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Neural Correlates of Inhibitory Function Following the Implicit Processing of Emotional Faces

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NEURAL CORRELATES OF INHIBITORY FUNCTION FOLLOWING THE IMPLICIT PROCESSING OF EMOTIONAL FACES

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ABSTRACT

Emotion and cognitive function interact to play a central role in determining human thought and behavior. Attention to emotion can facilitate or hinder cognitive control efforts based on the given contextual demands of the task at hand. This study used scalp electroencephalography (EEG) methods to examine the link between valence of facial stimuli and neural changes associated with emotional face processing and subsequent inhibitory response. 20 participants completed a gender discrimination stop-signal task using emotional faces. Facial valence did not differentially modulate the P200 event-related potential (ERP), indicating that happy and sad faces recruit similar neural resources in the context of implicit emotional processing. However, facial valence did significantly affect participant accuracy during response trials of gender discrimination. Trials of sad faces resulted in a higher accuracy in comparison to trials of happy faces. No significant modulation of the frontal P300 due to facial valence was observed. These results suggest that while facial valence may not modulate neural response during implicit processing of affective facial stimuli and subsequent inhibitory response, differences can be observed in behavioral response.

CHAPTER ONE

INTRODUCTION

Emotion and cognitive function interact to play a central role in determining human behavior. Attention to emotion can facilitate or hinder cognitive control efforts based on the given contextual demands of the task at hand. Emotional content of stimuli have been found to affect cognitive processing mechanisms as early as 200-300 ms following exposure (Ashley, Vuilleumier, & Swick, 2004; Schupp, Junghöfer, Weike, & Hamm, 2003). In daily life, individuals are constantly navigating a flood of emotions, ranging from interpreting the facial expressions of others to regulating their own emotional responses. The extant literature suggests that how an individual perceives their surrounding emotional stimuli will influence their cognitive function (Blair et al., 2007; Ochsner & Gross, 2005; Pessoa, 2009; Schultz, 2005); however, minimal research has explicitly tested the cascade of emotional perception on cognitive function using measures that are adequate to capture the rapid time course of this cascade. The proposed study will examine the neural correlates of implicit processing of emotionally valenced faces on early emotion processing and subsequent inhibitory function, a component of cognitive control.

While individual factors such as various types of psychopathology and adverse developmental experiences are known to modulate the perception of emotions (Drevets, 2001; Fox, Russo, & Georgiou, 2005; Kohler et al., 2010), very little is known about how

"in the moment" emotion perception influences subsequent inhibitory function in healthy individuals or those with psychopathology. Developing a basic understanding of the cascade of emotion perception on subsequent inhibitory response is a crucial first step to build a strong foundation for future research in psychopathology and related treatments for psychopathology.

Cognition encompasses a number of sophisticated processes including: attention, memory, language, and cognitive control. These processes largely recruit from resources within the prefrontal cortex (dorsolateral prefrontal cortex, DLPFC; anterior cingulate cortex, ACC; inferior frontal cortex, IFC; Aron, Robbins, & Poldrack, 2004; Rubia, Smith, Brammer, & Taylor 2003). As human processing capacity is limited, competition for neural resources will occur under conditions of high perceptual and cognitive demand (Marois & Ivanoff, 2005). Rapid detection of the most important information in a given scenario is central to adaptive function. It is hypothesized that the more flexible an individual is at adjusting processing efforts, the more adaptive they will be at deciding between competitive choices (Pessoa, 2009). The mechanisms utilized to adjust to a given environment are largely guided by selective attention and inhibitory control. Selective attention is directed by the appraisal of salient stimuli, with the affective significance of a stimuli being of importance (Compton, 2003). The activation of these appraisal and emotional attention mechanisms may operate independently of more voluntary components of attentional control. The rapid succession of emotional processing necessitates objective and temporally resolute measures of perception and response.

The interactions of emotion and cognitive functions are further echoed in the structural and connective characteristics of the human brain. The prefrontal cortex (PFC) has been associated with both effortful control and affective processes (Engels et al., 2007). Specifically within the PFC, the anterior cingulate cortex (ACC) plays an integral role in the attentional regulation of both cognitive and emotional processing. Historically the dorsal ACC (dACC) has been viewed as broadly servicing cognitive information and the rostral ACC (rACC) attending primarily to affective information (Bush, Luu & Posner, 2000; Mohanty et al., 2007). However, emerging work suggests that discrete labelling of cognitive (dorsal) and emotional (rostral) processes results in an oversimplification of the complex association between goal-directed and affective processes (Phelps, Lempert & Sokol-Hessner, 2014). Additionally, the orbital PFC is closely associated with medial temporal limbic structures central to affective and motivational experience. Within the limbic system, the hypothalamus is recruited during goal-directed behaviors through outputs via the thalamus to the cortex as well as descending connections to the brainstem motor systems. The hypothalamus receives direct projections from PFC components and plays an integral role in generating both reflexive and controlled behaviors (Swanson, 2000).

Given the shared employment of cortical and subcortical structures in both emotion and cognitive function, limitations on pooled resources can result in impaired cognitive function (Vuilleumier, 2005). More specifically, models of resource depletion describe cognitive control as a finite resource, with engagement in one task of executive control impairing the performance on a subsequent task recruiting the same resource (Baddeley & Hitch, 1974; Persson, Larsson, & Reuter-Lorenz, 2013). Similarly,

according to capacity theory, human ability to perform multiple concurrent tasks is constrained as supply of control resources is restricted (Marois & Ivanoff, 2005). What then happens when emotional information is presented in conjunction with cognitively demanding tasks? The dual competition model (Pessoa, 2009) asserts that emotion and motivation affect both perceptual and executive competition. Resulting behavior will either experience an enhancement or impairment to cognitive function, such as inhibitory response, that is dependent upon the specific interaction between emotion and motivation with cognitive control. According to the dual competition framework, the affective significance of incoming data plays a critical role in how information is processed under conditions of limited resource. The proposed study aims to build upon this framework by investigating how the implicit processing of emotional faces impacts inhibitory response.

