Effects of auditory context on face expression processing:

An ERP Investigation

by

Anna Hudson

A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Master of Arts

in

Psychology

Waterloo, Ontario, Canada 2018

Author's Declaration

I hereby declare that I am the sole author of this thesis. This a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Facial expressions of emotion are a critical source of social information within the environment, but their interpretation is seen to be modulated based on the situational context in which they are presented. Most empirical work examining context on face expression processing have utilized visual cues only, with few studies examining cross-modal effects on face expression processing, despite auditory information being a second critical source of social information within the environment. The present study investigates the effect of positive and negative situational auditory (verbal) information on the identification of happy and angry face expressions. Both behavioural measures, and Event-Related Potentials (ERPs), derived from EEG recordings, were examined. Research has previously demonstrated ERP components elicited by the presentation of faces that are modulated simply by early visual attention (the P1 changes in facial expressions (the N170), emotional valence (the Early Posterior Negativity (EPN)) and the integration of these facets with contextual cues (Late Positive Potential (LPP)). In the present study, congruently paired positive sentences –happy face expressions received a cognitive gain such that reaction times were improved relative to all other conditions. Additionally, accuracy for congruent trials were significantly higher than incongruent trials for both happy and angry faces. Happy expressions elicited marginally enhanced P1, and larger N170 amplitude relative to angry faces. The EPN was more negative for angry relative to happy faces, which continued into the LPP as the counter positive enhancement. There was no interaction between sentence valence and face expression across any indices, potentially reflecting distinct neural networks for processing auditory information, or that the auditory information had been processed much earlier, with no modulation on the visual indices measured in this study.

Acknowledgements

The research presented in this thesis was conducted at the University of Waterloo, and was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) under the NSERC Discovery Grant #418431, the Canada Foundation for Innovation (CFI) under Grant #213322, the Canada Research Chair under Grant #213322 and #230407 awarded to my supervisor, Dr. Roxane Itier, and SSHERC awarded to my supervisor, Dr. Heather Henderson.

Firstly, I wish to extend my sincerest gratitude to my supervisors, Dr. Roxane Itier and Dr. Heather Henderson, for their continued support throughout this process. It has been a pleasure working under such strong and caring women, whom inspire me every day in my work, and in my life. I also wish to extend my thanks to my thesis readers; Dr. Michael Dixon and Dr. Katherine White for their insight, comments, and suggestions.

A warm appreciation is extended to my lab and office mates from both Dr. Itier's lab (Sarah McCrackin, and Karisa Parkington) and from Dr. Henderson's lab (Emma Green, and McLennon Wilson) for their unwavering support, feedback, and assistance.

On a personal level, I also wish to extend a heartfelt appreciation to my parents, John and Jo Hudson, sister Laura Hudson, my dear friend Erica Naccarato, and extended family and friends for their encouragement and support that has made this final product possible.

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Chapter 1: INTRODUCTION

Successful social cognition requires integrating various informative cues elicited by the social partner, and the environmental cues surrounding them. Of critical importance are the visual changes in facial expression in response to some external stimulus. Consequently, research examining the effect of context on the processing of facial expression has received empirical attention. The majority of this work has examined context cues within the visual domain. However, incoming social information is typically experienced across multiple sensory inputs, including both visual *and* auditory modalities. Despite audio-visual integration being a fundamental aspect of social cognition, few studies within the facial expression processing field have utilized auditory context. Thus, the overarching goal of this project is to examine audio-visual effects on social cognition, with a secondary aim of creating ecologically valid experimental stimuli.

Facial expressions are typically elicited in response to a situational cue, with context informing the interpretation of the configurable changes in a face. For example, if someone experiences a particularly happy situation, such as winning a competition, an observer will likely witness a happy facial expression. However, if the observer witnesses an unhappy facial expression in response to a win, then the observer would feel compelled to investigate the reasoning behind the incongruent emotional response. Situational cues such as winning a competition, allow the observer to quickly and accurately predict the resulting facial expression. However, typical research in the face-expression literature has studied faces in isolation, acting under the assumption that emotions are easily and automatically recognized. Results from priming studies on face expression processing suggest this assumption is flawed, with context modulating how faces are encoded (Barrett, Mesquita, & Gendron, 2011; Wieser & Brosch, 2012).

Of the growing body of research examining contextual influences on face expression processing, the majority have presented visual context primes. Outside of language, faces have been presented on emotional scenes (Herring, Taylor, White, & Crites, 2011; Righart & de Gelder, 2006), with behavioural and neural responses suggesting the scene in which a face is presented may modulate the way it is encoded. Within language, context has been manipulated via written words (Carroll & Young, 2005), sentences (Diéguez-Risco, Aguado, Albert, & Hinojosa, 2013; Diéguez-Risco, Aguado, Albert, & Hinojosa, 2015), or paragraphs (Carroll, & Russell, 1996). These context primes have demonstrated language-driven semantic context modulates the perception of a facial expression. Carroll and Russel (1996) specifically demonstrated that providing situational context changed a pre-identified facial expression to be interpreted differently based on the context provided (e.g. an "angry face expression" was interpreted as fear after reading about a person in a frightening situation). Diéguez-Risco et al. (2013) presented a written situational sentence before asking participants to categorize the emotion of a face. The critical manipulation was the congruency of the emotion induced by the situation (happy/angry) and the subsequent facial expression (happy/angry). Behaviorally, participants responded more slowly to incongruent trials (i.e. happy sentence-angry facial expression) compared to congruent trials (i.e. happy sentence-happy face expression). These results were interpreted as reflecting impaired processing for facial expressions following an incongruent prime, suggesting participants expect the facial expression to match the context in which it is presented.

There are various shortcomings of studying context effects on a visual target while using a visual prime. One criticism lies in the shared processing of visual information, as both the contextual prime and the target stimulus (i.e. the emotional face) are processed within the same modality. This shared set of processing resources may be delaying the integration of context and target information early within cognition (Frassinetti, Bolognini, & Làdavas, 2002). Secondly, rarely in a typical social situation is the context presented in the form of a written scenario. Instead, daily situational context is often observed *auditorily.* Therefore, previous work that has paved the way in establishing a basic understanding of context effects on face expression processing, do not truly reflect what is occurring in real social situations, in which both visual and audible information are processed together (Vesker, et al., 2018). Consequently, research concerning the integration of auditory context cues on face expression processing is receiving empirical attention. The present work aims to contribute to this growing body of literature.

Critically, perception studies demonstrate that auditory and visual information modulate the interpretation of one another. While visual information has been shown to modulate auditory information, through the McGurk illusion, in which visually presented mouth movements forming the sounds /ba/ or /da/ modulates the perception of the elicited word (van Wassenhove, Grant, & Poeppel, 2007), the converse has also been demonstrated. For example, presenting multiple auditory beeps can make a single flash of light be perceived as multiple flashes (Shams, Kamitani, & Shimojo, 2002). In recent work, the effects of auditory context on face expression processing have taken the form of emotional vocal interjections (ie. “Ah”, “Oh”; see Jessen & Kotz, 2015) or neutral words and phrases expressed in a positive or negative emotional tone (Conde, Gonçalves, & Pinheiro, 2015; de Gelder & Vroomen, 2000; Hiyoshi-Taniguchi et al., 2015), presented as context prior to the presentation of a face.The results of these studies demonstrate that auditory context biases the expected facial expression in a similar way to visual context, such that reaction times are longer to incongruent context-face emotion trials (de Gelder & Vroomen, 2000; Herring et al., 2011).

