

AN ABSTRACT OF THE THESIS OF

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Title: An Electrophysiological Study of Emotional Perception in a Dual-Task Paradigm.

Abstract approved:

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The present study examined whether emotion perception requires central attentional resources. A dual-task paradigm was used to examine whether people can direct their attention to a face expressing a target emotion, even while they are still selecting a response to another task. Task-1 required an auditory discrimination while for Task-2, one happy face and one angry face were presented adjacent to each other. Participants were asked to find the face with a pre-specified emotion and indicate its gender (Experiment 1), location (Experiment 2), or identify whether the faces were the same gender or different gender without emotional goal settings (Experiment 3). The stimulus onset asynchrony (SOA) between the two tasks was varied. To determine where people were attending, an electrophysiological measure of attention known as

the N2pc component of the event-related brain potential was used. The face expressing the target emotion elicited an N2pc effect, indicating attention capture, even when participants were already pre-occupied with processing Task-1 (i.e., short SOAs). Thus, it appears that emotion perception can occur even when central attentional resources are unavailable. In addition, angry faces elicited a much larger N2pc effect than happy faces, indicating an attentional bias toward negative emotions.

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An Electrophysiological Study of Emotional Perception in a Dual-Task

Paradigm

by

Kathleen Elizabeth Shaw

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I understand that my thesis will become part of the permanent
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Kathleen Elizabeth Shaw, Author

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CHAPTER 1: LITERATURE REVIEW

AN ELECTROPHYSIOLOGICAL STUDY OF EMOTIONAL PERCEPTION IN A DUAL-TASK PARADIGM

Studies have demonstrated that our ability to perceive and express emotions is a hard-wired and valuable tool in our learning and development (Thompson & Lagattuta, 2006), with infants being able to discriminate individual faces with a preference for their mother's face within hours of birth (Bushnell, Sai, & Mullin, 1989), suggesting that prenatally, brain mechanisms are localized for facial processing (Farah, Rabinowitz, Quinn, & Liu, 2000). From our early visual preference for human faces (see Johnston & Morton, 1991) to infant-care taker social referencing (see Thompson & Lagattuta, 2006) to positive effects of receptive and expressive language in interpersonal relations (Fabes, Gaertner, & Popp, 2006), we are clearly expressive beings that begin to explore the affective aspects of our world shortly after birth. These early skills are essential for healthy development as we progress through the life course, helping facilitate social relationships and enhance survival.

From an evolutionary perspective, emotional facial expressions are an essential communication medium. A happy or joyful expression may symbolize a friend or potential sexual mate, capable of sharing food or aiding in raising offspring. An angry expression can pose a direct threat to one's self, sending the message of possible harm and guiding attention to the negative stimulus (Fox, Russo, & Dutton, 2002; Georgiou et al., 2005). Similarly, a fearful expression indirectly alerts others to dangers within the environment, such as a large animal or a poisonous bug. Research has shown that children

before one year of age, children develop the ability to recognize fright in their mother's faces and restrict their activities accordingly (de Rosnay, Cooper, Tsigaras, & Murray, 2006), demonstrating the early engraining of negative emotional superiority.

Recently, cognitive research has sought to determine whether emotional processing requires attentional resources considering the innate survival benefits facilitated processing would provide (Eastwood, Smilek, & Merikle, 2003; see Palermo, & Rhodes, 2007, for review). A metaphor for attentional resources can be described as a jar of marbles and two empty bowls. Each bowl represents a cognitive task, and the marbles are akin to available attentional resources. When one bowl is larger and requires more marbles to be filled, the second bowl is left with little or no marbles to fill it. The larger the first bowl (i.e., the task requires more cognitive resource), the less attentional resources will be available for the second bowl. The adaptive value of threat detection would lend credence to the hypothesis that emotional expressions have priority processing and capture attention rapidly (e.g., Fenker et al., 2010; Fox et al., 2002; Frischen, Eastwood, & Smilek, 2008). Previous research has investigated whether this attentional priority is purely driven by the stimulus itself, in the sense that the presence of a face triggers attentional shifts automatically without attentional resources (e.g., West, Anderson, & Pratt, 2009) or is dependent upon available cognitive resources (e.g., Pessoa & Ungerleider, 2004).

BACKGROUND AND SIGNIFICANCE

Attention and Constructs of Automaticity

Current models of attention assume that human attention is limited in capacity, resulting in a prioritization process that allocates primacy to stimuli or tasks that facilitate goal completion (see Pashler, 1998, for a review). In 1890, William James described attention as the “withdrawal from some things in order to deal effectively with others,” an apt perspective considering we are bombarded daily by multiple sensory stimuli. When a person is multi-tasking or performing two tasks in rapid succession, attentional capacity is seen as being dependent upon the resources available for that particular cognitive demand. For example, Wickens (1984) described attention as being a multidimensional space composed of modalities of input (i.e., visual, tactile), output (i.e., physical response, vocalization), stages of processing (i.e., perceptual, response initiation), and mental codes (i.e., verbal and spatial). When two tasks compete simultaneously for resource demands that are near each other in this multidimensional space, mental workload is increased with prioritization attributed to the task that aids in goal completion (Wickens, 1984). This limit in attentional resources is a cornerstone of dual-task paradigms, which manipulate mental workload by having participants perform two tasks concurrently. With the instructions emphasizing on the first task performance, secondary task costs are then evaluated (i.e., response times) to determine whether the secondary task requires attentional resources. If the secondary task does not compete for limited attentional resources (assuming to be occupied by the first task), the task is said to be automatic, reflected by little

to no costs on the secondary task. Tasks that are considered to be automatic can be defined as being unintentional, outside conscious awareness, and able to be processed without interfering with an ongoing task or mental activity (Posner & Snyder, 1975).

Despite the advantageous adaptive value of emotional perception, research evaluating the automaticity of emotional stimuli processing has resulted in contradictory evidence, with some studies purporting that it is automatic (e.g., West et al., 2009), non-automatic (e.g., Morgan, Klein, Boehm, Shapiro, & Linden, 2008), or demonstrates facilitated processing but is still reliant on some attentional resources (e.g., Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). Emotional perception studies have utilized either behavioral or electrophysiological designs, both of which provide their own advantages, disadvantages, or logic which I will discuss in detail in the following sections.

Automaticity of Emotional Processing and the Superiority of Negative Stimuli

Behavioral Evidence

The view of automaticity of emotional perception assumes that processing of emotional stimuli is non-conscious, mandatory, rapid (e.g., Ohman, 1997), and does not require attentional resources (e.g., Eastwood, Smilek, & Merikle, 2001, 2003). Previous studies have demonstrated that geometric shapes can take on emotional connotation, even when they are as simple as the letter “V”, which when inverted, resembles an angry frown (Larson, Aronoff, Sarinopoulos, & Zhu, 2009). For instance, Eastwood,

Smilek, and Merikle (2003) demonstrated how attentional resources are quickly and efficiently allocated to emotional stimuli even when in the presence of additional target stimuli. In their Experiment 1, an array of four schematic faces were presented upright for half of the participants and inverted for the other half. Each face consisted of three upward- and/or downward-curved arcs in varying arrays that gave the impression of being a positive or a negative neutral facial expression. Participants were instructed to count one of the two arc orientations as quickly and accurately as possible, with half of the trials consisting of positive facial representations and the remaining trials composed of negative facial representations. They hypothesized that in comparison with positive face trials, negative face trials would have longer response times for the counting task as a result of negative stimuli capturing attention and delaying disengagement. Upright and inverted faces were compared in respect to the emotional stimuli (i.e., upright negative faces, inverted negative faces) because it was assumed that inverted faces would disrupt perception of emotional content and control for local feature differences in detection between the positive and negative stimuli. Their results supported their hypothesis, with participants taking significantly longer to count the number of arcs during negative trials, regardless of schematic face orientation. Their findings demonstrate differential abilities of varied emotional expressions in capturing attention, particularly for negative stimuli, even when a motivational set is contrary to their capture, supporting a facilitated processing mechanism for negative stimuli. Negative arc

orientations disrupted task performance due to the stimuli being automatically processed and guiding attention.

From an evolutionary perspective, negative stimuli that are perceived as threatening should have superiority effects over positive stimuli on capturing attention due to the possible danger of a situation, as illustrated by the Eastwood et al., (2003) study. Their findings support a three-level superiority effect (Astikainen & Hietanen, 2009) where emotional expression has dominance over non-emotional stimuli, but within that dimension negative emotional expression has dominance over positive emotional expression (Eimer, Holmes, & McGlone 2003).

This three-level superiority effect has led to a theory of the brain having an innate and evolutionarily viable threat detection system (Astikainen & Hietanen, 2009; Becker, 2009). Becker (2009), for instance, investigated the wide-ranging effects of this system in a single-task visual search paradigm (see Vecera & Rizzo, 2003, for a review of visual search paradigms in attention research). In Becker's (2009) study, he utilized facial expressions in the role of a cue as participants looked for the presence or absence of a house in a multi-stimuli display set. Three facial expressions (fearful, happy, and neutral) varied between blocks and were briefly presented in the center of the screen before the visual search task. Results indicated that when a fearful facial expression preceded the task, participants were able to determine the presence of a house more quickly and efficiently, lending credence to the theory that negative stimuli increase the attention field. Becker's study demonstrated the

value placed on threat within an environment and subsequent effects as a result, providing evidence for an innate threat detection system with the ability to override non-emotional goal settings.

Electrophysiological Evidence

Behavioral measures serve as one means of identifying automaticity of stimuli, but an alternative method is to look at event-related potentials (ERPs) using electrophysiological instruments, particularly electroencephalograms (EEGs). This research approach has found to be more sensitive indices to automatic activation (Heil, Rolke, & Pecchinenda, 2004).

ERPs are a valuable tool in studying the allocation of attention because of their ability to assess both location and temporal mechanics of attention deployment (for a review, see Luck, 2005). ERP components are particularly valuable when evaluating emotional processing, with earlier components reflecting structural encoding of facial stimuli [such as the N170, a negative wave with a peak amplitude roughly 170-milliseconds (ms) post-stimulus onset], although there are contradictions within the literature on whether this component is affected by emotional expression (see Blau, Maurer, Tottenham, & McCandliss, 2007; Utama, Takemoto, Koike, & Nakamura, 2009) or merely facial processing, regardless of emotion (Ashley, Vuilleumier, & Swick, 2004). Later components in the time-course may demonstrate categorization, facial identification, and attention deployment [for instance, the P600f component, characterized by an enhanced positivity 500-ms post-stimulus latency (Eimer, 2000)] (Ashley et al. 2004; Balconi & Lucchiari, 2005).