Perception of Emotion and Attentional Control

In conditions where attentional resources are limited, as temporally or spatially dictated, emotionally salient information is prioritized and receives privileged access to attention and awareness (Vuilleumier & Schwartz, 2001). Despite the preferential allocation of resources directed at emotionally salient stimuli, conventional regulatory influences (e.g., high attentional load and suppression) still impact sensory processing. However, under conditions of limited resources the preferential representation of emotional stimuli provides a robust persistence against regulatory influences in comparison to the processing of neutral stimuli (Vuilleumier, 2005). This resistance has been replicated across various mechanisms of emotional arousal, including: faces, words, scenes, and conditioned stimuli (Öhman, Flykt, & Esteves, 2001; Vuilleumier, 2005). These emotional biases are increasingly reinforced when presented with “biologically

prepared" stimuli, such as faces or threat-related emotions that have been established through evolutionary function (Lang, Davis, & Öhman, 2000).

Effects of emotional valence should not be studied in a vacuum, as arousal has been observed to significantly impact the dynamics of attentional processing (Anderson, 2005). Research has found that images and expressions of a strong valence are generally viewed as more arousing than neutral stimuli (Kensinger & Corkin, 2003; Lane, Chua, & Dolan, 1999). Stimuli may be viewed as having appetitive or aversive activation. Both appetitive and aversive emotional stimuli have been found to more effectively capture and sustain attention, resulting in increased processing even when not directly attended (Hartikainen, Ogawa, & Knight, 2000; Pessoa, 2005). While response modulation has been observed for negatively valenced emotional stimuli (both threatening and nonthreatening), attentional resources are more dramatically recruited for the processing of emotional stimuli when emotional salience is high in threat, resulting in a more pronounced effect on behavior (Öhman, Flykt, & Francisco, 2001). Since high-threat items are more likely to recruit common resources of attention that activate limbic circuitry central to emotional processing, this may result in a possible depletion of resources for subsequent cognitive control processes such as inhibition, shifting, and updating.

A facilitative effect of emotion is observed in visual task paradigms in which an emotional target must be identified among distracters (Fox, 2002; Öhman, Flykt, & Esteves, 2001). Supplementary effects of emotion have been observed during tasks in which participants are asked to discern targets (T1 and T2) from distractor stimuli following the rapid presentation of stimuli. Commonly referred to as attentional blink

paradigms, participants are likely to miss the identification of T2 (a "blink" in attention) when it follows T1 by a brief delay. However, increased T2 identification has been observed when T2 is emotionally salient in comparison to neutral conditions (Anderson, 2005).

Emotion Processing and Inhibitory Function

Cognitive control processes are the mechanisms through which humans use internal intentions to guide thought and behavior (Banich et al., 2009). While the exact components of cognitive control remain a topic of debate, it is generally believed that inhibition, shifting, and updating are central to executive function (Miyake & Friedman, 2012). Relevant to the proposed study, inhibition is the ability to modulate prepotent, automatic responses. Inhibitory function requires top-down attentional control and contributes to the ability to preclude maladaptive negative emotions and thoughts that may interfere with daily function (Silton et al., 2011). Top-down inhibitory-control processes engage frontocingulate brain networks (DLPFC and ACC) to recruit resources. When individuals are required to inhibit a prepotent response during a task, as required in stop-signal paradigms, a number of midfrontal ERPs are observed (Stockdale et al., under review). Specifically relevant to inhibitory processes, the P300 is a midline positive inflection that occurs 300-500ms following stimuli presentation during a task that requires response inhibition (Polich, 2007; Stockdale et al., under review).

Emotional stimuli have been observed to compete with limited resources allocated to inhibitory function processes during emotional variants of cognitive tasks (Macleod, 1991; Verbruggen & De Houwer, 2007; Yu et al 2009). During modified Stroop paradigms (i.e., "emotional stroop task"), color naming of a word is slowed when the

stimulus has an emotional meaning, despite emotion being irrelevant to the task (Koven, Heller, Banich, & Miller, 2003; Macleod, 1991). Increased response time to negative stimuli has also been observed during "Go trials" of Go/Nogo tasks (Yu et al., 2009). In two experiments investigating the modulation of inhibitory response by emotional stimuli, Verbruggen and Jan De Houwer (2007) demonstrated that the presentation of emotional stimuli impaired inhibitory function during a stop signal paradigm that required participants to inhibit behavior following exposure to emotionally valenced stimuli (positive, negative and neutral). Verbruggen and De Houwer reported a significant effect of stimuli based on arousal level, but found no evidence that modulation of inhibitory control was related to valence (positive vs negative). In contrast, a study of similar design conducted by Pessoa and colleagues (2012) found a supplementary effect of low-threat emotion stimuli on inhibitory function in comparison to neutral stimuli. Mixed findings on the effects of emotion on subsequent inhibitory function suggest that distinct emotional stimuli may differentially impact cognitive control processes and necessitate further research to parse apart the complex nature of these exchanges.