While behavioural work has demonstrated that what we hear modulates what we see, this work cannot answer when or how cross-modal information is integrated at the neural level. These sets of questions are important in understanding if integrative processes occur early within the course of processing, and if early neural changes modulate behaviour. With the addition of neuroimaging techniques, we can also determine if contextual cues and facial expressions are indeed integrated to guide cognition, or if they require discrete attentional resources. While various neuroimaging techniques are available to answer these sets of questions, Event Related Potentials (ERPs), derived from electroencephalography (EEG), are arguably the most relevant for investigating whether audition can alter face perception. EEG is particularly sensitive to small changes in neural processing, and most importantly has exceptional temporal resolution. These facets allow researchers to identify when experimental manipulations have impacted neural processes. Of particular interest is *if* stimulus integration occurs, and if this takes place at early sensory stages, or later stages, with later neural processing reflecting top down processing (Luck, Woodman, & Vogel, 2000). In particular for this study, ERPs allow researchers to make inferences about *when* an auditory stimulus has modulated visual stimulus processing – that is, whether auditory information alters the early processing stages, or only later interpretation stages. Previous work has implicated neural markers modulated by faces and face-expressions. This study focuses on four ERP components of relevance: The P1, N170, early posterior negativity (EPN), and late positive potential (LPP).

An early ERP within visual processing is the P1, peaking approximately 100ms post stimulus onset. Enhanced amplitude on the P1 is thought to reflect early attentional processing for visual stimuli (Luck, Woodman, & Vogel, 2000; Meeren, van Heijnsbergen, & de Gelder, 2005; Mangun 1995)**.** Within the face expression literature, emotional effects on the P1 are controversial. Some studies have found an enhanced amplitude to emotional relative to neutral faces (Batty and Taylor, 2003; Eger, Jedynak, Iwaki, & Skrandies, 2003; Luo, Feng, He, Wang, & Luo, 2010; Pourtois, Dan, Grandjean, Sander, Vuilleimier, 2005). One study by Rellecke, Sommer, and Schacht (2012) found an enhanced P1 amplitude to angry faces relative to happy and neutral faces. Additionally, previous work has seen an enhanced P1 to fearful faces relative to neutral faces in gender discrimination tasks (Pourtois et al, 2005; Wijers and Banis, 2012). The enhanced P1 amplitude to negative face expressions has been interpreted to reflect attention capture for potentially threatening stimuli. However, other studies have failed to find any effect of emotion on the P1 (e.g. Itier & Neath-Tavares, 2017; Neath & Itier, 2015; Neath-Tavares & Itier, 2016; Vuilleumier & Pourtois, 2007). The conflicting emotion effects on the P1 has been attributed to poorly controlled stimuli, in which equating low level factors, such as pixel intensity and luminance, is ignored. Critically, the P1 is sensitive to low level factors of a stimulus (Mangun, 1995). Consequently conclusions from previous works are difficult to interpret, as the resulting ERP differences (or lack thereof) may be due to low-level stimulus factors, as opposed to any empirical manipulation involving emotional expression. Despite the controversies in the literature, the P1 may be picking up differences in emotional valence information before specific emotion identification processes are fully completed (Luo et al., 2010). As far as we know, there is no research examining the effects of an auditory prime on P1 amplitude following the presentation of an emotional face. Therefore it is unclear how an auditory prime impacts the P1 during visual processing. This study will therefore be one of the first to analyze whether auditory information can influence this early ERP component associated with emotional faces.

Following the P1 component is the N170, a face sensitive ERP modulated by configurable changes of the face during emotion processing (Hinojosa, Mercado, & Carretié, 2015; Calvo and Nummenmaa, 2016). The N170 has been found to be modulated both in terms of amplitude and latency in response to various face expressions. The seminal paper by Batty and Taylor (2003) explicitly examined the neural response to the seven basic emotions (sadness, fear, disgust, anger, neutral, surprise, and happiness). N170 latency was seen to be longer for fear, disgust, and sadness relative to neutral, happy, and surprised emotions. This prolonged latency for these emotions may reflect the low frequency with which these emotions are viewed in the natural world, with shorter latency reflecting ease in processing for these latter (more common) facial expressions (Batty & Taylor, 2003). This study also found an enhanced amplitude to fearful faces relative to all other emotions, which may reflect a uniqueness of viewing fearful faces (i.e. low exposure to viewing this expression) relative to all other emotions. Other studies have similarly found enhanced N170 amplitudes to fearful relative to neutral faces (Blau, Maurer, Tottenham, & McCandliss, 2007; Itier & Neath-Tavares, 2017), and angry relative to happy faces (Krombholz, Schaefer, & Boucsein, 2007; Rellecke, Sommer, & Schacht, 2012), providing further support for enhanced processing to negative (relative to neutral) environmental stimuli on early visual ERPs. Critically, the N170 has also been seen to be modulated by the context in which the facial expression is presented. Righart and de Gelder (2006) presented fearful and neutral faces in isolation, or over fearful and neutral backgrounds (congruently and incongruently presented). The results indicated that facial expressions presented on a fearful background elicited a larger N170 amplitude than when presented on a neutral background, suggesting context may modulate the encoding process of a face. No congruency effects were reported. This leaves open the possibility that auditory context primes may modulate the processing of emotional face expressions at this relatively later visual stage, and not earlier (e.g. at P1), *if* audio-visual integration does occur at early visual processing stages.

The Early Posterior Negativity (EPN) is a negative wave occurring maximally around 200-400ms post stimulus onset. The EPN is valence sensitive, such that negative emotions elicit an enhanced negative amplitude (Schacht & Sommer, 2009; Schupp, Junghöfer, Markus, Weike, & Hamm, 2003). Specifically, Rellecke et al. (2012) found an enhanced negativity for angry face expressions relative to happy and neutral. Additionally, the late positive potential (LPP), occurring maximally between 400-600ms post-stimulus and spanning both parietal and frontocentral regions (Wieser, et al., 2014), also appears to be enhanced to negative emotions (Schupp et al., 2004; Rellecke, et al., 2012). Priming studies using visual stimuli have also demonstrated a sensitivity to the congruency of context and target stimuli on the LPP, such that amplitudes to incongruent targets are enhanced (Herring et al., 2011; Hinojosa, , Carretié, Valcárcel, Méndez-Bértolo, & Pozo, 2009; Diguez-Risko, et. al., 2013), potentially reflecting a violation of expectation to the target stimulus presented. This work suggests visually presented primes modulate target stimuli at later neural processing stages.

The goal of the present paper is to extend previous research on contextual effects on face-expression processing through cross-modal stimuli presentation, with a secondary goal of using more realistic auditory and visual stimuli. These goals will address the primary concern about *when* linguistically driven context primes modulate face expression processing. This study is based on Diéguez-Risco et al. (2013), with the critical change of using auditory, as opposed to visual, stimuli. Since this study is the first that we are aware of to present auditory situational context primes, we first had to create and validate the stimuli for the subsequent ERP study, to control for effects that may modulate the ERP signal, above and beyond the experimental manipulations. This includes equated syllable count across sentences, equivalent positive/negative sentences that only differed on one word, as well as ratings of intensity and arousal. This paper will begin by outlining the validation of the newly created stimuli (methods section 2.1). The goal of this validation was to identify auditory stimuli (in the form of sentences) that elicited positive and negative emotions, which would be consistent with the expression of happy and angry faces. Following the validation study, this paper will describe the ERP study itself (methods section 2.2).