Using electrophysiological measures, Astikainen and Hietanen (2009) provided evidence for Becker's (2009) conclusions. Utilizing an oddball paradigm, Astikainen and Hietanen (2009) had participants listen to a story and identified how many words started with a specific letter while watching facial expressions appear on a screen without having to act on their presence. They found that when neutral faces, which appeared 9 out of 10 times, were replaced with the oddball happy or angry face stimuli, an increased negativity, particularly the visual Mismatch Negativity (vMMN) ERP component, was evident at the 150-180-ms post-stimulus. The vMMN has been suggested to be an index of preattentive change detection (see Pazo-Alvarez, Cadaveira, & Amenedo, 2003 for a review). Astikainen and Hietanen's findings not only provide a more direct measurement for the facilitated processing of emotional information, particularly when it is task-irrelevant, but also aid in demonstrating the influence of emotion in face detection and identification during the early stages of visual perception. In addition, they provide one of the few studies in which positive emotion showed a nearly equal perceptual facilitation as negative emotional stimuli did.

Non-Automaticity of Emotional Perception

Erthal et al. (2005) demonstrated that emotional perception is reliant on attentional resources. In their study, participants were asked to perform a bar orientation discrimination task while an irrelevant negative or neutral image was displayed simultaneously. In their experiment, a neutral or negative image was centered on the screen with two peripheral bars. The bars could either be

vertical, horizontal, or diagonal, at differing points, increasing in difficulty of discrimination as degrees of difference grew smaller and smaller (e.g., right bar at 90°, left bar at 102°). Participants were asked to determine whether the two peripheral bars were in the same or different orientation. Increasing the difficulty of the orientation task by making the bars more similar than dissimilar, interfered with the distractor effect of the emotional stimuli. It was determined that as line discrimination difficulty increased, the distracting influence of the emotional stimuli decreased. By manipulating the processing resources required to complete a primary task, also known as cognitive load, Erthal et al. were able to demonstrate that emotional perception was dependent on attentional resources as evidenced by the diminishing influence of emotional distracters on the primary task.

To determine whether processing of emotional perception requires attentional resources as claimed by Erthal et al. (2005), Tomasik, Ruthruff, Allen, and Lien (2009) had participants perform the emotional discrimination task simultaneously with a non-emotional judgment task using a psychological refractory period (PRP) paradigm. Participants were asked to quickly and accurately respond to both tasks, with the primary manipulation being the temporal overlap between the stimuli of the tasks. This temporal overlap is termed the stimulus onset asynchrony (SOA) and is the crux of the paradigm.

Studies using the PRP paradigm have typically found that response time for Task-2 (RT₂) increases as SOA decreases, known as the PRP effect (see Telford, 1931; for a review, see Pashler, 1994). Considerable evidence

supports the view that the PRP effect is caused by an inability to perform central operations for two tasks simultaneously, creating a central processing bottleneck, (e.g., Lien & Proctor, 2002; Pashler & Johnston, 1989; see Figure 1).

Within the framework of the central bottleneck model, a well-established method to examine whether a particular cognitive process requires central attentional resources (i.e., is automatic) is the locus-of-slack logic (e.g., Pashler, 1994; Schweickert, 1978). According to this logic, if the manipulation of a variable affecting Task-2 pre-bottleneck (e.g., does not require central attentional resources), the effect should be absorbed into this slack period at short SOAs, resulting in an underadditive interaction with SOA (see Figure 2a). However, if the manipulation of a variable affects Task-2 bottleneck or after, the effect should be additive with the effect of SOA (see Figure 2b). This theoretical framework provides a means of examining whether processing facial expressions requires central attention, as response times for various SOAs can be compared and contrasted as a function of cognitive load.

In the Tomasik et al. (2009) study, participants were presented with Task-1, an auditory-discrimination task (pure tone vs. a noise), and then given Task-2, an emotion discrimination task (happy vs. angry), with two levels of emotion identification difficulty (easy vs. difficult). The primary manipulation was that of SOA, with four levels; 100, 300, 500, and 900 ms. In the easy condition, angry stimuli were merged at a 99% emotional expression with 1% neutral expression by compositing two pictures of an individual into a single

stimulus. In the hard condition, the stimuli were merged with 50% angry expression and 50% neutral expression (see Figure 3).

It was predicted that if emotion perception cannot proceed without central attentional resources, the effects of emotion-perception difficulty on Task-2 would be similar at all SOAs (i.e., additivity). If emotion perception can proceed even when central attentional resources are not available, the effects of emotion-perception difficulty on Task-2 would be absorbed in the slack at the short SOA but not at the long SOA (i.e., underadditivity). In line with their hypothesis, Tomasik et al. (2009) found that in two experiments the emotion perception difficulty effect on Task-2 was similar across all SOAs, confirming the hypothesis that central attentional resources were necessitated for the perception of emotion and were not independent of attention.

Criticisms with Previous Emotional Perception Studies

Although Tomasik et al.'s (2009) results favor the non-automaticity of emotional perception, their finding should be further examined. Their participants were required to identify the facial expressions of emotions from the picture and then press the corresponding key, presumably by first assigning the appropriate label – happy or angry. Studies have suggested that this emotional labeling requires central attentional resources (e.g., Phillips, Channon, Tunstall, Hedenstrom, & Lyons, 2008). It is possible that participants were able to detect facial expressions automatically but were unable to then produce the corresponding label without utilizing central resources. This possibility would be difficult to test with traditional behavioral

measures (e.g., RT), because these measures provide only an indirect index of what processes took place during emotion perception.

A criticism of using behavioral techniques to assess the allocation of attention is that they are rather insensitive to evaluating it appropriately as they are an indirect measurement tool in comparison with electrophysiological measures, such as ERPs (Lien, Ruthruff, Goodin, & Remington, 2008). Eimer et al. (2003) conducted a study to assess whether structural encoding of emotion can occur when facial expressions are task irrelevant with six emotional expression stimuli (i.e., angry, happy, sad, fearful, surprised, and disgusted) with electrophysiological measures. Participants were presented with a computer screen comprised of two categories of stimuli- faces and vertical bars, both of which were presented for each trial. The presentation was arranged with vertical bars being centered on the screen and two identical faces (either one of the six emotional faces or a neutral, non-emotional face) with one of each side of the paired bars. For 12 blocks of the trials, the participants' task was to identify whether the facial expression was emotional or neutral (i.e., the emotion task); thus, the vertical bars were task-irrelevant. For the remaining 12 blocks of trials, participants were to make a keypress response to indicate whether two vertical bars differed in length or were identical (i.e., the line task); thus, the emotional expression stimuli were irrelevant. When emotional expression was relevant, response times were faster for the emotional stimuli than for the neutral, non-emotional stimuli regardless of the emotional expression. When emotional expression was

irrelevant, response times to the line task did not depend on emotional expression. In addition, the N170 component for all six expressions was essentially absent in the line task, suggesting that structural encoding of facial expressions is reliant on available spatial attentional resources. Although the results in Eimer et al.'s study suggest that emotional perception requires spatial attention, they did not necessarily indicate the need for central attention for emotional perception, which the current study seeks to more thoroughly investigate.

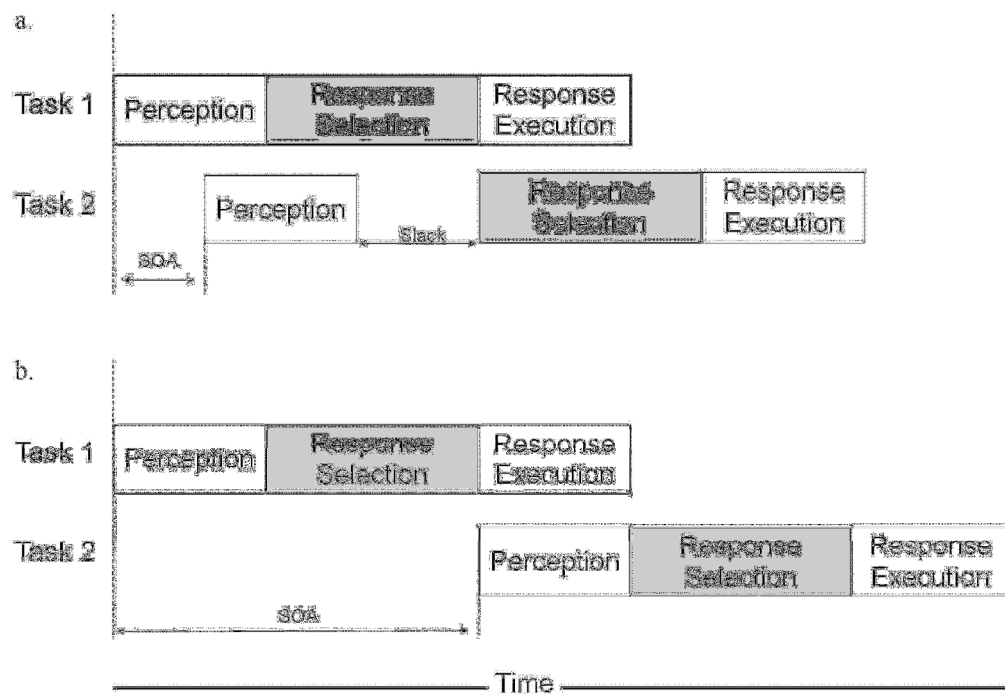


Figure 1: The temporal relations between processing stages of Task-1 and Task-2 at (a) a short SOA condition and (b) a long SOA condition in the psychological refractory period paradigm, as suggested by the central bottleneck model. The model assumes that Task-2 perception and response execution can occur in parallel with Task-1 operations, but response selection of Task-2 is queued until completion of Task-1 response selection.