Emotional Processing in Daily Life: Interpreting Facial Expressions

Navigating nonverbal-human interactions, such as emotional facial expressions, is essential to daily function. Facial expressions are one of the most frequent emotional stimuli encountered on a daily basis, and facial emotion perception likely influences subsequent cognitive function "in the moment" for most humans. Dysfunctional processing of facial expressions may result in interpersonal impairments that underlie many clinical disorders, such as social anxiety, major depressive disorder, and autism spectrum disorder (Bourke, Douglas, & Porter, 2010; Grelotti, Gauthier, & Schultz, 2002;

Horley, Williams, Gonsalvez, & Gordon, 2004). Additionally, facial processing plays a critical role in perceiving and interpreting potential threat as well as aiding in aversion of negative experience (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003). Given the significance placed on interpreting emotional expressions in social settings, the use of facial stimuli in laboratory settings offers a strong approximation to the demands one would expect in the real world.

The processing of facial emotions largely involves visuospatial and attentional resources, activating cortical (e.g., ACC, DLPFC, primary and secondary visual cortex) and subcortical (e.g., amygdala, hippocampus, thalamus) structures (Palermo & Rhodes, 2007). Event-related potentials (ERP) are an ideal electroencephalography (EEG) measure for assessing the rapid processing of emotional faces given the excellent temporal resolution offered by ERPs. ERPs corroborate subjective accounts of emotion, which are greatly limited in terms of retrospection and conscious processing (Kozak & Miller, 1982). The P200 component has been shown to track the valence of emotional faces. Modulations in the P200 have been interpreted as indexing the allocation of additional attentional resources required to comprehend the emotional content of stimuli beyond holistic processing (Paulmann & Pell, 2009; Stockdale et al., under review). The P200 is observed as a positive inflection occurring around 200ms after exposure to an emotional face. The component is typically observed in right-lateralized frontal electrode sites (Ashley, Vuilleumier, & Swick 2004), consistent with the right hemisphere's dominant role in spatial processing (Becker & Karnath, 2007; Shulman et al., 2010).

While the prioritization of emotional stimuli during attentional processing has been previously observed (Schupp et al., 2003; Vuilleumier, 2005), the mechanisms

underlying the integration of emotional information and cognitive control necessitate further exploration. Specifically, it is not clear what effect early emotion processing may have on subsequent cognitive control function. The current study aims to elucidate the neural and behavioral dynamics involved in the integration of affective processing and inhibitory control. It is hypothesized that findings of the proposed study will show that individuals are not only sensitive to the emotional content of faces during implicit presentation of facial emotions, but that stimuli response is facilitated by the implicit processing of positively valenced faces and inhibitory control is reduced by the implicit processing of negatively valenced faces.

CHAPTER TWO

METHOD

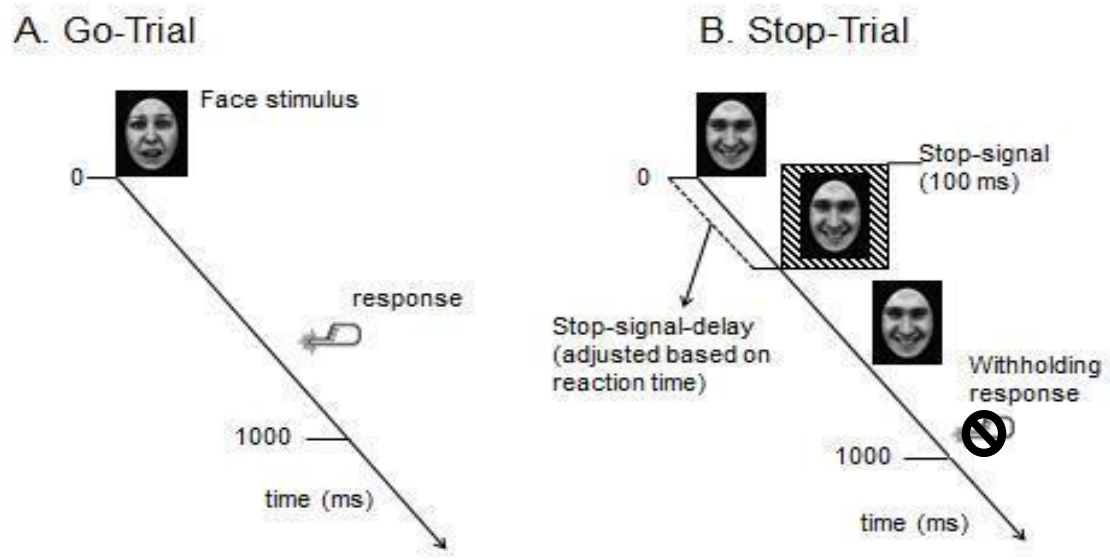
Participants

Participants were recruited from an urban Midwestern university. All participants were right-hand dominant with no known history of neurological disorders. Participants included in this study are a part of a larger, on-going study and were compensated $15/hour for their time. All procedures described were approved by the university Institutional Review Board.

Materials and Procedure

Participants (N = 20) completed a stop-signal task in order to assess implicit processing of valenced faces (Sagaspe, Schwartz, & Vuilleumier, 2011). This task required participants to indicate gender of human faces; however, each face also conveyed either happiness or sadness. The task included 60 (30 male, 30 female) digitized photographic images of Caucasian faces selected from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998). Face stimuli were converted to grayscale, and then balanced for luminance and contrast in Adobe Photoshop. In order to minimize non-facial gender cues, images were cropped with an oval mask (see Figure 1).