The primary hypothesis is that participants will have improved processing of emotional faces when the context is manipulated so as to be congruent with expressed emotion of the face being viewed. Behaviourally, participants will have faster reaction times to congruent sentence valence-face expression trials (i.e. positive sentence- happy face, negative sentence-angry face) compared to incongruent context-face emotion matches (i.e. positive sentence-angry face, negative sentence-happy face). At the neural level, the emotional impact on the P1 is unclear, as the literature is controversial, with no studies finding converging evidence for amplitude differences between happy and angry facial expressions. Given the conflicting evidence, it is unlikely auditory information will impact face expression processing this early. The N170 will be larger for angry faces relative to happy faces, regardless of context, as it is reflective of early visual processing, not necessarily impacted by top down integrative processes. If auditory information modulates visual processing, at a relatively early stage the N170 may be modulated by context effects, although the direction of this effect between positive context and negative context is unclear, as previous work has only found differences between negative and neutral context. The later EPN and LPP are hypothesized to be modulated by the congruency effects between the context and subsequent face expression, as these components reflect more top-down cognitive processing. Specifically, incongruent trials will have increased amplitude relative to congruent trials, as this is reflective of a violation of expectation. Additionally, these ERP components are modulated by face emotion, and therefore an enhancement of the components will be seen for angry faces relative to happy faces.

Chapter 2: METHOD

2.1 Sentence Validation study

2.1.1 Participants

Forty-seven participants from the University of Waterloo (UW) psychology participant pool were tested. Two of these were eliminated because of missing data leaving a final sample of 45 participants, aged 17-29 years (Mean = 19.71 years, SD 2.25; 25 females). Participants were required to speak English as their first language, have normal or corrected-to-normal hearing and vision, and rated their ability to recognize facial emotions at least a 6 (mean = 8.12) on a 10-point scale. Participants signed written informed consent and the study was approved by a UW Research Ethic committee. Participants received one credit towards their Psychology course, or $10, upon completion of the study.

2.1.2 Stimuli and Apparatus

Coloured face stimuli were taken from the Chicago Face Database (Ma, Correll, & Wittenbrink, 2015), and equated for mean pixel intensity (.62) and RMS contrast (.44) using home-made matlab programs based off the SHINE toolbox (Willenbockel et al., 2010). This was accomplished by first removing the colour information, and adding the colour back once luminance and contrast information were equated. Ten male and ten female identities were selected with their corresponding neutral, happy-closed-mouth, and angry-closed-mouth facial expressions [1] (see Figure 1 for example). Each face was cropped to include part of the hair and

[1] Female identities CFD-WF-005; 009; 011; 022; 024; 025; 027; 029; 034; 035.
Male identities CFD-WM-006; 009; 012; 014; 016; 020; 023; 024; 029; 040.

the upper part of the shoulders and neck. Identities were also edited to ensure no hair fell on the face or filled any of the background. All identities were white-Caucasian.

A total of 160 audio file sentences, spoken by a female speaker were recorded in a sound attenuated Faraday cage using Audacity® (version 2.2.1) software. Her voice kept a neutral prosody through each sentence. Each sentence contained 11 syllables and described a negative or positive situation. A total of 40 unique sentence themes were created, with four sentences per theme differing on two dimensions: gender pronoun (i.e. she/he) and valence (i.e. won/lost; e.g. she/he just won/lost the ice skating competition). After recording, an additional 100ms of silence was added to the end of each sentence to prevent abrupt endings, and each audio file was made to be exactly 3 seconds long by adding additional silence to the beginning of each sentence using Audacity®. This design ensured all sentences ended at the same time to equate the time listeners had for cognitive processing.

The 2 (sentence gender) by 2 (sentence valence) by 2 (face expression) within subjects design was conducted in the lab using Qualtrics software (Qualtrics, Probo, UT; http://www.qualtrics.com; copyright© 2017). After completing a brief demographics questionnaire on a computer screen, participants were instructed to click a "play" button at the top of the screen to initiate the audio file and listen to each sentence as it was presented over speakers. At the same time, four questions were presented on the screen. The first two questions asked participants to rate, on a 0-9 Likert scale, how well a happy facial expression and an angry facial expression matched the situation described in the sentence. This match status between the linguistic information and the face expression was critical for the ERP study. The happy and angry faces were of the same person, whose gender matched the gender portrayed in the sentence. The order of the face expressions was pseudo-randomized across sentences. The third and fourth questions asked participants to rate the emotion intensity, described as how strongly the emotion would be felt by the person, and arousal, described as how exciting/stressful the emotion would be felt by the person experiencing the situation described by the sentence. The verbal instructions emphasized that those latter two ratings were independent from the face matching responses. The 40 unique sentence themes (positive/negative equivalents, repeated for each gender; total of 160 sentences) were pseudo-randomly presented to each participant so that no two sentences of the same theme were presented in a row, and identities were randomly assigned to each sentence pair. There was no time constraint for responding. Upon completion of the study, participants responded to an 'honesty' question which asked if participants answered the questions honestly, to ensure they were responding as accurately as possible.

2.1.3 Data processing and analyses

All statistical analyses were completed using IBM SPSS Statistics 25 software. Participants' data were inspected to ensure every question was answered, including the honesty question. The data of two participants were eliminated because they did not answer all the questions, leaving a total of 45 participants for data analyses.

For each of the 40 unique sentence themes (with positive and negative equivalents; each with a male and female protagonist), participants' face matching scores were subjected to a two (sentence gender: male; female) by two (sentence valence: positive; negative) by two (face expression: happy; angry) repeated measures ANOVA, for a total of 40 distinct ANOVAs. Sentences were eliminated if one of the following was obtained: a main effect of gender, *lack* of a main effect of sentence valence, *lack* of a face expression by sentence valence interaction, or a significant interaction between face expression and sentence gender. These criteria ensured that the final selection of sentence pairs did not differ based on gender pronoun, and protected against sentence pairs that did not elicit divergent emotions, or that did not match the appropriate face expression. Eight sentence pairs were eliminated, leaving 32 unique sentence themes to be used in the subsequent ERP study (see below). Of the 32 sentences, two were randomly selected to be used as practice trials. All further analyses are reported on the final sample of 30 sentence themes (see Table 1 for the happy/angry face match mean scores).

Table 1 Descriptive information for each of the remaining 30 sentences. Mean scores for each DV averaged across the 45 participants, with SD in parentheses, are reported.