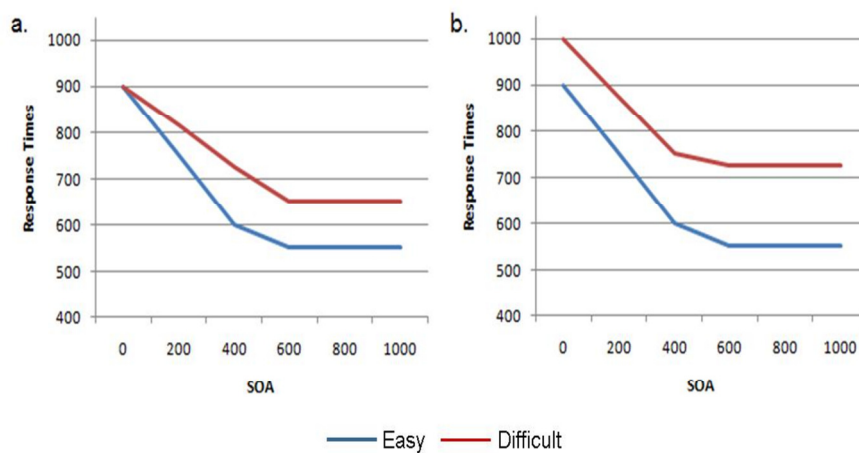


Figure 2: Two possible predictions of the central bottleneck model for manipulating Task-2 stage duration (easy vs. difficult Task-2 discrimination as an example in the figure). Panel a shows underadditivity if the manipulated stage occurs prior to the bottleneck and Panel b shows additivity if the manipulated stage occurs at or after the bottleneck.

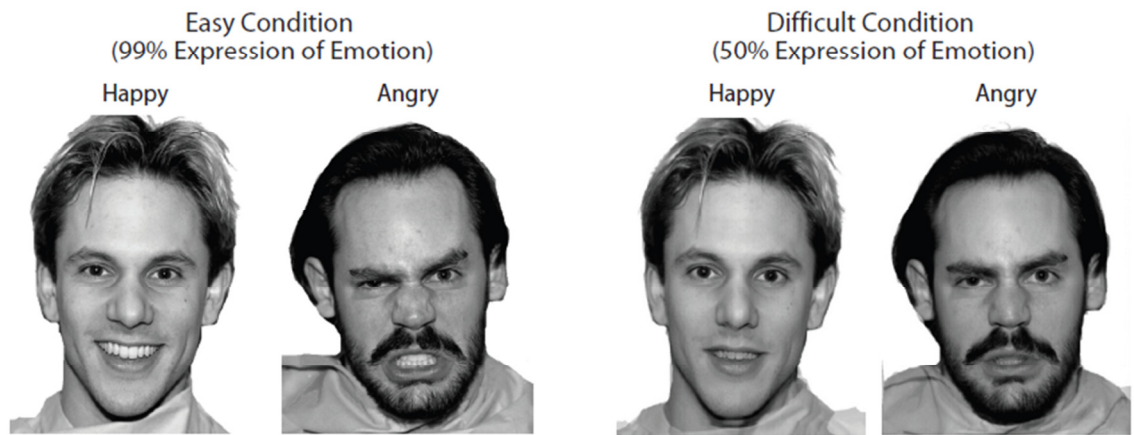


Figure 3: Examples of easy and difficult emotional expression stimuli used in the Tomasik et al (2009) study.

CHAPTER 2: THE PRESENT STUDY

DESIGN AND PREDICTIONS

The present study sought to utilize the PRP paradigm to assess differences in automaticity of emotional perception in typically-developing individuals. Similar to Tomasik et al. (2009), participants were first asked to complete a tone-discrimination Task-1 followed by a visual-discrimination Task-2, with varying SOAs randomized at 50-, 200-, and 1000- milliseconds. Instead of presenting one face on the screen as in the Tomasik et al. study, the visual-discrimination Task-2 involved two different faces presented side-by-side (one picture with an angry emotional expression and one with a happy emotional expression). To avoid the emotional labeling (as in Tomasik et al.'s study), the present study used a task where emotional labeling is less likely. Participants were to identify the gender of the face (male vs. female) presenting a target emotional expression (angry for the half of the participants or happy for the other half) in Experiment 1, identify the location (left or right) of the target emotional expression in Experiment 2, and perform a same or different gender task for the two faces in Experiment 3. To obtain a more direct indicator of emotion perception, the present study used ERP measures.

The ERP component we used to examine whether emotional perception occurs without central attentional resources is the N2pc effect (short for N2-posterior-contralateral). When attention is directed to the left or right visual field, brain potentials are found to be more negative in the contralateral (opposite-side) hemisphere than in the ipsilateral (same-side) hemisphere (e.g.,

Luck & Hillyard, 1990). This difference is usually strongest over the posterior part of the scalp, about 200-300-ms after stimulus onset (Eimer, 1996; Kiss, Van Velzen, & Eimer, 2008). By measuring this difference in ERPs, which is known as the N2pc effect, we can determine whether attention has been directed to the left or right visual field (see Figure 4).

The main interest in this study was the N2pc effect elicited by the target Task-2 faces at different SOAs. If emotion perception can occur without central resources (i.e., automatic), one would expect similar N2pc effects elicited by the target face at all SOAs. However, if emotion perception requires central resources, one would expect the N2pc effect to be smaller or even diminished at short SOAs than at long SOAs. It was also hypothesized that negative emotional stimuli would result in more pronounced N2pc effects in comparison with positive emotional stimuli, but that any emotional display would result in facilitated processing and attentional allocation.

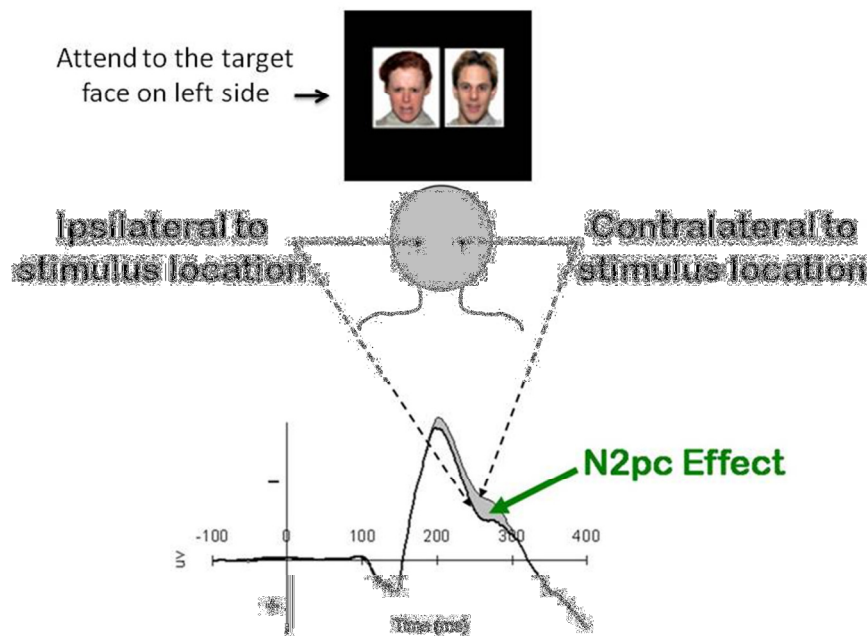


Figure 4: A hypothetical N2pc effect produced when attention is allocated to the face in the left visual field. Roughly 200-300 ms after stimulus onset, the event-related potentials are more negative for posterior electrode sites contralateral to the target location than ipsilateral to the target location. The N2pc effect (the shaded region) is defined as the difference in amplitude between the contralateral and ipsilateral waveforms. Negative is plotted upward and time zero represents stimulus onset.

CHAPTER 3: EXPERIMENT 1

As a first step, Experiment 1 examined whether the visual Task-2 emotional faces can capture spatial attention while central resources are devoted to a two-choice auditory Task-1. The particular Task-1 we chose was a tone vs. noise discrimination that has been used in numerous PRP studies (e.g., McCann & Johnston, 1992; Pashler, 1989, 1991; Pashler & Johnston, 1989).

On each trial, participants first made a speeded response to the Task-1 tone. After a variable SOA (50-, 200-, or 1000-ms), two faces (one happy, one angry) appeared on the screen. The happy and angry facial expressions always appeared in opposite hemifields. Half of the participants were instructed to respond to the gender of the happy face and the other half were instructed to respond to the gender of the angry face. All participants received the same displays, but were given different instructions regarding the target emotion.

Method

Participants

Eighteen undergraduate students (four men, fourteen women; all self-reported as being right-handed) from Oregon State University participated in a 2-hour session in exchange for extra course credit. Their mean age was 19 years (range: 18-22 years). Nine participants looked for angry faces and the other 9 looked for happy faces. All reported having normal or corrected-to-normal visual acuity.

Apparatus and Stimuli

Stimuli were presented on an IBM-compatible microcomputer

connected to a 19-inch ViewSonic monitor and were viewed from a distance of about 55 cm. The Task-1 stimulus was a pure tone or white noise (22 kHz, 8 bits, 100-ms duration) and was presented via speakers on both sides of the computer monitor). The Task-2 stimuli contained two pictures in each trial – one picture with an angry emotional expression and one with a happy emotional expression, (see Figure 5 for event sequence).

There were 20 pictures with different actors (5 male/angry, 5 male/happy, 5 female/angry, and 5 female/happy) taken from Tottenham et al. (2009). Each face was presented 108 times per participant. Each picture was 5.61° (width) \times 6.96° (height). The distance between the pictures was 6.02° from center to center and the gap between the two pictures was 0.42° . For both tasks, manual responses were collected using a response box containing five buttons labeled 1 to 5 from left to right.

Design and Procedure

Each trial started with the presentation of the fixation display for 800-ms. The Task-1 auditory stimulus then sounded for 100-ms. After one of three SOAs (50-, 200-, or 1000-ms) randomized within blocks, the two Task-2 pictures appeared on the screen until a response was made by the participant.

For Task-1, participants were asked to press the button labeled “1” with their left-middle finger for a pure tone and press the button labeled “2” with their left-index finger for a white noise (similar to a hissing sound). For Task-2, half of the participants were instructed to respond to the gender of the angry face and the other half were instructed to respond to the gender of the happy

face. They were asked to press the button labeled “4” with their right-index finger for female faces and press the button labeled “5” with their right-middle finger for male faces. They were asked to respond to Task-1 and Task-2 quickly and accurately. Also, they were asked to respond to Task-1 before Task-2. Immediately after a response was recorded, the next trial began with the 800-ms fixation display.

Participants performed one practice block of 24 trials, followed by 11 experimental blocks of 96 trials each (a total of 1,056 experimental trials). After each block, participants received a summary of their mean RT and accuracy for that block, and were encouraged to take a break.