Figure 1. Stop-Signal Paradigm



Note. Task trials, displaying one Go (A) and one Stop (B) trial. Participants will perform an implicit emotion (gender discrimination) task by pressing a button to respond to the gender, but inhibiting their response if the picture is framed by a dashed line. Faces will express either happiness or sadness (50% each), which is irrelevant to the task. The stop-signal delay will be adjusted based on the participants' behavior using the following rule: 50 ms added after successful inhibition (making it harder on the next stop-signal trial) or 50 ms subtracted after unsuccessful inhibition (making it easier to inhibit on the next stop-signal task).

During *go-trials* (Figure 1), participants were instructed to press a button to indicate whether the stimulus image was a male or female (regardless of facial expression valence). Go-trials began with a fixation screen that was followed by the 1-second presentation of a valenced face. During the 1-second display of the valenced face, participants were to respond to stimuli gender by pressing one of two buttons on an electronic response box. A black screen was displayed following the stimulus. As shown

in Figure 1, *stop-trials* included the 100ms presentation of a stop-signal (a shaded box placed behind the valenced face stimuli) shortly after presentation of the face stimulus. In efforts to standardize task difficulty across participants, the short delay between valenced face stimulus presentation and onset of the stop signal was jittered (200 – 500 ms) based on participant task performance. For example, if a participant successfully inhibited his/her response on two consecutive stop-trials, the delay between face stimulus presentation and stop-signal onset was increased by 20 ms. Accordingly, the better a participant performed at inhibiting response on stop-trials the longer the stop-signal delay became, thereby making the next stop trial more difficult and regulating effort across participants (Sagaspe, Schwartz, & Vuilleumier, 2011).

Participants were provided task instructions and then asked to complete two practice blocks of 20 trials each. Practice blocks included performance feedback in order to assure participant comprehension of the task. Upon completion of practice blocks, participants completed a total of 720 trials (12 blocks of 52 trials). A 20 second break was given between each block to attenuate participant fatigue. "Stop" and "Go" trials were evenly divided across all blocks. Additionally, blocks were balanced for valence (happy/sad) and gender (male/female). Participants were seated 100cm from a 21-inch CRT monitor in noise-controlled chamber. E-Prime 2.0 (Schneider, Eschman, & Zuccolotto, 2002) was utilized for stimuli presentation.

EEG Recording and Data Reduction

EEG data was recorded with a Biosemi Active2 EEG system, using custom-designed Falk Minow caps with 64 equidistant active electrodes. Common Mode Sense

(CMS) and Driven Right Leg (DRL) electrodes were placed near the vertex. Two additional electrodes were positioned on the inferior edge of the orbit of each eye to monitor eye movements. Data was collected at a sampling rate of 512 Hz.

EEG data was processed in Brain Electrical Source Analysis software (BESA,Version 6.0). Following the adaptive artifact correction method (Ille, Berg, Scherg, 2002), ocular artifacts were removed using a spatial PCA filter. Muscle and other artifact were manually removed through visual inspection of individual data. Baseline adjustment was corrected using the averaged amplitude of 100 ms prestimulus onset. Data was referenced using an average reference and digitally filtered with a .01 high-pass filter and band-stop filter from 59-61 Hz.

Mean amplitude and latency was calculated for the right frontal P200 on go-trials and the frontocentral P300 on stop-trials. Electrode selection and temporal windows were informed by visual inspection of the current data as well as *a priori* judgments based on findings from previous studies investigating these ERP components in similar contexts.

Power Analysis

To determine sufficient sample size to detect differences between conditions, a power analysis was conducted using G*Power version 3.1 (Faul, Erdfelder, Lang, Buchner, 2007). Power (1-β) was set at .80 and α was set at .05 for a two-tailed test. The power analysis indicated that a total sample size of N = 24 participants is recommended to detect a medium effect size in the proposed study (f = .25; Cohen, 1988).

CHAPTER THREE

RESULTS

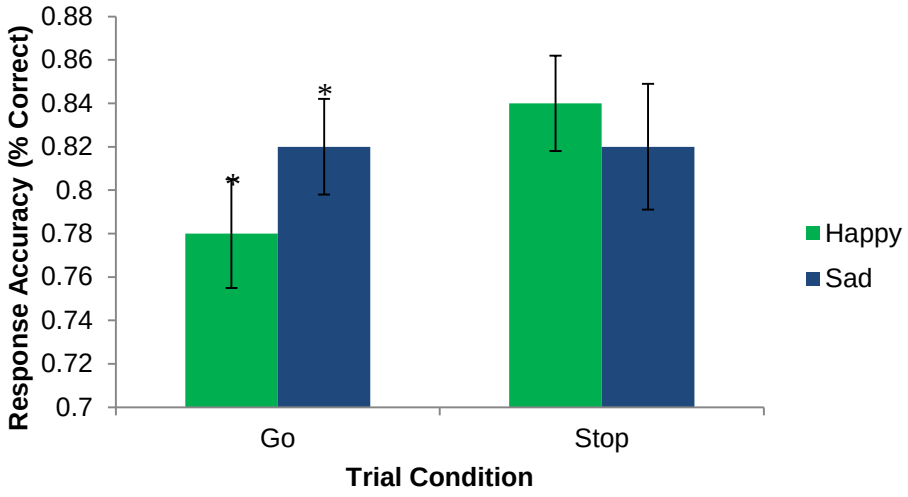
In order to investigate the effect of valence on the implicit processing of emotional faces, behavioral data in conjunction with P200 amplitude and latency during Go trials were examined. To explore the effect of valenced emotional faces on inhibitory response, behavioral data and P300 amplitude and latency obtained during Stop trials were examined. Three participants were excluded from data analysis due to technical difficulties that resulted in missing EEG data. The following results were calculated using the 17 remaining participants.