		Male Identity				Female Identity			
Theme	**Sentence**	Happy Face Match	Angry Face Match	Intensity	Arousal	Happy Face Match	Angry Face Match	Intensity	Arousal
1	*She/He just* won *the ice skating competition.*	7.16(1.80)	.111(.383)	7.36(1.58)	7.58(1.51)	7.22(1.80)	.200(.588)	7.40(1.23)	7.44(1.41)
1	*She/He just* lost *the ice skating competition.*	.356(.743)	6.13(2.46)	6.80(1.70)	6.16(2.29)	.289(.694)	6.42(2.06)	7.04(1.57)	6.49(2.18)
2	*She/He* won *the hardest music competition.*	7.07(1.99)	.133(.504)	7.51(1.66)	8.07(1.14)	7.20(1.63)	.244(.570)	7.44(1.77)	7.91(1.22)
2	*She/He* lost *the hardest music competition.*	.311(.792)	6.51(1.97)	6.87(1.73)	6.42(2.15)	.511(.920)	5.76(2.49)	6.93(1.44)	6.11(2.26)
3	*She/He just* won *the best ballet competition.*	7.53(1.49)	.222(.636)	7.67(1.62)	8.02(.988)	7.84(1.24)	.178(.535)	7.78(1.68)	8.16(1.36)
3	*She/He just* lost *the best ballet competition.*	.533(1.31)	6.11(2.25)	7.09(1.31)	6.33(2.24)	.578(1.37)	6.29(1.95)	6.93(1.45)	6.47(1.91)
4	*She/He just* won *the basketball game for her/his team.*	7.33(1.61)	.178(.490)	7.44(1.52)	7.73(1.10)	7.11(1.73)	.267(1.01)	7.31(1.77)	7.73(1.45)
4	*She/He just* lost *the basketball game for her/his team.*	.200(.505)	6.42(2.14)	7.18(1.56)	6.84(2.18)	.178(.490)	6.07(2.66)	7.02(1.95)	6.84(2.24)
5	*She/He just* won *the world cup final for her/his team.*	7.36(2.01)	.089(.358)	8.18(1.51)	8.18(1.85)	7.11(2.01)	.287(1.10)	8.27(.986)	8.60(.863)
5	*She/He just* lost *the world cup final for her/his team.*	.244(.645)	6.62(2.54)	7.96(1.54)	7.62(2.31)	.156(.474)	6.27(2.71)	8.00(1.58)	7.91(1.99)
6	*She/He* won *the final soccer game for her/his team.*	7.29(1.60)	.133(.344)	7.87(1.10)	7.96(1.13)	7.11(1.89)	.289(.968)	7.67(1.21)	8.02(.988)
6	*She/He* lost *the final soccer game for her/his team.*	.289(.757)	6.67(2.30)	7.58(1.32)	7.24(2.05)	.133(.457)	6.42(2.19)	7.49(1.20)	7.22 (1.70)
7	*She/He* passed *her/his very difficult English test.*	7.18(1.70)	.400(1.09)	6.69(1.61)	6.64(1.67)	7.78(1.29)	.133(.405)	6.80(1.69)	6.91(1.83)
7	*She/He* failed *her/his very difficult English test.*	.244(.609)	6.60(2.11)	6.42(1.86)	6.47(2.29)	.244(.609)	6.42(2.53)	6.64(1.65)	6.84(1.95)
8	*She/He* passed *one of her/his many final exams.*	7.20(1.98)	.244(.570)	6.36(1.90)	6.67(1.71)	7.18(1.56)	6.49(1.87)	6.38(1.77)	6.49(1.87)
8	*She/He* failed *one of her/his many final exams.*	.133(.344)	6.62(2.28)	7.16(1.65)	7.49(1.89)	.200(.504)	6.38(2.26)	7.11(1.53)	7.38(2.09)
9	*She/He* passed *a very difficult science test.*	7.49(1.38)	.378(.960)	6.76(1.45)	6.76(1.88)	7.42(1.37)	.222(.823)	6.60(1.71)	7.022(1.48)
9	*She/He* failed *a very difficult science test.*	.444(.999)	6.20(2.33)	6.69(1.79)	6.60(2.13)	.333(.707)	6.49(2.14)	6.82(1.90)	6.64(2.23)
10	*She/He* received *the keys to her/his new vehicle.*	7.24(1.54)	.133(.404)	6.42(1.51)	7.07(1.76)	7.33(1.60)	.267(.963)	6.58(1.50)	7.07(1.63)
10	*She/He* misplaced *the keys to her/his new vehicle.*	.489(1.36)	5.87(2.76)	6.13(2.01)	6.27(2.45)	.156(.424)	6.20(2.37)	6.27(2.04)	6.53(2.38)
11	*She/He just* received *the keys to her/his new cottage.*	7.18(1.48)	.133(4.05)	6.47(1.60)	6.98(1.34)	7.04(1.89)	.133(.405)	6.47(1.46)	6.87(1.74)
11	*She/He just* misplaced *the keys to her/his new cottage.*	.311(.733)	6.62(2.08)	6.22(2.01)	6.82(2.17)	.222(.517)	6.24(2.42)	6.49(1.88)	6.80(2.16)
12	*She/He* won *the vacation she/he always wanted.*	6.78(2.16)	.089(.288)	7.27(1.59)	8.00(1.59)	7.20(1.89)	.111(.487)	7.33(1.41)	7.89(1.05)
12	*She/He* missed *the vacation she/he always wanted.*	.289(.787)	7.22(1.69)	7.18(1.54)	6.16(2.30)	.156(.424)	6.87(2.26)	7.18(1.53)	6.56(2.21)
13	*She/He was* accepted *by the school she/he wanted.*	7.47(1.53)	.111(.318)	7.44(1.50)	7.76(1.60)	7.56(1.57)	.178(.490)	7.31(1.79)	8.02(1.01)
13	*She/He was* rejected *by the school she/he wanted.*	.378(.912)	6.47(2.41)	6.87(2.01)	6.91(2.20)	.267(.654)	.267(.654)	7.47(1.65)	7.00(2.18)
14	*She/He* raised *the most money for the hospital.*	7.56(1.36)	.200(.505)	6.44(1.73)	6.98(1.63)	7.42(1.48)	.244(.743)	6.60(1.63)	6.84(1.89)
14	*She/He* lost *the most money for the hospital.*	.200(.588)	6.40(2.11)	7.31(1.66)	7.13(2.30)	.244(.679)	5.82(2.48)	6.89(1.73)	6.89(2.20)
15	*She/He* earned *the money for her/his dream vacation.*	7.47(1.32)	.111(.382)	6.98(1.79)	7.80(1.22)	7.58(1.25)	.178(.442)	7.67(1.17)	7.76(1.63)
15	*She/He* lost *the money for her/his dream vacation.*	.333(.953)	6.73(2.03)	7.69(1.36)	7.31(2.08)	.244(.645)	6.47(2.16)	7.29(1.67)	7.18(2.22)
16	*She/He just* bought *an amazing new vehicle.*	7.20(1.85)	.178(.490)	6.56(1.93)	7.33(1.67)	7.18(1.42)	7.18(1.42)	6.67(1.58)	7.29(1.73)
16	*She/He just* broke *an amazing new vehicle.*	.178(.442)	6.31(2.29)	7.53(1.63)	7.80(1.87)	.156(.367)	6.36(2.37)	7.69(1.38)	7.67(1.85)
17	*She/He just* won *a fast and expensive new car.*	7.40(1.71)	.222(.636)	7.82(1.40)	8.16(1.40)	7.29(1.58)	7.29(1.58)	7.73(1.76)	8.07(1.48)
17	*She/He just* crashed *a fast and expensive new car.*	.311(.874)	6.60(2.63)	8.04(1.38)	7.84(2.30)	.156(.424)	6.36(2.78)	8.13(1.18)	7.71(2.08)
18	*She/He* won *a very expensive brand new truck.*	7.24(1.78)	.156(.562)	7.64(1.23)	8.12(.842)	7.36(1.81)	7.69(1.29)	7.36(1.81)	7.84(1.15)