EEG Recording and Analyses

The EEG activity was recorded using Q-cap AgCl electrodes from F3, F4, C3, C4, T7, T8, P3, P4, P5, P6, PO5, PO6, O1, and O2. These sites and the right mastoid were recorded in relation to a reference electrode at the left mastoid. The ERP waveforms were then re-referenced offline to the average of the left and right mastoids (see Luck, 2005). The horizontal electrooculogram (HEOG) was recorded bipolarly from electrodes at the outer canthi of both eyes, and the vertical electrooculogram (VEOG) was recorded from electrodes above and below the midpoint of the left eye. Electrode impedance was kept below 5 k Ω . EEG, HEOG, and VEOG were amplified using Synamps2 (Neuroscan) with a gain of 2,000 and a bandpass of 0.1-50 Hz. The amplified signals were digitized at 500 Hz.

Trials with possible ocular artifacts were identified in two steps (see

also Lien, Croswaite, & Ruthruff, 2011; Lien et al., 2008). First, trials with ocular artifacts were rejected automatically using a threshold of $\pm 75\mu\text{V}$ for a 2,200-ms epoch beginning 200-ms before Task-2 stimulus onset to 2,000-ms after Task-2 stimulus onset. Next, each of these candidate artifact trials was inspected manually. To determine whether individual participants systematically moved their eyes in response to the Task-2 stimulus, we computed for each participant average HEOG waveforms for left-target and right-target trials, separately, during the period 200-400-ms after the Task-2 stimulus onset. Following Woodman and Luck (2003), we included in the data analyses only participants whose average HEOG activity was less than $\pm 3\mu\text{V}$ during this time window. Rejection of trials with ocular artifacts in the EEG data led to the elimination of 6% of trials, but no more than 17% for any individual participant.

To quantify the overall magnitude of the N2pc effect, we focused on the time window 200-400-ms after Task-2 target onset. Specifically, the N2pc effect was measured as the mean amplitude during this time window for electrode sites contralateral to the target location minus the mean amplitude for ipsilateral electrode sites, at the P5/P6, O1/O2, and PO5/PO6 electrode sites, relative to the mean amplitude during a 200-ms baseline period prior to Task-2 onset.

Results

In addition to trials with ocular artifacts, we excluded trials from the final analyses of behavioral data (RT and proportion of errors; PE) and EEG

data if RT1 or RT2 was less than 100-ms or greater than 3,000-ms (2.4% of trials). Trials were also excluded from RT and EEG analyses if either response was incorrect.

Analysis of variance (ANOVA) was used for all statistical analyses, with an alpha level of .05 to ascertain statistical significance. The p-values were adjusted using the Greenhouse-Geisser epsilon correction for nonsphericity, when appropriate. Although our key predictions concern only the N2pc effect, we also report the behavioral data for the sake of the completeness.

Behavioral Data Analyses

Data were analyzed as a function of Task-2 emotion type (angry vs. happy), SOA (50-, 200-, and 1,000-ms), and Task-2 gender (male vs. female). Task-2 emotion type was a between-subject variable, whereas both SOA and Task-2 gender were within-subject variables. Table 1 shows mean RT and PE for Task-1 and Task-2 at each SOA.

For Task-1, PE1 decreased as SOA increased, $F(2, 32) = 5.04$, $p < .05$, $MSE = 0.0003$; mean PE1 was 0.040, 0.033, and 0.027 at the 50-, 200-, and 1,000-ms SOAs, respectively. No other effects were significant.

For Task-2, a large PRP of 374-ms was observed on RT, $F(2, 32) = 151.17$, $p < .0001$, $MSE = 9,149$ (RT2 was 1,191-, 1,106-, and 817-ms at the 50-, 200-, and 1,000-ms SOAs, respectively). RT2 was 23-ms shorter and PE2 was 0.027 lower when the Task-2 target was female (RT2 = 1,026-ms; PE2 = 0.057) than when it was male (RT2 = 1,049-ms; PE2 = 0.084), $F(1, 16) = 6.10$,

$p < .05$, $MSE = 2,295$, and $F(1, 16) = 7.79$, $p < .05$, $MSE = 0.0025$. The interaction between SOA and Task-2 gender approached significance, $F(2, 32) = 3.02$, $p = .0528$, $MSE = 710$; The PRP effect was larger when the Task-2 target was male (390-ms) than when it was female (358-ms). No other effects were significant.

ERP Analyses

The N2pc data analyses (i.e., the different waveforms) focused on the time window in which the allocation of spatial attention to the Task-2 face expressing the target emotion would produce an N2pc effect (200-400-ms after Task-2 stimulus onset). The N2pc data were analyzed as a function of Task-2 emotion type (angry vs. happy), electrode pair (P5/P6, O1/O2, vs. PO5/PO6), and SOA (50-, 200-, vs. 1,000-ms). Task-2 emotion type was a between-subject variable, whereas both electrode pair and SOA were within-subject variables.

For each participant, a total of 352 trials were included for each SOA condition before trials that fell outside our RT cutoff or showed ocular artifacts were rejected. Figure 6 shows the pooled N2pc effects averaged across these electrode pairs and Figure 7 shows the averaged N2pc effects separated by Task-2 emotion type (a group variable; angry vs. happy). The overall N2pc effect was larger for the group looking for angry faces ($-0.481 \mu V$) than for the group looking for happy faces ($-0.069 \mu V$), $F(1, 16) = 8.53$, $p < .05$, $MSE = 0.8044$. The overall N2pc effect was similar across SOAs, $F < 1.0$; the effect was $-0.286 \mu V$, $-0.205 \mu V$, and $-0.333 \mu V$ at the 50-, 200-, and 1,000-ms

SOAs, respectively. The interaction between Task-2 emotion type and SOA was not significant, $F < 1.0$, indicating similar N2pc effects across SOAs were obtained for both angry and happy face groups. For the angry face group, the N2pc effect was 0.452 μV , -0.469 μV , and -0.521 μV at the 50-, 200-, and 1,000-ms SOAs, respectively. For the happy face group, the N2pc effect was -0.121 μV , 0.058 μV , and -0.144 μV at the 50-, 200-, and 1,000-ms SOAs, respectively.

Pairwise comparisons revealed no significant differences between any two SOAs, $F_s < 1$. Further t-tests also revealed that the N2pc effect at the 50- and 1,000-ms SOAs was significantly different from zero, both $t_s(17) = -3.19$, $p_s < .01$. The N2pc effect at the 200-ms SOA approached statistical significance, $t(17) = -1.81$, $p = 0.0875$. The N2pc effect was similar for all three electrode pairs, $F < 1.0$; the effect was -0.310 μV , -0.250 μV , and -0.265 μV at the P5/P6, O1/O2, and PO5/PO6 electrode pairs, respectively.

Discussion

Experiment 1 used a PRP paradigm to examine whether the shift of visual-spatial attention to facial expressions requires central attention. To avoid emotional labeling, participants were asked to perform a gender task on a specific emotion. We measured the N2pc effect elicited by the Task-2 target face. The critical finding is that the face with the target emotion triggered a substantial (i.e., statistically greater than zero) N2pc effect that did not depend on SOA, $F < 1.0$. Most importantly, a significant N2pc effect was obtained at the 50-ms SOA condition, where Task-1 central operations are still underway.

This finding suggests that an attention shift to the facial expression occurred even when central attentional resources were occupied by non-emotional Task-1. Thus, emotions can be processed without central resources and, having been processed, can attract spatial attention without central resources. In addition, Experiment 1 revealed a larger N2pc effect elicited by angry faces than happy faces, suggesting a greater capture by negative emotions.

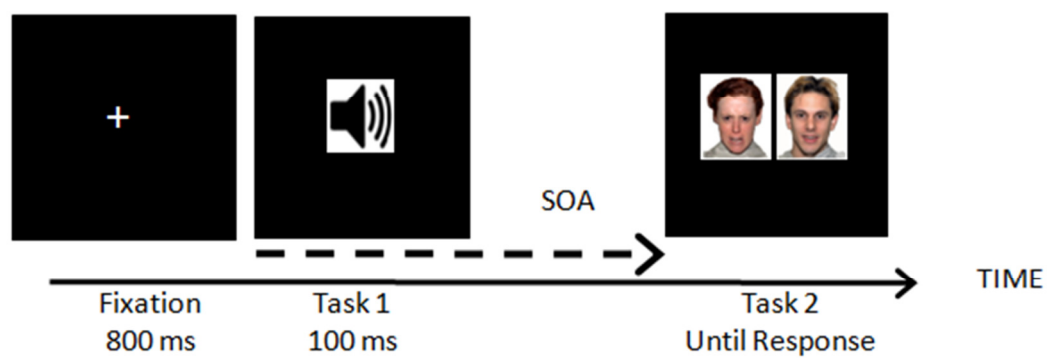


Figure 5: An example event sequence in experiments. Stimulus onset asynchrony (SOA) was varied at 50-, 200-, and 1,000-ms, intermixed within blocks.

Table 1: Mean Response Time (RT in Milliseconds) and Proportion of Errors (PE) for Task-1 and Task-2 as a Function of Task-2 Emotion Group (Happy vs. Angry), Stimulus Onset Asynchrony (50, 200, and 1,000 ms), and Task-2 Gender (Female vs. Male) in Experiment 1.

		Stimulus Onset Asynchrony					
		50 ms		200 ms		1,000 ms	
		RT	PE	RT	PE	RT	PE
Task-1							
Happy							
Female		653	.042	655	.039	650	.028
		(33)	(.012)	(34)	(.010)	(.028)	(.009)
Male		647	.049	633	.045	647	.036
		(37)	(.017)	(32)	(.011)	(42)	(.008)
Angry							
Female		707	.033	694	.024	654	.023
		(64)	(.008)	(58)	(.006)	(59)	(.005)
Male		703	.034	704	.023	644	.021
		(57)	(.008)	(53)	(.005)	(55)	(.006)
Task-2							
Happy							
Female		1,147	.064	1,093	.074	812	.071
		(42)	(.022)	(46)	(.019)	(37)	(.023)
Male		1196	.109	1098	.096	832	.090
		(45)	(.027)	(49)	(.020)	(38)	(.025)
Angry							
Female		1,194	.049	1,099	.044	813	.041
		(102)	(.010)	(90)	(.009)	(67)	(.006)
Male		1,226	.071	1,133	.070	810	.068
		(101)	(.018)	(90)	(.017)	(58)	(.021)

Note. The standard error of the mean is shown in parentheses.