Behavioral Results

Go Trials

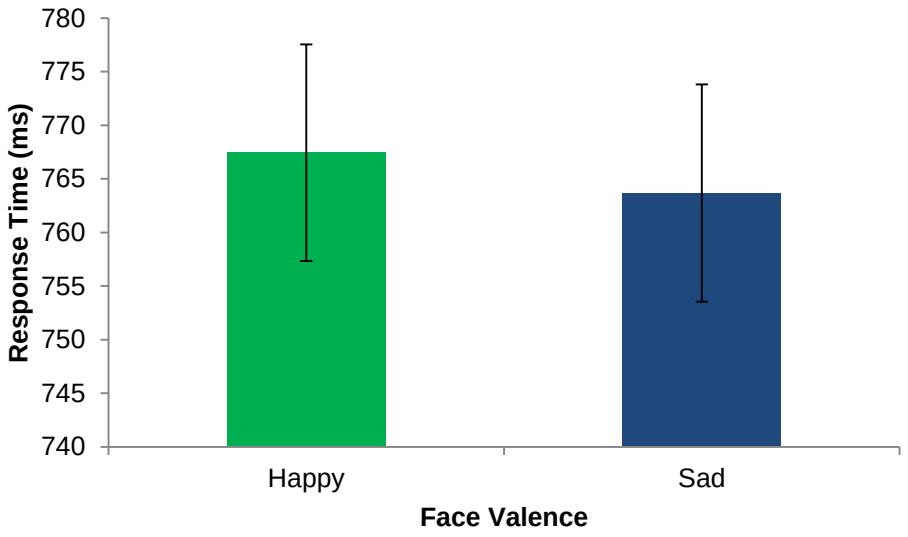
To assess potential behavioral differences in response due to valence of emotional-face processing, two repeated-measures ANOVAs were conducted to examine accuracy and response time (RT) for happy and sad faces for the go-trials only. With regard to accuracy, a significant effect of face valence was observed ($F(1, 16) = 17.09$, $p < 0.01$, $\eta^2p = .52$). Individuals were more accurate at identifying the gender of sad faces compared to happy faces (See Figure 2). Response time (RT) did not differ across face valence conditions ($F(1, 16) = 0.93$, $p = 0.35$, $\eta^2p = 0.06$; See Figure 3).

Figure 2. Accuracy by Valence on Go- and Stop-Trials of the Stop-Signal Task



Note. *$p<.01$; Mean response accuracy representing percentage correct for each trial condition by face valence is presented. Standard errors are represented in the figure by the error bars attached to each column.

Figure 3. Response Time by Valence on Go-Trials of the Stop-Signal Task.



Note. Mean response time (ms) representing average time to correctly discriminate gender by face valence is presented. Standard errors are represented in the figure by the error bars attached to each column.

Stop-Trials

To assess the impact of face valence on inhibitory response a repeated-measures ANOVA was conducted. There was no significant effect of face valence on stop-signal accuracy ($F(1, 16) = 1.75$, $p = 0.21$, $\eta^2p = 0.10$; See Figure 2). This is in contrast to the go-trial results discussed above, in which participants were more accurate on trials involving sad faces.

The behavioral data from the go-trials suggest that negatively-valenced images (sad faces) may facilitate the accurate discrimination of gender, while the same effect is not present when participants engage in a task demands requiring increased top-down attentional resources for behavioral inhibition. In lieu of RT (as a correct response is achieved by withholding a response) the average delay (i.e., stop-signal delay) between the presentation of the face and the stop-signal was calculated. However, as the stop-signal delay is adjusted using the two previous trials, a measurement of stop-signal delay could not be specifically calculated for each happy and sad faces.

ERP Results

Go-Trials

P200 Mean Amplitude and Peak Latency (see Figure 4). A repeated-measures ANOVA was conducted to examine the influence of face valence on the mean amplitude of the right frontal P200. No significant effect of face valence was detected ($F(1, 16) = 0.80$, $p = 0.39$, $\eta^2p = 0.05$; see Figure 5). These analyses suggest that valence of facial expression does not differentially modulate P200 response. A second repeated measures ANOVA was also conducted to examine the influence of face valence on the right frontal P200 latency in response to emotional faces. Face valence was not found to significantly

impact P200 latency ($F(1, 16) = 0.04$, $p = 0.84$, $\eta^2p = 0.003$; see Figure 6). Together, these analyses suggest that exposure to happy and sad faces recruit similar neural resources during implicit processing of emotional faces.

Figure 4. P200 ERP by Face Valence on Go-Trials of the Stop-Signal Task.