18	*She/He* crashed *a very expensive brand new truck.*	.111(.383)	6.27(2.61)	7.84(1.24)	7.64(2.22)	.156(.475)	6.16(2.50)	7.78(1.54)	7.89(1.87)
19	*She/He just* won *a powerful new computer.*	7.29(1.49)	.333(1.17)	7.00(1.40)	7.22(1.51)	7.42(1.48)	.244(.933)	6.89(1.73)	7.60(1.07)
19	*She/He just* broke *a powerful new computer.*	.222(.599)	6.62(1.89)	7.16(1.61)	7.31(1.76)	.200(.548)	6.62(1.90)	7.02(1.41)	7.04(2.34)
20	*She/He* loves *the cell phone she/he got for her/his birthday.*	7.02(1.71)	.133(.405)	6.31(1.73)	6.22(1.25)	7.40(1.34)	.156(.424)	6.40(1.53)	6.71(1.32)
20	*She/He* hates *the cell phone she/he got for her/his birthday.*	.622(1.25)	5.71(2.28)	5.09(1.83)	4.04(2.34)	.533(1.18)	5.87(2.33)	5.13(1.63)	3.93(2.26)
21	*She/He* loves *the football she/he got for her/his birthday.*	7.13(1.55)	.111(.383)	5.64(1.61)	5.69(1.76)	7.09(1.81)	.178(.442)	5.82(1.53)	5.93(1.60)
21	*She/He* hates *the football she/he got for her/his birthday.*	.689(1.35)	6.22(2.14)	5.13(1.90)	3.40(2.08)	.600(1.44)	6.11(2.45)	5.27(1.99)	3.47(2.06)
22	*She/He* loves *the new city she/he has to live in.*	7.47(1.49)	.111(.318)	6.51(1.47)	6.51(1.73)	7.38(1.43)	.111(.318)	6.51(1.47)	6.93(1.18)
22	*She/He* hates *the new city she/he has to live in.*	.289(.757)	6.82(1.94)	6.60(1.85)	5.96(2.27)	.289(.626)	6.93(1.89)	6.58(1.86)	6.04(2.34)
23	*She/He* loves *the new school she/he has to enroll in.*	7.24(1.55)	.111(.318)	6.62(1.52)	6.96(1.52)	7.38(1.77)	.133(.405)	6.53(1.52)	6.84(1.92)
23	*She/He* hates *the new school she/he has to enroll in.*	.244(.609)	6.80(2.16)	6.73(2.09)	6.33(2.09)	.311(.996)	6.80(2.04)	6.71(1.67)	6.22(2.23)
24	*She/He* loves *the book she/he has to read for her class.*	7.18(1.79)	.178(.442)	5.42(1.60)	5.09(2.03)	7.27(1.47)	.111(.383)	5.27(1.68)	5.22(2.18)
24	*She/He* hates *the book she/he has to read for her class.*	.289(.727)	6.13(1.20)	4.82(1.20)	3.67(2.07)	.311(.763)	6.09(2.14)	5.24(1.82)	3.64(2.14)
25	*She/he was* welcomed *by the basketball captain.*	6.87(1.78)	.222(.560)	5.42(1.89)	5.40(2.05)	7.02(2.06)	.200(.548)	5.33(1.80)	5.16(2.16)
25	*She/he was* annoyed *by the basketball captain.*	.689(1.59)	6.24(2.05)	5.71(1.59)	4.51(2.20)	.444(1.14)	6.47(1.98)	5.71(2.02)	4.64(2.19)
26	*She/he was* welcomed *by the new soccer captain.*	6.36(2.23)	.178(.490)	4.96(1.83)	5.04(2.23)	6.78(1.86)	.378(1.03)	5.64(1.82)	5.33(1.87)
26	*She/he was* annoyed *by the new soccer captain.*	.467(1.01)	6.44(2.80)	5.73(1.64)	4.40(1.79)	.578(1.36)	6.47(2.27)	5.87(1.66)	4.16(2.19)
27	*She/he was* welcomed *by the teaching assistant.*	6.58(2.12)	.244(.680)	4.60(1.90)	4.24(1.82)	6.93(1.96)	.222(1.64)	4.67(1.76)	4.24(1.98)
27	*She/he was* annoyed *by the teaching assistant.*	.533(1.25)	6.44(2.25)	5.58(1.76)	4.18(2.22)	.422(.917)	6.42(2.05)	5.40(1.64)	4.38(2.22)
28	*She/He was* hugged *by the coach after the big game.*	7.02(1.62)	.378(1.03)	6.02(1.53)	5.80(1.77)	6.91(1.62)	.533(1.36)	5.93(1.56)	5.78(1.80)
28	*She/He was* punched *by the coach after the big game.*	.467(1.38)	6.47(2.55)	7.36(1.87)	7.09(2.10)	.356(1.40)	5.93(2.60)	7.56(1.80)	6.91(2.59)
29	*She/He was* hugged *by her/his teammate after the game.*	6.80(2.10)	.689(1.69)	6.11(1.54	5.64(1.96)	6.98(1.63)	.533(1.39)	5.96(1.50)	5.56(2.02)
29	*She/He was* punched *by her/his teammate after the game.*	.289(.787)	6.73(2.16)	7.33(2.02)	6.44(2.35)	.400(1.14)	6.27(2.36)	7.07(2.08)	6.07(2.53)
30	*She/He was* hugged *by her/his teammate after the goal.*	6.67(2.26)	.378(1.09)	6.27(1.89)	6.44(2.24)	6.96(1.89)	.400(1.23)	6.49(1.70)	6.64(2.01)
30	*She/He was* punched *by her/his teammate after the goal.*	.67(1.40)	6.29(2.20)	6.91(1.56)	6.42(2.08)	1.00(1.82)	6.02(2.53)	6.84(1.88)	6.29(2.41)

2.2 ERP audio-visual study

2.2.1 Participants

Thirty-six participants aged 18-28 years (M = 20.4, S.D = 2.8; 16 female) were recruited from the University of Waterloo (UW) psychology participant pool. Participants could not participate in the ERP study if they had completed the validation study. Exclusion criteria also included a history of neurological or psychiatric disease, brain lesions, and regular use of recreational drugs (e.g., marijuana, cocaine, heroin), or alcohol abuse (defined as everyday consumption). Participants were required to understand English as their first language, and have normal, or corrected-to-normal hearing and vision. All participants rated their ability to recognize facial-expressions of emotions as 6 or higher on a 10-point Likert Scale. After EEG pre-processing (see data analysis section below), a final sample of 26 participants (mean age = 20, SD = 2.26; 13 female) was kept for behavioural and ERP data analyses. Participants received 2 credits towards their Psychology course, or $20, upon completion of the study. Participants signed written informed consent and the study was approved by a UW Research Ethics committee.

2.2.2 Stimuli and Apparatus

The 2 sentence valence (positive; negative) by 2 face expression (happy; angry) ERP experimental design contained the 20 face identities and 30 sentence themes from the validation study. Each identity was randomly paired to the sentence presented within each block. The 30 sentence themes were arranged into three blocks. Each block contained 20 sentence themes (10 positive, 10 negative), and each sentence theme was repeated for each gender within a block, for a total of 40 sentences per block (see Appendix for list of final sentences per block). One

ANOVA was conducted for each of the intensity and arousal ratings across each valence and block, demonstrating all blocks were statistically equivalent in terms of intensity and arousal (all F's < 1.10, all *p*'s > .35). Table 2 displays the mean intensity and arousal values for each block. Two ANOVAs were also conducted comparing the valence across blocks, which demonstrated all blocks were statistically equivalent in terms of positive (*p* = .478) and negative (*p* = .982) valence.

Table 2 Mean intensity and arousal ratings (SD in parentheses) of the sentences (on the 0-9 Likert scale) for each of the 3 blocks used in the ERP study. The ratings are from the validation study (N=45). Each block contained 10 positive sentence themes, and 10 negative sentence themes.