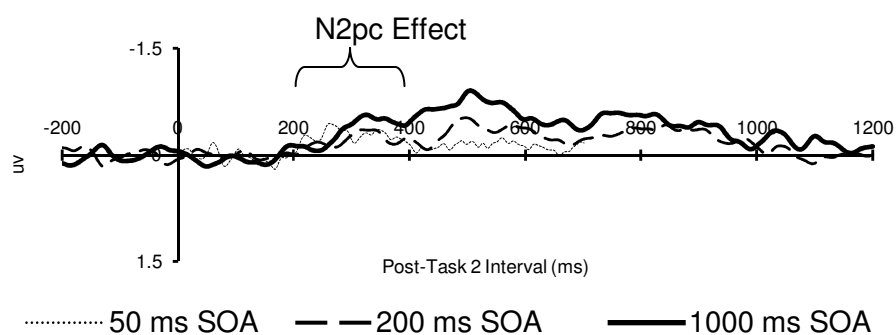


Figure 6: Grand average N2pc difference waveforms for Task-2 as a function of SOA (50, 200, and 1,000 ms) in Experiment 1. These N2pc effects were averaged across the P5/P6, O1/O2, and PO5/PO6 electrode pairs and Task-2 emotion type (angry vs. happy). The N2pc difference waveforms were calculated by subtracting the ipsilateral potentials from contralateral potentials (with respect to Task-2 target location). The baseline period was the 200 ms prior to Task-2 stimulus onset. Negative is plotted upward and time zero represents Task-2 stimulus onset.

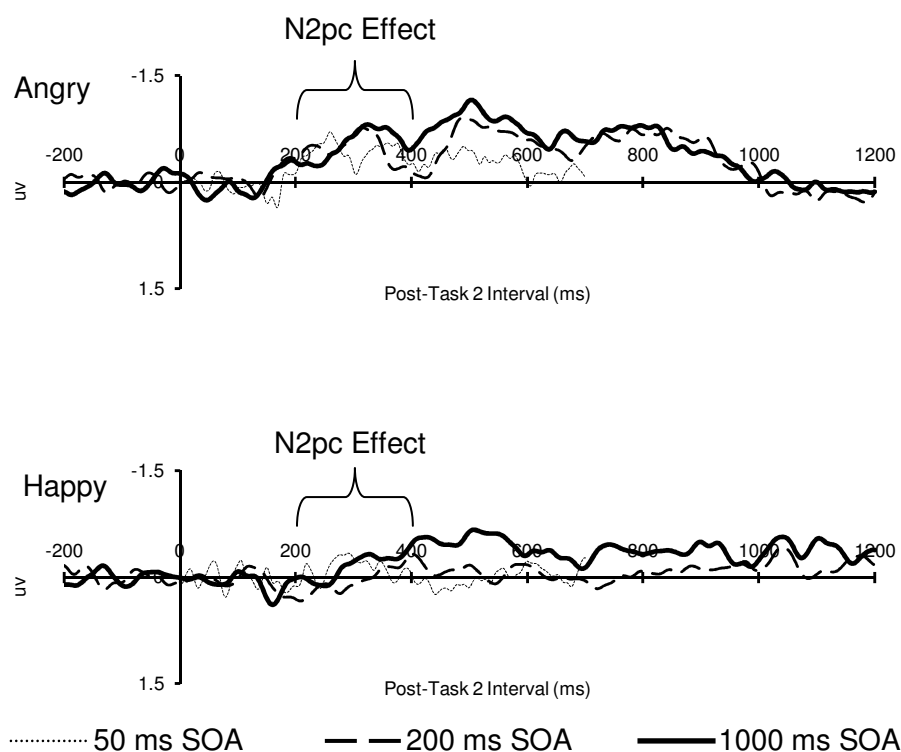


Figure 7: Grand average N2pc difference waveforms for Task-2 as a function of Task-2 emotion type (angry vs. happy) and SOA (50, 200, or 1,000 ms) in Experiment 1. These N2pc effects were averaged across the P5/P6, O1/O2, and PO5/PO6 electrode pairs. The N2pc difference waveforms were calculated by subtracting the ipsilateral potentials from contralateral potentials (with respect to Task-2 target location). The baseline period was the 200 ms prior to Task-2 stimulus onset. Negative is plotted upward and time zero represents Task-2 stimulus onset.

CHAPTER 4: EXPERIMENT 2

Experiment 2 replicated Experiment 1 but with a different judgment required on the Task-2 face expressing the target emotion. Specifically, participants indicated the location of the target emotion (left vs. right) instead of making a gender discrimination (female vs. male). This was done to confirm that the early N2pc effect observed in Experiment 1 generalizes beyond the gender task. As in Experiment 1, we measured the N2pc effect to the Task-2 target face as an index of the attentional shift at several different SOAs between Task-1 and Task-2.

Method

Participants

There were 29 participants (13 men, 16 women; 28 self-reported as being right handed, 1 self-reported as being left handed), drawn from the same participant pool as in Experiment 1. None had participated in the previous experiment. Data from three participants were excluded from the final data analyses due to excessive eye movement artifacts in the electroencephalographic data. Therefore, data from 26 participants were included in the final data analyses. Their mean age was 22 years (range: 19-37 years). Of the participants whose data were analyzed, half were instructed to respond to the location of the angry face and the other half to the location of the happy face. All reported having normal or corrected-to-normal visual acuity.

Apparatus, Stimuli, and Procedure

The tasks, stimuli, and equipment were the same as in Experiment 1,

except for Task-2. Instead of indicating the gender of the target emotion, participants were instructed to indicate its location; they pressed the button labeled “4” with their right-index finger if the target facial expression was on the left side and pressed the button labeled “5” with their right-middle finger if the target facial expression was on the right side.

Results

The data analysis in Experiment 2 was similar to that of Experiment 1, except that the Task-2 gender variable was replaced with the Task-2 location variable (left vs. right). Application of the RT cutoffs eliminated approximately 1% of trials. Rejection of trials with ocular artifacts in the EEG data led to the further elimination of 7% of trials, but no more than 25% for any individual participant.

Behavioral Data Analyses

Table 2 shows mean RT and PE for Task-1 and Task-2 at each SOA. Data were analyzed as a function of Task-2 emotion type (angry vs. happy), SOA (50-, 200-, and 1,000-ms), and Task-2 location (left vs. right). Task-2 emotion type was a between-subject variable whereas the SOA and Task-2 location were within-subject variables. For Task-1, RT decreased as SOA increased, $F(2, 48) = 14.50, p < .001, MSE = 7,475$; mean RT1 was 781, 772, and 698 at the 50-, 200-, and 1,000-ms SOAs, respectively. PE1 decreased as SOA increased, $F(2, 48) = 10.59, p < .001, MSE = 0.0004$; PE1 was 0.042, 0.036, and 0.025 at the 50-, 200-, and 1,000-ms SOAs, respectively. PE1 was slightly higher when Task-2 target was on the left side (0.038) than when it

was on the right side (0.031), $F(1, 24) = 6.69$, $p < .05$, $MSE = 0.0003$. The three-way interaction between Task-2 emotion type, SOA, and Task-2 location was significant on PE1, $F(2, 48) = 5.82$, $p < .01$, $MSE = 0.0001$. For the group looking for happy faces, PE1 decreased as SOA increased regardless of whether the target face appeared on the left or right side of the screen. For the group looking for angry faces, the decreasing function was only evident when the target face appeared on the left side.

For Task-2, a large PRP of 395-ms was observed on RT, $F(2, 48) = 264.73$, $p < .0001$, $MSE = 8,352$; mean RT2 was 1,044-, 950-, and 649-ms at the 50-, 200-, and 1,000-ms SOAs, respectively. The between-experiment comparison shows that the PRP effect on RT2 was similar between Experiments 1 and 2 (374- vs. 395-ms, respectively), $F < 1.0$. PE2 was larger for the group looking for angry faces (0.061) than for the group looking for happy faces (0.035), $F(1, 24) = 5.04$, $p < .05$, $MSE = 0.0052$. The interaction between SOA and Task-2 location on PE2 was significant, $F(2, 48) = 7.73$, $p < .01$, $MSE = 0.0003$. When the Task-2 target was on the left side, PE2 was lower at the longest SOA (0.044) than the other SOAs (0.051, 0.052 at the 50- and 200-ms SOAs). However, when Task-2 target was on the right side, PE2 was lower at the shortest SOA (0.044) than the other SOAs (0.052, 0.046 at the 200- and 1,000-ms SOAs, respectively). No other effects were significant.

ERP Analyses

As in Experiment 1, the N2pc data were analyzed as a function of Task-2 target emotion (angry vs. happy; a between-subject group variable),

electrode pair (P5/P6, O1/O2, vs. PO5/PO6) and SOA (50-, 200-, vs. 1,000-ms). Figure 8 shows the pooled N2pc effects and Figure 9 shows the separate N2pc effects by Task-2 emotion type (a group variable; angry vs. happy), averaged across these electrode pairs.

The overall N2pc effect was larger for the group looking for angry faces ($-0.567 \mu\text{V}$) than for the group looking for happy faces ($-0.056 \mu\text{V}$), $F(1, 24) = 6.12$, $p < .05$, $MSE = 2.503$. As in Experiment 1, the interaction between Task-2 emotion type and SOA was not significant, $F(2, 48) = 1.28$, $p = .2868$, $MSE = 0.256$. For the angry face group, the N2pc effect was $-0.561 \mu\text{V}$, $0.484 \mu\text{V}$, and $-0.657 \mu\text{V}$ at the 50-, 200-, and 1,000-ms SOAs, respectively. For the happy face group, the N2pc effect was $-0.075 \mu\text{V}$, $0.168 \mu\text{V}$, and $-0.260 \mu\text{V}$ at the 50-, 200-, and 1,000-ms SOAs, respectively.

The main effect of SOA was significant, $F(2, 48) = 6.89$, $p < .01$, $MSE = 0.256$; the N2pc effect was $-0.318 \mu\text{V}$, $-0.158 \mu\text{V}$, and $-0.458 \mu\text{V}$ at the 50-, 100-, and 1,000-ms SOAs, respectively. Further t-tests also revealed that the N2pc effect at the 50- and 1,000-ms SOAs was significantly different from zero, $t(25) = -2.78$, $p < .05$, and $t(25) = -3.71$, $p < .001$, respectively. The N2pc effect at the 200-ms SOA was not significantly different from zero, $t(25) = -1.21$, $p = .2371$. Pairwise comparisons revealed that the N2pc effect approached significance between the 50- and 200-ms SOAs, $F(1, 25) = 3.29$, $p = .08$, $MSE = 0.203$, but was significant between the 200- and 1,000-ms SOAs, $F(1, 25) = 17.38$, $p < .001$, $MSE = 0.135$. Although the N2pc effect was numerically smaller at the 50-ms SOA than at the 1,000-ms SOA, the

difference was not statistically significant, $F(1, 25) = 2.86$, $p = .104$, $MSE = 0.178$. No other effects were significant.