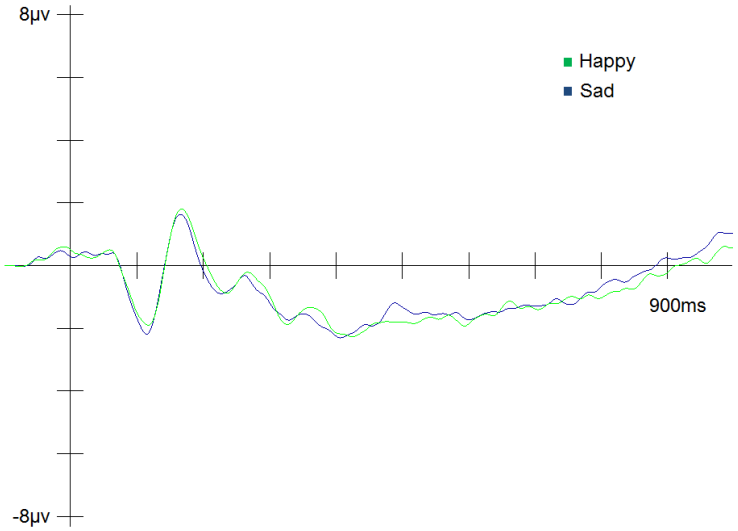
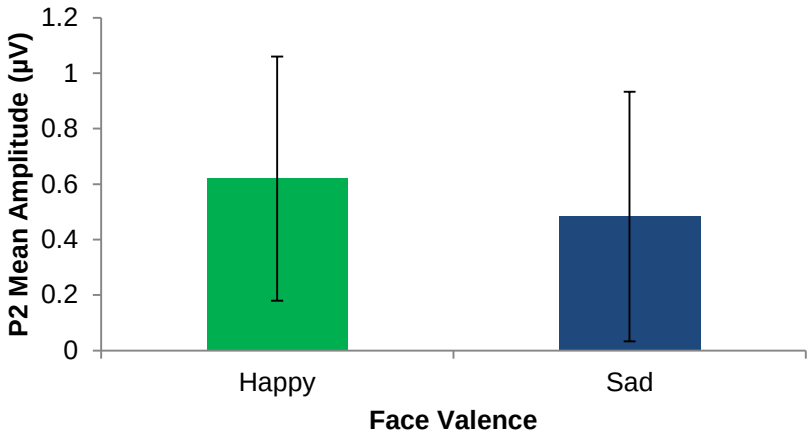
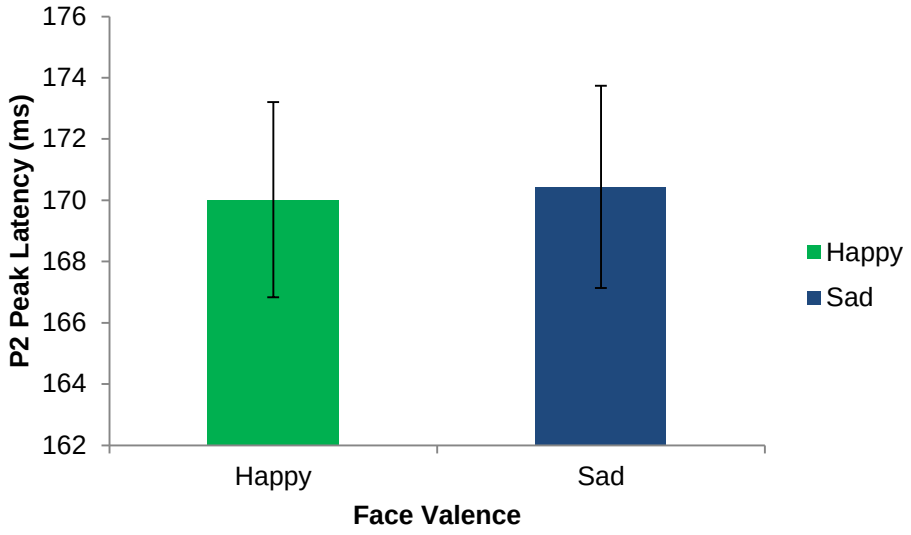


Figure 5. P200 Mean Amplitude by Face Valence.



Note. P200 mean amplitude (μv) by face valence is displayed. Standard errors are represented in the figure by the error bars attached to each column.

Figure 6. P200 Peak Latency by Face Valence.



Note. P200 peak latency (ms) by face valence is displayed. Standard errors are represented in the figure by the error bars attached to each column.

Stop Trials

P300 Amplitude (See Figure 7). A repeated-measures ANOVA was conducted to examine the influence of face valence on the frontocentral P300 mean amplitude. No significant effect of valence was detected ($F(1, 16) = 1.27$, $p = 0.28$, $\eta^2p = .07$; See Figure 8). A second repeated measures ANOVA was also conducted to examine the influence of face valence on the right frontal P300 latency. Similarly, no significant effect of valence was detected on right frontal P300 latency ($F(1, 16) = 0.01$, $p = 0.93$, $\eta^2p < .01$; See Figure 9). Contrary to our hypotheses, sad and happy faces were not found to have differential effects on the recruitment of neural resources during a task requiring response inhibition.

Figure 7. P300 ERP by Face Valence on Stop-Trials of the Stop Signal Task.