		Sentence List	
	Block 1 Sentence List	Block 2 Sentence List	Block 3 Sentence List
Positive Sentences			
Intensity ratings	6.81 (.726)	6.70 (.647)	6.52 (1.19)
Arousal ratings	7.12 (.676)	6.99 (.837)	6.62 (1.50)
Negative Sentences			
Intensity ratings	6.71 (.627)	6.66 (.922)	6.97 (.926)
Arousal ratings	6.36 (1.08)	6.30 (1.36)	6.13 (1.51)

Each of the three blocks created contained 40 sentences (10 positive, 10 negative x 2 gender variations) repeated twice for congruent (i.e. he just won the basketball game for his team – happy face), and incongruent trials (i.e. he just won the basketball game for his team – angry face), for a total of 80 trials per block. Each block was repeated 3 times for a total of 9 blocks within the entire experiment, and a total of 720 trials. In attempts to reduce repetitiveness, the positive and negative counterparts of each sentence pair were not presented in the same block. All 10 male and 10 female identities were presented in each block. Across the 9 blocks, there were a total of 180 trials per each of the 4 conditions (positive sentence – happy face; positive sentence – angry face; negative sentence – happy face; negative sentence – angry face). Table 3 displays the ratings of each face expression to the positive and negative sentences.

Table 3 Mean ratings of Happy Face Expression and Angry Face Expression matching (on the 0-9 Likert scale) for the final set of 30 sentences used in the ERP study, separated into each sentence type. Ratings are from the sentence validation study (N=45).

	Sentence Valence			
	Female Positive	Female Negative	Male Positive	Male Negative
Face Valence				
Happy face expression match	7.26 (1.12)	.347 (.562)	7.15 (1.15)	.390 (.626)
Angry Face expression match	.225 (.422)	6.30 (1.60)	.207 (.380)	6.41 (1.50)

Stimuli were presented and responses were recorded using Experiment Builder (version 1.11.0.1316). Eye movements were recorded on an Eyelink 1000 Plus eye-tracker to ensure participants were looking on the face during each trial.

2.2.3 Procedure

Once participants provided written informed consent, head measurements were taken to place the electrode cap. While the electrodes were placed in the cap, participants competed a brief demographics form, and five self-report measures for reasons peripheral to this study.

Participants received the instructions verbally from the experimenter, as well as read them off the screen. Participants were situated in a chin rest 70 cm in front of the computer screen and eye tracker. Each trial began with a fixation cross jittered between 400-500ms. Following the fixation cross, a neutral face appeared on the screen, while the audio file playing one sentence was simultaneously presented over speakers at the same volume for each participant. Following Dieguez-Risko et al. (2013) the neutral face remained on the screen for the duration of the sentence (3 seconds), and immediately upon sentence completion, the depicted person’s neutral face was replaced with a happy or angry face, presented on screen for

500ms. Each trial ended with a 1000ms fixation cross. Participants were instructed to respond to the emotion of the face once they saw the fixation cross, and to try to withhold eye-blinks until this point to prevent artifacts in the EEG data (See Figure 1 for sample trial progression). Participants completed a series of eight practice trials before beginning the experiment to ensure they were responding and blinking at the correct time.

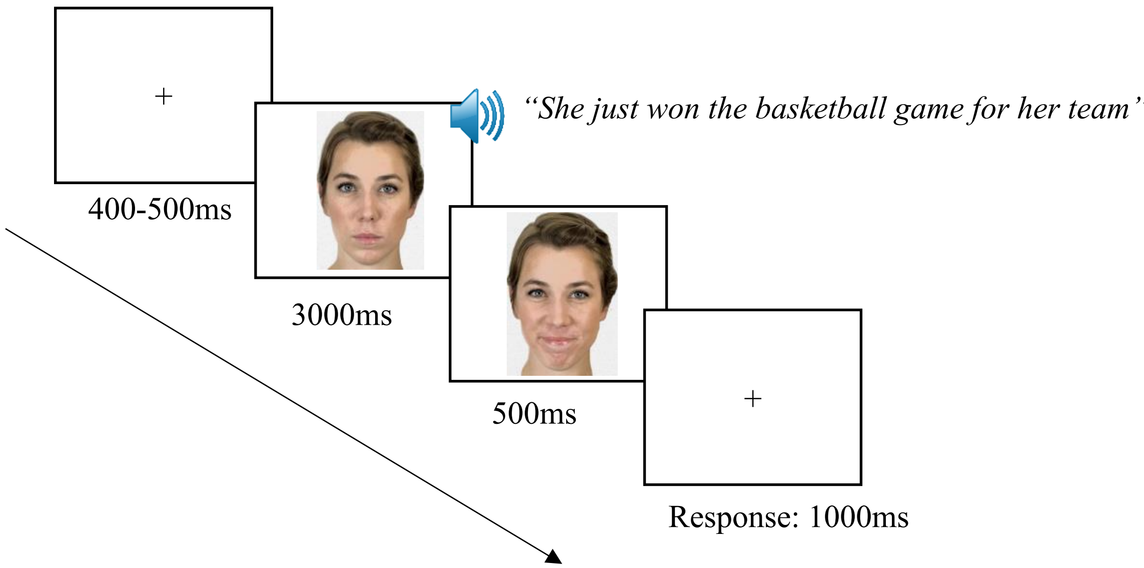

Figure 1 Sample trial progression reflecting a congruent, positive sentence-happy face expression trial.

2.2.4 Electrophysiological Recording

EEG was recorded continuously at 500 Hz by an Acti64Champ system (Brain Vision Solutions Inc.). Custom-made caps under the extended 10-20 system included 64 recording electrodes with PO9 and PO10, with Cz as the reference site during recording. All EEG data were average-referenced offline. F1, F2, AF3, and AF4 sites were not recorded. An additional 5 electrodes were used to monitor eye movements: 2 placed above and below the right eye to monitor vertical eye movements, 2 placed on each outer canthus to monitor horizontal eye movements, and one ground placed by the right ear. Two additional electrodes were placed directly on the participant's mastoids. Electrode impedance was kept below a value of 50 kOhms.

2.2.5 Data processing and analyses

EEG and EOG data were processed offline using EEGlab (Delorme & Makeig, 2004) and ERPlab (http://erpinfo.org/erplab) toolboxes working under the 2014b Matlab software (Mathorks, Inc.). Eye tracking and EEG recordings were synchronized to remove trials in which participants were not looking at the face during presentation. ERPs were time locked to the onset of the presentation of both the neutral face, and the emotional face. For both face types, each epoch was digitally band-pass filtered (0.01 – 30 Hz) using a two-way least-squares FIR filter. Trials were inspected and those containing artifacts greater than ±70 µV were rejected. Data from six participants were lost due to equipment failure, and data from three additional participants were discarded due to excessive blinks or other artifacts, leaving a total of 26 participants with usable EEG data for analysis.

For the neutral face analysis, epochs were created from 200ms pre-stimulus onset to 350ms post-stimulus onset. This epoch was only inclusive of the P1 and N170, consequently no analyses on the EPN and LPP were conducted. Two averages were created according to which sentence (positive or negative) was played during the neutral face presentation. This was completed to ensure no ERP components recorded to the neutral face showed modulations due to the auditory context. Epochs for the emotional face analyses spanned 200ms pre-stimulus onset, to 600ms post-stimulus onset. Four averages were created based on sentence prime and subsequent face expression (positive sentence-happy face; positive-sentence-angry face; negative sentence-happy face; negative sentence-angry face). Mean number of trials per condition are presented in Table 4[2].

Table 4 Mean number of correct trials with standard deviation in parentheses for each condition.