Discussion

Experiment 2 replicated the design of Experiment 1, but with a location-discrimination for Task-2 rather than gender-discrimination. The N2pc effect to the face expressing the target emotion was reduced slightly (by 31%), but not significantly, as the SOA decreased from 1,000-ms to 50-ms. Not only was the numerical decline very modest, the N2pc effect at the short SOA was still significantly greater than zero, $t(25) = -2.78$, $p < .05$. A between-experiment comparison including Experiment (1 vs. 2), Task-2 emotion type (angry vs. happy), and SOA (50, 200, and 1,000 ms) was conducted. Neither the two-way interaction of Experiment and SOA nor the three-way interaction of these variables with Task-2 emotion type was significant, $F_s < 1.0$. This finding suggests that Task-2 target emotion proceeds in parallel with the processing of Task-1 at all SOAs (as evident in the N2pc effect) regardless of the nature of Task-2. Consistent with the findings of Experiment 1, attentional shifts to target emotion occurred even when central attentional resources were not available. Again, this suggests that emotions can be processed automatically.

Similar to Experiment 1, a negativity bias was demonstrated by the N2pc effect between the happy and angry conditions (see Figure 9), supporting previous studies that found a superiority effect for emotional expressions, particularly negatives ones (e.g., Astikainen & Hietanen, 2009; Becker, 2009;

Eastwood et al., 2003).

Table 2: Mean Response Time (RT in Milliseconds) and Proportion of Errors (PE) for Task-1 and Task-2 as a Function of Task-2 Emotion Group (Happy vs. Angry), Stimulus Onset Asynchrony (50, 200, and 1,000 ms), and Task-2 Location (Left vs. Right) in Experiment 2.

		Stimulus Onset Asynchrony					
		50 ms		200 ms		1,000 ms	
		RT	PE	RT	PE	RT	PE
Task-1							
Happy							
	Left	821 (49)	.043 (.012)	825 (49)	.036 (.010)	767 (72)	.026 (.007)
	Right	834 (51)	.040 (.011)	835 (53)	.031 (.011)	772 (75)	.020 (.006)
Angry							
	Left	726 (52)	.056 (.009)	713 (56)	.038 (.007)	630 (50)	.028 (.004)
	Right	742 (57)	.031 (.003)	715 (56)	.037 (.005)	622 (49)	.027 (.005)
Task-2							
Happy							
	Left	1,068 (66)	.025 (.007)	979 (61)	.027 (.008)	670 (47)	.037 (.011)
	Right	1,078 (63)	.044 (.009)	997 (66)	.043 (.011)	660 (42)	.035 (.010)
Angry							
	Left	1,008 (61)	.059 (.013)	908 (61)	.058 (.012)	631 (36)	.059 (.007)
	Right	1,022 (65)	.062 (.011)	914 (59)	.080 (.012)	635 (36)	.049 (.008)

Note. The standard error of the mean is shown in parentheses.

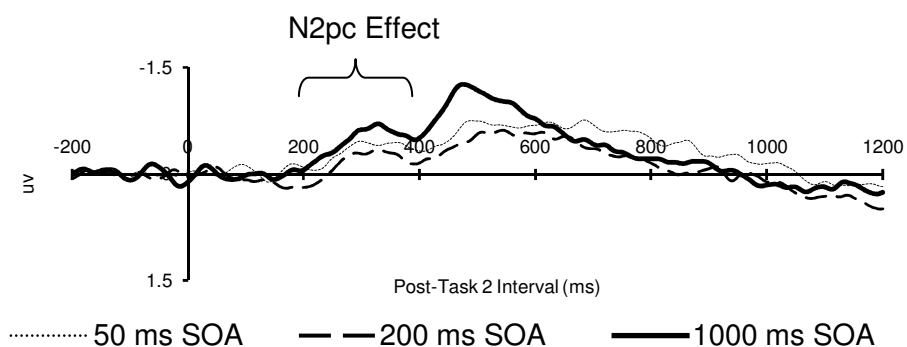


Figure 8: Grand average N2pc difference waveforms for Task-2 as a function of SOA (50, 200, and 1,000 ms) in Experiment 2. These N2pc effects were averaged across the P5/P6, O1/O2, and PO5/PO6 electrode pairs and Task-2 emotion type (angry vs. happy). The N2pc difference waveforms were calculated by subtracting the ipsilateral potentials from contralateral potentials (with respect to Task-2 target location). The baseline period was the 200 ms prior to Task-2 stimulus onset. Negative is plotted upward and time zero represents Task-2 stimulus onset.

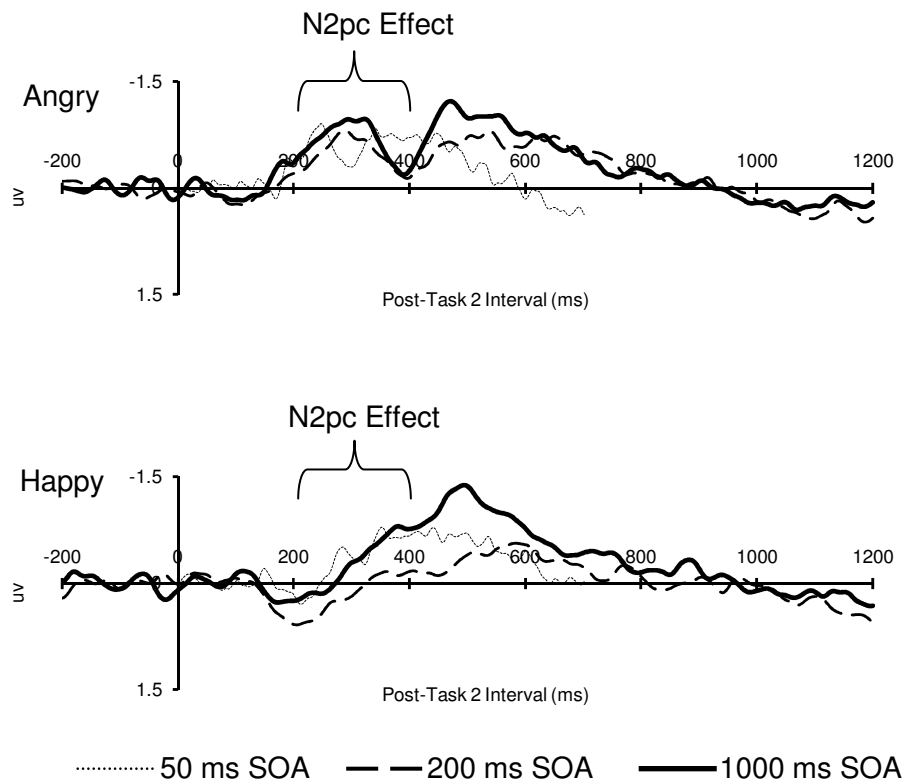


Figure 9: Grand average N2pc difference waveforms for Task-2 as a function of Task-2 emotion type (angry vs. happy) and SOA (50, 200, or 1,000 ms) in Experiment 2. These N2pc effects were averaged across the P5/P6, O1/O2, and PO5/PO6 electrode pairs. The N2pc difference waveforms were calculated by subtracting the ipsilateral potentials from contralateral potentials (with respect to Task-2 target location). The baseline period was the 200 ms prior to Task-2 stimulus onset. Negative is plotted upward and time zero represents Task-2 stimulus onset.

CHAPTER 5: EXPERIMENT 3

In both Experiments 1 and 2, the N2pc effect elicited by the face stimuli was larger when participants looked for the angry faces than happy faces, suggesting greater capture by angry faces. This result supports previous findings that negative emotions have high attentional priority (e.g., Astikainen & Hietanen, 2009; Becker, 2009; Eastwood et al., 2003). Note that in both experiments, participants were asked to search for a specific emotion. Thus, the greater capture by angry faces than happy faces may occur only when emotion is the top-down (goal) task set (i.e., contingent on the top-down control setting). Experiment 3 was designed to examine this hypothesis. Instead of searching for a specific emotion, participants were to determine whether the two faces appeared on the screen in each trial were the same gender or different genders. Thus, there was no need to establish the top-down task set for a specific emotion. As in Experiments 1 and 2, the two faces always contained one angry and one happy. If high attentional priority for negative emotion occurs only when participants searched for a specific emotion, then one would expect the absence of N2pc effect elicited by the angry face in Experiment 3. However, if high attentional priority for negative emotion occurs regardless of the top-down control task set, then one would expect the N2pc effect elicited by the angry face even when it competes with the happy face.

Method

Participants

There were 33 participants (8 men, 25 women; 32 self-reported as being right-handed and 1 self-reported as being left-handed), drawn from the same participant pool as in Experiments 1 and 2. None had participated in the previous experiments. Data from 8 participants were excluded from the final data analyses due to excessive eye movement artifacts in the EEG data. Therefore, data from 25 participants were included in the final data analyses. Their mean age was 19.06 years (range: 18-35 years). All reported having normal or corrected-to-normal visual acuity.

Apparatus, Stimuli, and Procedure

The tasks, stimuli, and equipment were the same as in Experiment 2, except that participants were instructed to indicate whether both faces were the same gender or different. They pressed the button labeled “4” with their right-index finger if the two facial stimuli were the same gender and pressed the button labeled “5” with their right-middle finger if the two facial stimuli were opposite in gender. As in Experiment 2, each trial consisted of one happy and one angry facial stimuli.

Results

The data analysis in Experiment 3 was similar to that of Experiment 2, except that the Task-2 location variable was replaced with the Task-2 same vs. different gender variable. Application of the RT cutoffs eliminated approximately 0.77% of trials. Rejection of trials with ocular artifacts in the EEG data led to the further elimination of 5% of trials, but no more than 16% for any individual participant.

Behavioral Data Analyses

Table 3 shows mean RT and PE for Task-1 and Task-2 at each SOA.

Data were analyzed as a function of SOA (50-, 200-, and 1,000-ms), and Task-2 same vs. different gender. For Task-1, the main effect of SOA approached significance, $F(2, 48) = 2.86, p = .0671, MSE = 13,769$; mean RT1 was 772, 756, and 717, at the 50-, 200-, and 1,000-ms SOAs, respectively. PE1 increased as SOA decreased, $F(2, 48) = 5.31, p < .01, MSE = 0.0004$; PE1 was 0.032, 0.030, and 0.020 at the 50-, 200-, and 1,000-ms SOAs, respectively. PE1 was slightly higher when both faces in Task-2 were the same gender (PE1 = 0.029) than when they were different (PE1 = 0.025), $F(1, 24) = 4.45, p < .05, MSE = 0.0001$. No other effects were significant.