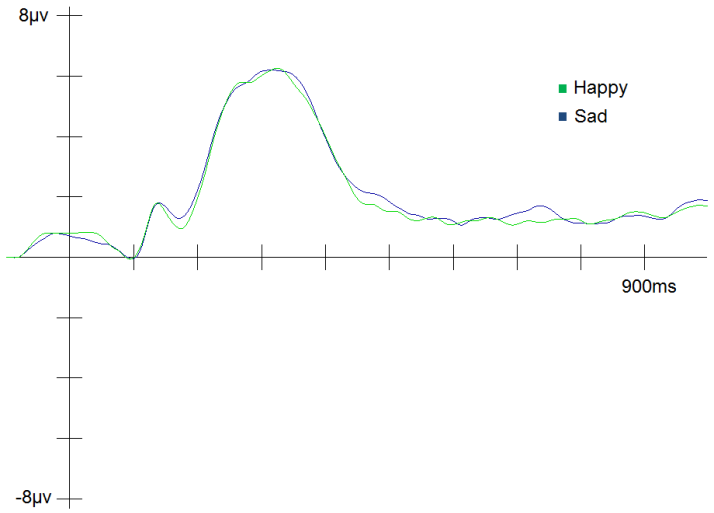
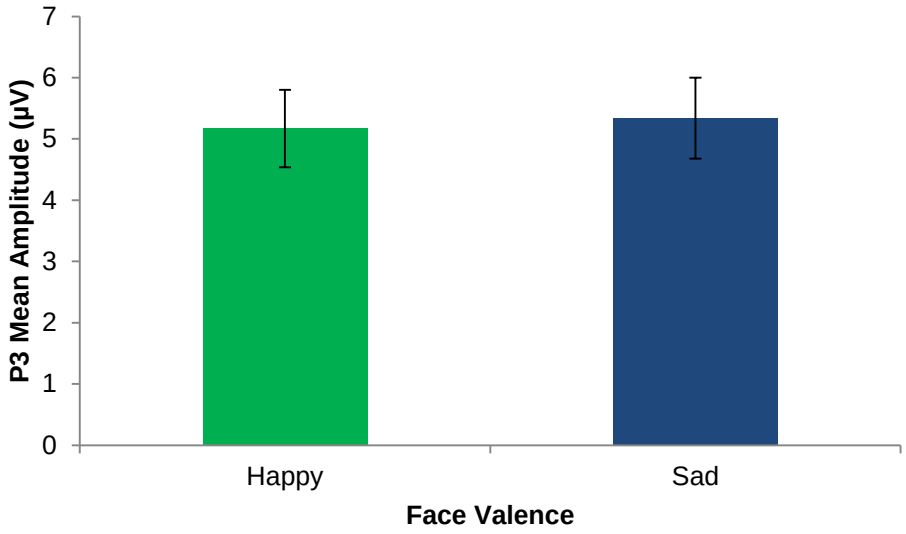
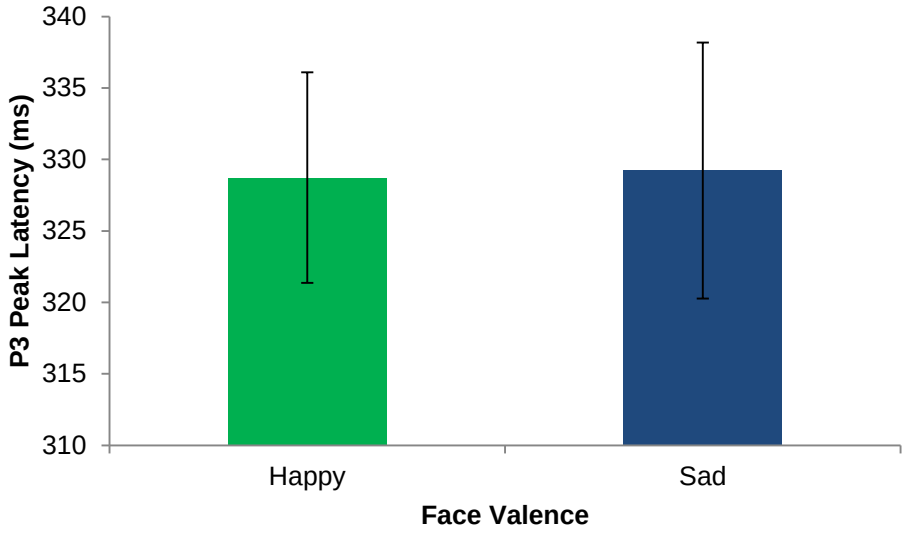


Figure 8. P300 Mean Amplitude by Face Valence.



Note. P300 mean amplitude (μV) by face valence is displayed. Standard errors are represented in the figure by the error bars attached to each column.

Figure 9. P300 Peak Latency by Face Valence.



Note. P300 peak latency (ms) by face valence is displayed. Standard errors are represented in the figure by the error bars attached to each column.

Behavioral and ERP Correlations

Additionally, correlations between behavioral performance and ERP results were examined. Specifically, the relationship between accuracy, RT, P200 amplitude, and P200 latency was examined for go-trials. The relationship between performance accuracy, P300 amplitude, and P300 latency was examined for stop-trials. On go-trials, P200 mean amplitudes and latencies for happy and sad conditions were positively related. Accuracy and response time for happy and sad trials were also positively related. On stop trials, P300 latency for happy and sad trials were found to be positively related. Accuracy in inhibiting response was also found to be positively related for happy and sad trials. On stop trials P300 mean amplitude involving happy faces was inversely related to P300 latency of happy faces. Results are displayed in Tables 1 and 2.

Table 1. Go Trials: Behavioral Data and P200 Mean Amplitude/Latency Correlations

	Happy A	Sad A	Happy RT	Sad RT	Happy MA	Sad MA	Happy PL	SadPL
HappyA	-							
SadA	.91*	-						
HappyRT	-.31	-.34	-					
SadRT	-.35	-.34	.93*	-				
HappyMA	-.01	.03	.00	-.08	-			
SadMA	.12	.10	-.04	-.14	.94*	-		
HappyPL	.32	.21	.13	.11	-.16	-.03	-	
SadPL	.17	.13	.04	-.07	-.07	.01	.81*	-

Note. *$p < .01$. HappyA = Accuracy on go-trials of happy faces; SadA = Accuracy on go-trials of sad faces; HappyRT = Response time on go-trials of happy faces, SadRT = Response time on go-trials of sad faces; HappyMA = P2 mean amplitude on trials of happy faces; SadMA = P2 mean amplitude on trials of sad faces; HappyPL = P2 peak latency on trials of happy faces; Sad PL = P2 peak latency on trials of sad faces

Table 2. Stop Trials: Behavioral Data and P300 Mean Amplitude/Latency Correlations