		Sentence Type	
		Positive	Negative
Face Expression			
	Happy	115 (20)	113 (20)
	Angry	114 (19)	116 (20)

Reaction Time. A 2 sentence valence (positive; negative) by 2 face expression (happy; angry) repeated measures ANOVA was conducted on the reaction time data using correct trials only. Reaction time was calculated from the offset of the emotional face until the participant made a response.

Accuracy. The same ANOVA from the reaction time data was conduction on the accuracy data for each condition. Accuracy for each participant was determined by dividing the total number of correct responses per condition by the total number of trials within the condition.

P1 analysis. A 2 sentence valence (positive; negative) by 2 face expression (happy; angry) by 3 electrode (PO3; POz ; PO4[3]) by two time window (70-100ms; 100-130ms) ANOVA was conducted on the P1 mean amplitude over these two time windows. The neutral face analysis excluded the factor of face expression, since no emotional face was presented during this epoch. Topographic maps of the P1 (see panel (a) on Figure 2) suggest a central-parietal and right-parietal distribution, hence analysis of the P1 amplitude was conducted on mean amplitudes calculated around the peak at parietal sites. To examine when the differences between conditions

[2]Paired samples T-tests were conducted on the mean trials per condition, Bonferroni corrected for significance of $p = .0125$. The positive sentence-happy face expression condition significantly differed from negative sentence-happy face expression, $t(1, 25) = 3.71$, $p = .001$.

[3]P1 was analyzed at the typical occipital sites (O1 and O2) with no effects. Effects were found at more parietal sites.

emerge during this time window, analyses were conducted across two time windows: 70-100ms, and 100-130ms.

N170 amplitude analysis. The N170 peak amplitude was extracted between 120-200ms, at the electrode at which the peak was maximum for each participant, on each hemisphere. See panel (b) on Figure 2 for topographic maps of the N170. Electrodes on the left hemisphere included P9, PO9, P07, and P7, and electrodes on the right hemisphere included P10, P8, PO8, and PO10 (see Table 5 for the number of participants whose N170 maximal at one of these electrodes). A 2 hemisphere (left; right) by 2 sentence valence (positive; negative) by 2 face expression (happy; angry) repeated measures ANOVA was conducted; however, for neutral faces the analyses again excluded the factor of face expression.

N170 latency analysis. A 2 hemisphere (left; right) by 2 sentence valence (positive; negative) by 2 face expression (happy; angry) repeated measures ANOVA was conducted on the N170 peak latency (the time at which the N170 peak was largest in amplitude) for emotional face expressions only, as visual inspection of the N170 neutral ERP wave indicated no difference between conditions (see Figure 5).

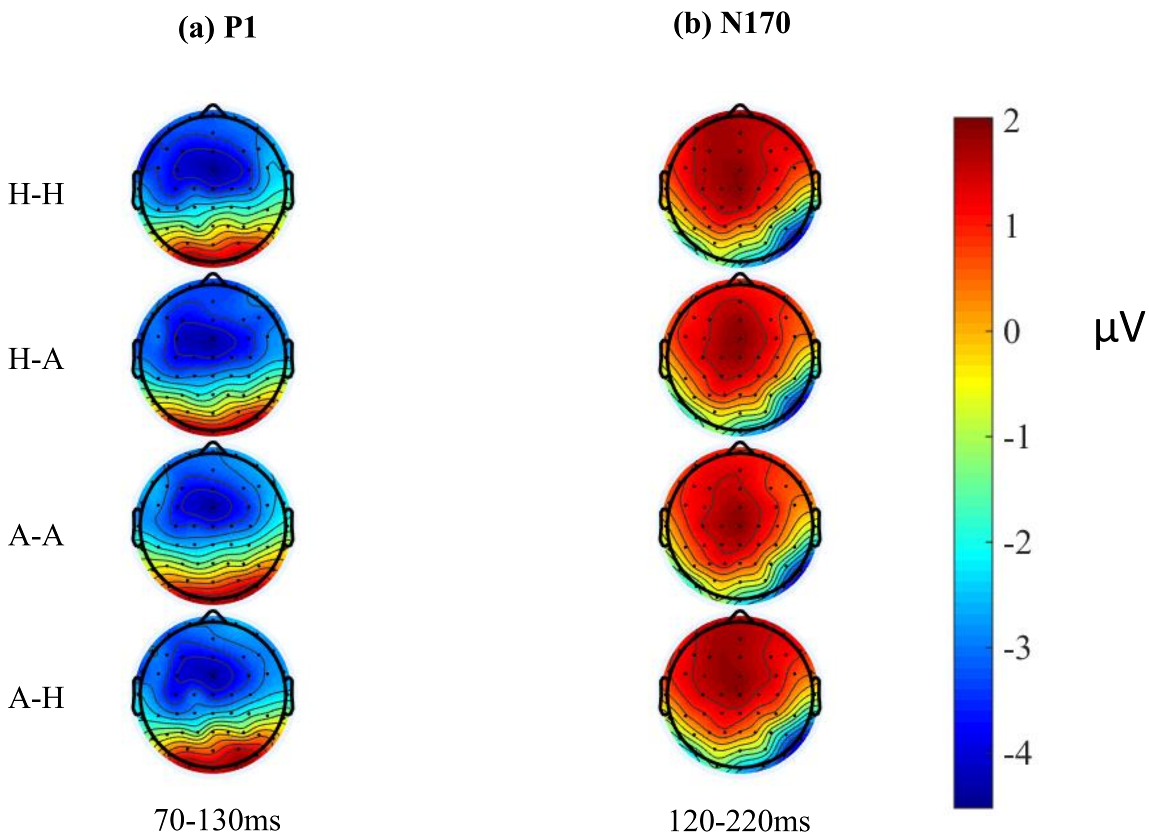

Figure 2 Topographic maps reflecting visual processing after the emotional face onset. A clear parietal positivity can be seen between 70-130ms ((a) P1, mostly right sided), followed by a clear posterior negativity between 120-220ms ((b) N170, mostly right-sided), with a concurrent frontal positivity. Each condition is presented, with from top-to-bottom: Positive sentence-Happy face; Positive sentence-Angry face; Negative sentence-Angry face; Negative sentence-Happy face.

Table 5 Number of participants selected at each electrode for the N170 analysis across both the left and right hemisphere.

	Number of Participants			
	Left Hemisphere		Right Hemisphere	
Electrode	P9	11	P10	9
	PO9	10	PO10	3
	PO7	4	PO8	6
	P7	1	P8	8

EPN and negative LPP counterpart. Both the EPN and negative LPP components were analyzed using a 2 time (EPN: 200-300ms; 300-400ms; negative LPP counterpart: 400-500ms; 500-600ms) by 2 hemisphere (left; right) by 2 sentence valence (positive; negative) by 2 face expression (happy; angry) ANOVA was conducted on the mean amplitudes at the same peak electrodes as those where the N170 was measured. See figure 3 for topographic maps demonstrating the EPN and LPP progression.

The true LPP was also measured at FCz, as commonly done, and was analyzed using the same ANOVA, without the factor of hemisphere.