For Task-2, a large PRP of 390-ms was observed on RT, $F(2, 48) = 191.51, p < .0001, MSE = 10,653$; mean RT2 was 1,111-, 1,008-, and 722-ms at the 50-, 200-, and 1,000-ms SOAs, respectively. The between-experiment comparison shows that the PRP effect on RT2 was similar between Experiments 1, 2, and 3 (374-, 395-, and 390-ms, respectively), $F < 1.0$. The main effect of Task-2 same vs. different gender discrimination was also significant, $F(1, 24) = 83.24, p < .0001, MSE = 1,724$, with longer RT2 for different genders than for the same gender (on average, 978-ms and 916-ms, respectively). For PE2, the main effect of SOA was significant, $F(2, 48) = 3.67, p < .05, MSE = 0.0006$; the PE2 decreased as SOA increased (PE2 was 0.088, 0.087, and 0.076 at the 50-, 200-, and 1,000-ms SOAs, respectively). The interaction between SOA and Task-2 same vs. different gender

discrimination was also significant on PE2, $F(2, 48) = 6.84, p < .01, MSE = 0.0008$. For different genders, PE2 decreased as SOA increased. For same gender, PE2 was higher at the 200-ms SOA than at the 50- and 1,000-ms SOAs (see Table 3). No other effects were significant.

ERP Analyses

To search for evidence of the greater capture by angry faces than happy faces, we examined the N2pc effect elicited by the angry face. The N2pc data were analyzed as a function of SOA (50-, 200-, vs. 1,000-ms) and electrode pair (P5/P6, O1/O2, and PO5/PO6). Figure 10 shows the N2pc effect averaged across these electrode pairs. The overall N2pc effect was similar across SOAs, $F < 1.0$; the N2pc effect was $-0.193 \mu V$, $-0.214 \mu V$, and $-0.214 \mu V$ at the 50-, 200-, and 1,000-ms SOAs, respectively. Pairwise comparisons revealed that the N2pc effect was not significant between any two SOA conditions, $F_s < 1.0$. Most importantly, further t-tests revealed that the N2pc effect was significantly different from zero at the 50-, 200-, and 1,000-ms SOAs, $t(24) = -3.47, p < .01$, $t(24) = -4.41, p < .01$, and $t(24) = -3.62, p < .01$, respectively. No other effects were found to be significant.

Discussion

Experiment 3 was designed to examine whether the greater capture by angry faces than happy faces occurs even when participants are not searching for any specific emotion. Different from Experiments 1 and 2 where participants were instructed to search for a specific emotion stimulus (happy or angry), participants in Experiment 3 were asked to determine if the two faces

were the same or different genders. Thus, no specific emotion was needed to maintain in the memory. The critical finding is that the N2pc effect elicited by the angry faces was still significantly different from zero at all SOAs. This result suggests that an attentional bias toward angry faces occurred even when participants were not searching for any specific emotion (i.e., is not contingent on the top-down goal). Although the N2pc effect elicited by the angry face was relatively small comparing to those in Experiments 1-2, it is possible that the angry face was pitted against the happy face given that both faces were relevant to the task.

Table 3: Mean Response Time (RT in Milliseconds) and Proportion of Errors (PE) for Task-1 and Task-2 as a Function of Stimulus Onset Asynchrony (50, 200, and 1,000 ms) and Task-2 same vs. different gender in Experiment 3.

Stimulus Onset Asynchrony						
50 ms		200 ms		1,000 ms		
RT	PE	RT	PE	RT	PE	
Task-1						
Same						
769 (41)	.035 (.007)	750 (44)	.033 (.006)	720 (53)	.020 (.004)	
Different						
775 (42)	.029 (.006)	762 (44)	.027 (.006)	715 (52)	.020 (.004)	
Task-2						
Same						
1,079 (42)	.074 (.011)	977 (42)	.075 (.012)	693 (22)	.081 (.014)	
Different						
1,144 (42)	.102 (.016)	1,040 (43)	.099 (.015)	750 (23)	.070 (.010)	

Note. The standard error of the mean is shown in parentheses.

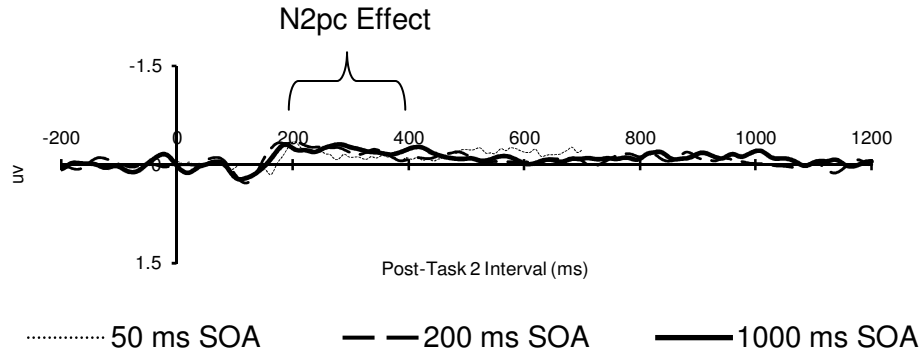


Figure 10: Grand average N2pc difference waveforms for Task-2 as a function of SOA (50, 200, or 1,000 ms) in Experiment 3. These N2pc effects were averaged across the P5/P6, O1/O2, and PO5/PO6 electrode pairs. The N2pc difference waveforms were calculated by subtracting the ipsilateral potentials from contralateral potentials (with respect to Task-2 angry face location). The baseline period was the 200 ms prior to Task-2 stimulus onset. Negative is plotted upward and time zero represents Task-2 stimulus onset.

CHAPTER 6: DISCUSSION AND CONCLUSION

GENERAL DISCUSSION

The goal of the present study was to determine whether emotion perception can occur without central attentional resources. Although Tomasik et al. (2009) found that processing emotion requires central attentional resources, one could argue that this might be because their task required people to assign a label (“happy” or “angry”) to the emotion in order to respond (Phillips et al., 2008). Perhaps some level of emotion processing is automatic, but cognitive labeling involves a more deliberate kind of emotional processing. To deal with this issue, the present study used a task where emotional labeling is less likely. Participants merely looked for the face expressing a particular emotion, and indicated its gender (Experiment 1) or location (Experiment 2), or determined whether the two faces were the same gender or different (Experiment 3). Although participants could conceivably assign a label to the emotion, there would appear to be no need to do so in our case (they were always searching for one specific target emotion). If participants can perceive emotions automatically, then spatial attention should shift to the face expressing the target emotion for Task-2, even when central attentional resources are occupied by Task-1.

Summary of Experimental Findings

As in most previous PRP studies, large PRP effects were observed on behavioral data (e.g., RTs) in all experiments. However, these behavioral data do not afford a test of whether emotions are processed automatically. The present study does not rely on the locus-of-slack logic nor manipulate Task-2

difficulty as in Tomasik et al. (2009) described above. The existence of a PRP effect in Experiments 1-3 merely indicates (as expected) that there is conflict somewhere between Task-1 and Task-2 processing, presumably between central processes such as response selection. Instead, the present experimental logic relies on the N2pc effect, which allows a much more direct assessment of whether emotion perception occurs without central attentional resources. If participants can perceive emotions automatically, and spatial attention can shift automatically, then spatial attention should shift to the face expressing the target emotion, regardless of the SOA between Task-1 and Task-2. Thus, the face expressing the target emotion should elicit an N2pc effect, without delay, even at the shortest SOA.

In both Experiments 1 and 2, where participants were searching for a specific target emotion, the Task-2 faces expressing the target emotion produced an overall N2pc effects, suggesting that spatial attention was allocated to its location. The important finding was that the N2pc effect was still substantial at the 50-ms SOA. In fact, there was essentially no reduction in Experiment 1, relative to the long SOA, and only a very modest reduction in Experiment 2 (31%). Thus, spatial attention initially moved to the face expressing the target emotion, even when central attention was still busy with Task-1. These findings are consistent with the claim that the processing of facial emotional expression does not require access to limited central attentional resources. In addition, a much larger N2pc effect was found when participants were searching for angry faces than for happy faces, supporting

the assertion that negative emotions have primacy over positive emotions.

Experiment 3 was conducted to assess whether the attentional bias toward the negative emotion occurs even when participants are not searching for any specific emotion (i.e., the emotion was not the top-down task set). Instead of instructing participants with an emotional task-goal, participants determined whether the two pictures (one angry and one happy) presented were of the same or different gender, with no instruction given for emotional expressions. The N2pc effect elicited by the angry face was still observed at all SOAs. This finding further argues that the attentional bias toward negative emotion is not contingent on the top-down task set.

In summary, the present findings lead to two important and pivotal conclusions – 1) emotional perception is not reliant on central attentional resources and can occur automatically, and 2) negative emotions have higher attentional priority than positive emotions.

Attentional Bias for Negative Emotions

The present finding of attentional bias toward negative emotions is consistent with Holmes, Bradley, Nielsen, and Mogg's (2008) research which used the N2pc to gauge allocation of attention in a visual-probe design. Holmes et al. measured N2pc effects while participants were first presented with two photos side by side with a cross in the middle, with one photo being neutral and the other presenting either an angry or a happy facial expression. After 500-ms, the cross became a downward or upward pointing arrow, with participants being instructed to assess the pointer direction via keypad

response. Results indicated that attention was not only allocated to emotional expression, but angry faces elicited N2pc effects earlier in the time course (180-250-ms post-stimulus) in comparison with happy faces (250-500-ms post-stimulus), leading the authors to conclude that the negativity bias has an important role in visual perception in everyday life.

In the current study, an assessment of the influence of top-down task settings on attentional bias for negative emotions was investigated in Experiment 3. Unlike Experiments 1 and 2, Experiment 3 had participants established for a non-emotionally related task goal (same vs. different gender) to determine whether attentional bias toward negative emotions still occurs. Results supported the hypothesis that attentional bias for negative emotions is not contingent on the top-down task goal. This promotes the conclusion that emotional perception, particularly of negative stimuli, is conducted in a more-or-less bottom-up fashion, with emotional environmental stimuli taking precedence over goal settings. To appropriately interpret the results of Experiment 3, though, it is essential to implicate not only a bottom-up processing approach but also view the results through a top-down lens. Note that participants were instructed to discriminate the gender of the two faces. Thus, the allocation of spatial attention to both left and right sides of the screen was necessary to perform the task correctly. The reduction of the N2pc effect elicited by angry faces in Experiment 3 comparing to the effect in Experiments 1 and 2 may reflect an interaction of both top-down and bottom-up processing.

