * GROUP * BLOCK * TRIAL	990.38	951.83	29004.88	1.04	0.30
PRES * EMOTION * GROUP * BLOCK * TRIAL^2	-321.94	961.11	28996.49	-0.34	0.74
Model 3, Low Load Only - Random Effects					
σ2	11021.41				
τ00 Participants	4190.48				
τ11 Participants*TRIAL	3369740.76				
ρ01 Participants	0.05				
ICC	0.28				
N Participants	103				
Observations	29195				
Marginal R2 / Conditional R2	0.042 / 0.306				
Model 3, High Load Only - Fixed Effects	**b-Value**	**Std. Error**	**df**	**t-value**	**p-value**
(Intercept)	627.94	11.30	108.57	55.55	<0.001
PRES	16.05	5.53	19750.66	2.90	0.0037
EMOTION	2.36	3.39	19839.42	0.70	0.49
GROUP	-7.00	17.31	108.90	-0.40	0.69
BLOCK	-29.78	3.44	13742.24	-8.67	<0.001
TRIAL	-2279.11	450.97	217.00	-5.05	<0.001
TRIAL^2	575.81	340.18	19815.78	1.69	0.09
PRES * EMOTION	11.33	7.74	19755.64	1.46	0.14
PRES * GROUP	-12.62	8.46	19750.42	-1.49	0.14
EMOTION * GROUP	-0.43	5.23	19871.55	-0.08	0.93
PRES * BLOCK	-0.23	4.94	19758.37	-0.05	0.96
EMOTION * BLOCK	2.45	6.02	11224.77	0.41	0.68
GROUP * BLOCK	-8.24	5.49	13717.52	-1.50	0.13
PRES * TRIAL	162.11	765.58	19764.74	0.21	0.83
PRES * TRIAL^2	390.33	759.31	19764.53	0.51	0.61
EMOTION * TRIAL	50.40	475.07	19753.60	0.11	0.92
EMOTION * TRIAL^2	156.18	475.33	19805.79	0.33	0.74
GROUP * TRIAL	-447.26	696.50	222.08	-0.64	0.52
GROUP * TRIAL^2	888.27	522.59	19798.81	1.70	0.09
BLOCK * TRIAL	243.97	371.11	753.75	0.66	0.51
BLOCK * TRIAL^2	-346.66	301.35	19812.08	-1.15	0.25

PRES * EMOTION * GROUP	-1.55	11.83	19754.11	-0.13	0.90
PRES * EMOTION * BLOCK	-3.98	6.95	19763.92	-0.57	0.57
PRES * GROUP * BLOCK	1.61	7.81	19755.27	0.21	0.84
EMOTION * GROUP * BLOCK	18.01	9.30	11279.12	1.94	0.053
PRES * EMOTION * TRIAL	206.45	1081.00	19770.36	0.19	0.85
PRES * EMOTION * TRIAL^2	-1025.56	1070.19	19770.33	-0.96	0.34
PRES * GROUP * TRIAL	-262.07	1168.07	19773.81	-0.22	0.82
PRES * GROUP * TRIAL^2	-1222.40	1171.59	19765.45	-1.04	0.30
EMOTION * GROUP * TRIAL	802.90	737.24	19605.05	1.09	0.28
EMOTION * GROUP * TRIAL^2	-377.11	728.78	19792.13	-0.52	0.60
PRES * BLOCK * TRIAL	207.22	687.65	19763.66	0.30	0.76
PRES * BLOCK * TRIAL^2	-564.12	679.60	19771.88	-0.83	0.41
EMOTION * BLOCK * TRIAL	933.42	584.52	335.82	1.60	0.11
EMOTION * BLOCK * TRIAL^2	36.22	422.94	19804.78	0.09	0.93
GROUP * BLOCK * TRIAL	473.70	591.18	731.99	0.80	0.42
GROUP * BLOCK * TRIAL^2	744.44	476.39	19798.34	1.56	0.12
PRES * EMOTION * GROUP * BLOCK	2.20	10.64	19757.28	0.21	0.84
PRES * EMOTION * GROUP * TRIAL	54.44	1642.18	19781.93	0.03	0.97
PRES * EMOTION * GROUP * TRIAL^2	1412.22	1648.09	19772.34	0.86	0.39
PRES * EMOTION * BLOCK * TRIAL	-1063.94	977.63	19790.45	-1.09	0.28
PRES * EMOTION * BLOCK * TRIAL^2	-138.03	963.71	19774.38	-0.14	0.89
PRES * GROUP * BLOCK * TRIAL	172.32	1092.64	19773.96	0.16	0.87
PRES * GROUP * BLOCK * TRIAL^2	-1250.72	1086.84	19759.27	-1.15	0.25
EMOTION * GROUP * BLOCK * TRIAL	-916.19	902.06	335.72	-1.02	0.31
EMOTION * GROUP * BLOCK * TRIAL^2	-1118.51	648.39	19795.51	-1.73	0.08
PRES * EMOTION * GROUP * BLOCK * TRIAL	625.92	1496.60	19777.75	0.42	0.68
PRES * EMOTION * GROUP * BLOCK * TRIAL^2	1899.57	1492.77	19768.53	1.27	0.20
Model 3, High Load Only - Random Effects					
σ2	25552.84				
τ00 Participants	7184.88				
τ11 Participants*TRIAL	5043174.39				
ρ01 Participants	-0.01				
ICC	0.22				
N Participants	103				
Observations	19939				
Marginal R2 / Conditional R2	0.042 / 0.252				

Vita

Nina Plotnikov was born on March 5th, 1996, in Pittsburgh, Pennsylvania. She graduated from Niskayuna High School, Niskayuna, New York in 2014 and received her Bachelor of Arts in Psychology from Barnard College of Columbia University in the City of New York, New York in 2018. While at Barnard, Nina worked as a research assistant for Dr. Lisa K. Son and Dr. Janet Metcalfe. In the fall of 2018, she enrolled in the Clinical Psychology Doctoral Degree program at Virginia Commonwealth University in Richmond, Virginia under the mentorship of Dr. Scott Vrana.