	HappyA	SadA	HappyMA	SadMA	HappyPL	SadPL
HappyA	-					
SadA	.94*	-				
HappyMA	.06	.02	-			
SadMA	.08	.04	.97*	-		
HappyPL	-.17	-.21	-.53	-.62*	-	
SadPL	-.07	-.20	-.34	-.46	.83*	-

Note. HappyA = Accuracy on stop-trials of happy faces; SadA = Accuracy on stop-trials of sad faces; HappyMA = P3 mean amplitude on trials of happy faces; SadMA = P3 mean amplitude on trials of sad faces; HappyPL = P3 peak latency on trials of happy faces; Sad PL = P3 peak latency on trials of sad faces
*$p < .01$

CHAPTER FOUR

DISCUSSION

The current study offers an initial step toward identifying how valence of facial stimuli influences the neural correlates of emotional face processing and subsequent inhibitory response function in healthy individuals. The study also examined behavioral response under two different demands of a stop-signal task: gender discrimination (go-trials) and behavioral inhibition (stop-trials).

While previous research has found evidence for enhanced P200 response to fearful faces in comparison to happy or neutral faces (Ashley, Vuilleumier, Swick, 2004), the current study failed to detect a similar enhancement of early processing for sad faces in comparison to happy faces. However, the absence of significant differences in early processing is consistent with a study conducted by Eimer and Holmes (2007), in which exposure to facial stimuli of six basic emotions (fear, anger, disgust, happiness, surprise, and sadness) evoked similar positive frontal ERP deflections occurring around 180 ms after stimuli onset. Given the mixed findings on valence-specific modulations of the frontal P200, interactions between emotional expression and early allocation of attentional resources warrant further investigation.

The current study also failed to detect significant differences in P300 modulations related to inhibitory response on stop-trials between conditions of happy and sad faces. This finding does not support the P300-related hypothesis, which posited that exposure to

negatively valenced stimuli (sad faces) would result in inefficient processing, necessitating increased recruitment of neural resources in order to successfully inhibit response during stop-trials. Previous work has found significant interactions between emotional context and neural activity during tasks requiring inhibitory control in both healthy and clinical populations (Albert, López-Martín & Carretié, 2009; Verona, Sprague & Sadeh, 2012). Lack of significant findings in the current study may be due to small sample size.

While the current study did not find differences in neural activity associated with task demands and valence of stimuli, a behavioral difference attributed to emotional valence was discerned during gender discrimination demands (go trials). In contrast to our hypothesis that exposure to sad faces would result in poorer performance, results of the current study indicated that gender discrimination accuracy was significantly greater during trials of sad faces than trials of happy faces. This may suggest a selective attention bias for processing negatively valenced faces that allows individuals to more accurately discern gender. Previous research has found that attentional focus is enhanced in the presence of negatively valenced stimuli in comparison to positive or neutral stimuli (Eastwood, Smilek & Merikle, 2001). Additionally, literature investigating the regulation of global-local processing of visual information suggests that negative affect tends to inhibit relational processing of information leading to increased perceptual and local processing (Clore, 2001). Therefore, increased focus to details of facial stimuli could explain the increased accuracy in gender discrimination discerned for negatively valenced trials in the current experiment. However, featural differences between happy and sad

stimuli should be considered when interpreting this result. Although the same faces were used for both happy and sad conditions, underlying featural contribution instead of the emotional valence of the images may have contributed to the behavioral results observed.

While the current study provides a preliminary investigation into the effects of valence on implicit emotional face processing and subsequent inhibitory control, limitations of the study must be addressed. Firstly, the present study was underpowered and has a reduced chance of detecting true significant effects. Additionally, the manipulation of facial valence only focused on two basic emotions and as such does not capture the vast variability in facial expressions typically encountered on a daily basis. The manipulation of valence through utilization of sad and happy faces did not allow for a neutral condition in the current study and therefore differences between emotional face processing and neutral face processing could not be addressed.

Future research should include a larger sample size and examine the potential unique neural modulations and behavioral responses associated with facial expressions beyond happy and sad stimuli. While the present study focused on healthy emerging adults enrolled at a Midwestern university, forthcoming investigations should broaden their recruitment to include children and adolescents as well as clinical populations. As children and adolescents are still developing emotion regulation abilities, sensory perceptual skills, and executive function they may be at increased risk for disruption in cognitive processes due to emotional input. Similarly, many psychiatric populations experience disorder-specific dysregulation of emotional and cognitive function and as such may differentially respond to specific facial expressions of emotion. For example,

studies have consistently found that individuals with depression demonstrate a perceptual and memory bias for negatively valenced input in comparison to positive or neutral stimuli (Hamilton & Gotlib, 2008).

As humans constantly encounter affective stimuli throughout our daily life, understanding the interaction between implicit processing of affective information and subsequent effects on cognitive processes in healthy populations is a critical first step in understanding how these systems may become dysregulated across the lifespan and in clinical populations.

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VITA

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Following graduation, Lorri continued working with Dr. Klein-Tasman as a research lab manager for two years. Additionally, she worked as a research assistant at the Medical College of Wisconsin, administering brief neuropsychological protocols and assisting in the fMRI scans of young children with posterior fossa tumors. Her early training in neuroimaging inspired Lorri to pursue graduate studies in Clinical Psychology with a specific research interests in investigating the neural mechanisms of cognitive and behavioral function in clinical populations. At Loyola, she worked as a teaching and research assistant for both Dr. Rebecca Silton and Dr. Robert Morrison. Upon completion of her doctorate, Lorri will pursue a post-doctoral position to gain further research

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