Theeuwes (2010) has asserted that bottom-up processing is faster than

top-down processing, with salient environmental stimuli being more quickly attended to and task-goal settings being able to ameliorate this processing later in the time-course. The results of Experiment 3 can be approached through this explanation, as it is feasible that the angry face initially captured attention but the task-goal of determining whether the genders depicted in the pictures were the same or different eventually overcame this stimulus processing. For instance, when the stimulus was presented, the angry face captured attention in a speeded fashion. However, the influence of the positive stimuli combined with the task-goal of same vs. different gender discrimination essentially cancelled out part of this capture effect, leading relative small N2pc effect elicited by the angry face.

IMPLICATIONS

Emotional Perception is Automatic

Evolutionarily speaking, the ability to process emotional stimuli rapidly and with precedence over other environmental stimuli is vital for everyday interactions and survival. The current study demonstrated that emotion perception is automatic and not reliant on attentional resources, in line with an adaptive mechanism for emotional stimuli. In both everyday interactions and survival situations, this innate mechanism serves to facilitate social exchanges, identify environmental threats, and aid in the engagement of others. Young children rely on parental models to non-verbally communicate praise, sympathy, anger, and danger, with these experiences aiding in the development of social skills and maintaining group networks of friends and relations,

scaffolding the learning process and the need to belong. Without this ability to perceive emotional expressions, vital messages, such as acceptance or frustration, would be lost and hinder social relationships, resulting in severed social ties or tension within the group. From an early age, parents model what is and is not appropriate, either verbally or non-verbally, with the result being an engrained understanding of societal norms and expectations, the implications of which spread across the life-span in employment, mate selection, and social support.

Superiority of Negative Stimuli

The current study not only found that emotion perception can proceed without central attentional resources, but that negative stimuli have facilitated processing over positive stimuli, a critical component of survival. Negative emotional stimuli can be direct (i.e., anger) or indirect (i.e., fear) with both types being essential for longevity. Anger as a direct threat indicator alerts us to the possibility of violence or altercation, from a physical fight between two rivals or a quarrel between lovers. By being able to automatically perceive these indicators of disputes, we can either work on protective measures or attempt to reduce the negativity. A shallow example may be someone talking on their cell phone while studying with a friend, disturbing their companion's concentration and efficiency. The studious friend may eventually become upset at the frequent disturbances and grow irate, evidenced by their facial expressions and posture. The cell-phone talking friend will get the message and can attenuate their anger by ceasing the conversation or moving to an

appropriate area. In comparison, a more dire implication of this primacy is the case where a person in a violent environment recognizes a direct and angry gaze, signaling the need to protect themselves or appease the aggressor. By reading their facial expression, they can try to avoid their partner's violent acts for the time being, a maladaptive but unfortunate reality for many of these types of relationships.

In summary, the current study's two findings that emotional perception is automatic and not reliant on central resources with negative stimuli having precedence over positive stimuli aid in the understanding of survival mechanisms, social relationship facilitation, and early development of social awareness.

LIMITATIONS

The current study provides evidence of greater attentional capture by angry faces in comparison with happy faces, coupled with the strength of using electrophysiological methods to investigate the automaticity of emotional perception, but the generalization of these findings should be taken cautiously. One limitation of the current experiment is the lack of information regarding participant anxiety levels, affect, or personality traits. In addition, individuals diagnosed with an Autism Spectrum Disorder (ASD) have been found to be stunted in their emotion perception of other's faces (Churches, Wheelwright, Baron-Cohen, & Ring, 2010; Corbett, et al., 2009; McPartland, Dawson, Webb, Panagiotides, & Carver, 2004). The current study did not assess the personality traits or use clinical data from participants to determine if they fit

categories that would be considered atypical in emotional facial expression processing. It is a possibility that there may have been participant variables including personality, disposition, or general mood that affected the present findings. For instance, it has been found that individuals characterized as being high in anxiety have demonstrated enhanced processing for negative stimuli in comparison with low-trait individuals (Holmes, Nielsen, Tipper, & Green, 2009). Without providing pre- and post-test measures to assess these possibilities, we cannot unequivocally state that results were dependent on the manipulated variables alone.

In addition, positive personality traits, such as empathy, may be influential in the processing and understanding of emotional expressions. Besel and Yuille (2010) found that individuals who were labeled as being highly empathic were more sensitive to emotional perception in comparison with lower-empathic individuals. Neither negatively-connotated (i.e., suffering from anxiety or meeting diagnostic criteria for social deficit disorders, such as autism) nor positively connotated (i.e., empathy) personality traits were controlled for in the current study. Future studies should utilize the current findings to explore how populations outside of typically-developing adults perceive emotional stimuli and inform interventions to facilitate emotional perception training, specifically in young children.

FUTURE DIRECTIONS FOR RESEARCH

Autism Spectrum Disorders and Deficits in Face Perception

As described above, personality factors or individual differences may

facilitate or hinder emotional perception, particularly for those who suffer from social deficits or disorders. The inability to express emotions and perceive them accurately can be highly damaging for an individual's social development, as both verbal and nonverbal communication are apt to be misunderstood or disregarded, as is the case with individuals diagnosed on the autism spectrum. Without the ability to relate to others via communication and emotional expression, effective social interactions are limited or non-existent and can perpetuate the symptoms already generated by autism (Njardvik, Matson, & Cherry, 1999). Cognitive and developmental researchers have sought to determine how the processing of facial expression and emotion is misattributed and its effects on memory in children with autism.

Dawson et al., (2002) used ERPs to assess emotional perceptions in children with autism and found that facial recognition impairment was severe and likely manifested at a young age. In that study, they presented three groups of children, one classified as being composed of children with autism, one being comprised of children with developmental delays but not diagnosed as autism, and a control group of typically-developing peers, a series of images and recorded their ERPs with the onset of each picture. The pictures were of their mothers, unfamiliar female faces, favorite objects, and unfamiliar objects. The P400 (a positive component considered to be the infantile N170) and Nc (a negative component between 400- and 800-ms post-stimulus that has been found to be larger when attention is given to infrequent stimuli; Richards, 2003) components were recorded due to their role in the processing of faces

versus objects (P400) and attending to salient stimuli (Nc). What the researchers found was that when presented with images of their mothers in comparison to an unfamiliar face, typical children showed a decrease in both P400 and Nc amplitude for the pictures of their mothers, demonstrating recognition of an established social relationship. In comparison, children with autism did not show no difference in P400 and Nc effects between for the unfamiliar (novel face) and familiar (mother's face) stimuli, signaling that both were perceived as being infrequent or rare stimuli. The findings provide evidence of facial recognition impairment in individuals diagnosed on the autism spectrum.

A deficit in emotional reciprocity has been demonstrated to predict poor social skills and/or social withdrawal because children are unable to fully interact and engage their developmentally normative peers (Coplan & Armer, 2007). Normatively developing young children engage in varied, complex interactions with others through play and social relationships, increasing their positive social competence or effectiveness in social interactions. Fabes, Gaertner, and Popp (2006) describe the development of social competence as a reciprocal relationship- the more an individual interacts with their peers in effective, positive manners and utilizing a shared emotional understanding, the more positive social competence skills they gain. These experiences are then used to broaden and strengthen their interpersonal skills which contribute to feed the acquisition of healthy relationships. On the other hand, a child with low social competency resulting in emotional reciprocity blocking is less likely

to engage with their peers in activities and therefore less likely to be able to practice or strengthen positive skills to boost their competency (Rubin, Bukowsky & Parker, 2006).

Electrophysiological Research and Autism Spectrum Disorders: Future Interventions

Recently, research in ASDs has investigated the likelihood of endophenotypes being a genetic predisposition to developing the disorder. Endophenotypes are characterized by being neuropsychological, biochemical, neuroanatomical, or cognitive markers of pre-behavioral traits (Jeste & Nelson, 2009), with the *Broader Autism Phenotype* (BAP) being characterized by dysregulations in joint attention, language, and social interaction (Scheeren, & Stauder, 2008). The biological undercurrents of the BAP enable researchers to assess whether relatives of individuals diagnosed on the autism spectrum share similar impairments but without detrimental social effects coming to the surface. For instance, McCleery, Akshoomoff, Dobkins, and Carver (2009) investigated whether 10-month old infants who had a sibling diagnosed on the autism spectrum (at-risk) differed in their processing of visual stimuli (familiar vs. an unfamiliar toy, familiar vs. and unfamiliar face) in comparison with infants whose siblings were not on the spectrum (low risk). Their results demonstrated support for a BAP, with at-risk infants showing atypical face processing in comparison with the low-risk infants. Although their results provide support for ERPs being used as a sign of autism risk, caution should be taken when viewing them as a diagnostic tool. Future research should empirically validate the use of ERPs paired with additional methodological

measures, such as functional magnetic resonance imaging (fMRI), to continue elucidating the relationship between visual processing and later disorder diagnoses.

The current research aids in this progress toward diagnoses and intervention. By assessing ERP components and actively searching for areas of processing that may be contrary to those of typically developing children, the goal is to narrow the gap in development and help facilitate integration into mainstream classrooms and social interactions. By determining that visual processing is occurring in a maladaptive manner, early interventions can take advantage of the critical developmental time windows early in the lifespan by aggressively counteracting the detrimental effects of social isolation and equipping individual at-risk for autism with social communication tools and exercises. The current study adds to the current literature in ERPs and emotional processing, providing a ground work for future research and strategies to understand the BAP and work to create an even social playing field for those most at-risk of social alienation.

CONCLUSIONS

The present study bridges the gap in the contradictory literature on emotional perception. Previous studies have asserted that emotion perception is automatic (see Eastwood et al., 2003) while others have demonstrated reliance on attentional resources for emotion processing (see Erthal et al., 2005). Results of the current study present evidence that emotional perception is automatic in that it is not reliant on central attention resources. In addition, the

present study supports the view of attentional bias for negative emotions.

Future research in emotion perception needs to further investigate the mechanisms of emotional perception and look to strategies of assessing at-risk populations, such as those with autism spectrum disorders, with the goal of instating early intervention strategies to ameliorate the maladaptive processing of the vital non-communicative signals.

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