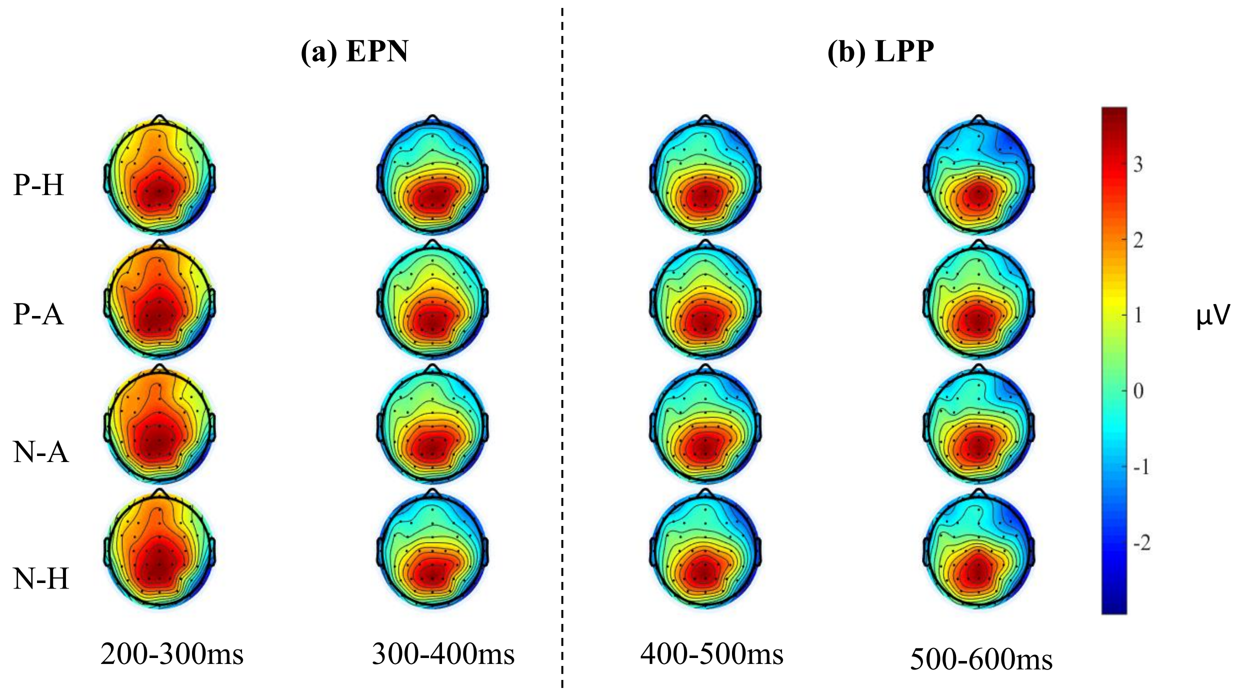

Figure 3 Topographic maps reflecting visual processing from 200-600ms, reflective of the (a) EPN (200-400ms) and (b) LPP (400-600ms).

Chapter 3: RESULTS

3.1 Behavioural Data.

3.1.1 Reaction time. There was a main effect of face expression, $F(1, 25) = 8.62$, $p = .007$, $n_p^2 = .256$, such that mean reaction times following a happy face expression were overall faster than mean reaction times following an angry face expression (Table 4). There was no effect of sentence type, but there was a sentence type by face expression interaction, $F(1, 25) = 8.933$, $p = .006$, $n_p^2 = .263$. Follow up t-tests suggested the effect of face expression was only seen with positive sentence processing, in which reaction time to categorizing a happy face following a positive sentence is significantly faster than all other conditions (all p's < .008). Additionally, reaction times to categorizing happy faces were modulated by the congruency of the context prime, being significantly faster when the sentence was positive (congruent) than when the sentence was negative (incongruent), $t(1, 25) = -2.86$, $p = .008$. No modulations on reaction time was seen for angry faces. Descriptive results are presented in Table 6.

Table 6 Average (SD in parenthesis) reaction time data of the 26 participants to correct trials only. Sentence valence means (collapsed across facial expression) and face expression means (collapsed across sentence valence) are also presented.

		Sentence Type		
		Positive	Negative	
Face Expression				Face Expression Mean
	Happy	352 (138)	362 (141)	357 (139)
	Angry	370 (140)	368 (142)	369 (141)
Sentence Mean		361 (138)	365(141)	

3.1.2 Accuracy. No main effects emerged, but the sentence type by face expression interaction was significant, $F(1,25) = 13.92$, $p = .001$, $n_p^2 = .358$. Follow up paired sample t-tests revealed a congruency effect for happy faces, such that congruently matched positive sentences-happy faces were more accurately identified relative to incongruently matched negative sentences-happy faces, $t(1,25) = 3.59$, $p = .001$. Angry faces saw the same effect of congruency, $t(1, 25) = 2.6$, $p = .017$. Additionally, angry sentence primes modulated accuracy for each face expression, such that angry faces following a negative prime were more accurate than happy faces following an angry sentences, $t(1,25)= 3.30$, $p = .003$. Positive sentences did not produce this modulation. Descriptive statistics are presented in table 7.

Table 7 Accuracy scores of the 26 participants across each condition.

		Sentence Type	
		Positive	Negative
Face Expression			
	Happy	94.12	92.19
	Angry	93.96	95.47

3.2 Event-Related Potential Data

3.2.1 Neutral faces.

Neural activity was measured to the neutral face to ensure there was no effect of the auditory stimuli that were presented concurrently. Mean amplitude values for each ERP component in processing the neutral face can be found in Table 8.

P1. There was no significant effect of sentence type, $F(1, 25) = 3.09$, $p = .091$, $n_p^2 = .110$, and the effect of electrode was marginal , $F(1,25) = 3.38$, $p = .051$, , $n_p^2 = .220$, with a trend for an enhanced P1 over electrode PO4 (Figure 4). There was no main effect of time ($p = .279$).

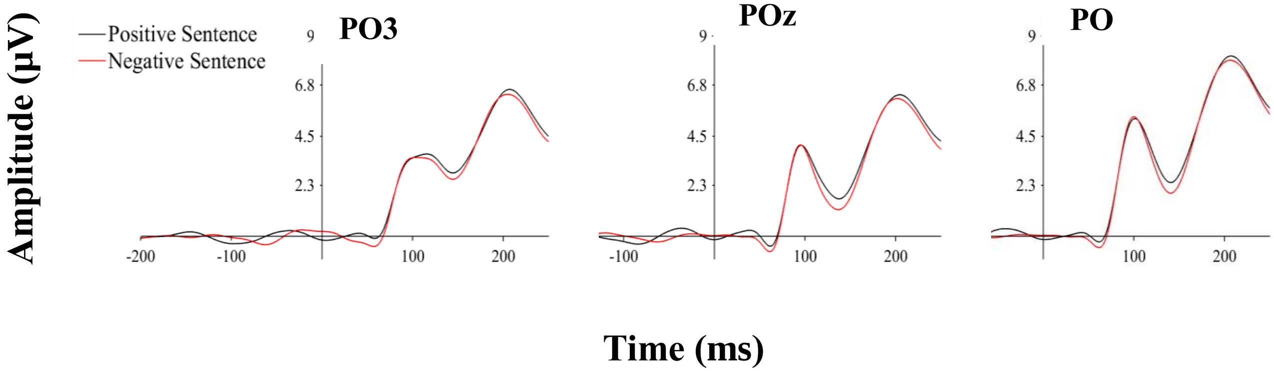

Figure 4 P1 waveforms to the neutral face presentation presented concurrently with positive and negative sentences, for each of the three electrodes at which it was measured (PO3, POz, and PO4). No differences between conditions occurred.

Table 8 Mean amplitudes (µV) and Standard Deviations (SD) averaged between 70-130ms for each condition across PO3, PO4, and POz during the presentation of the neutral face across the 26 participants.

	Electrode											
	PO3				POz				PO4			
	Positive Sentence		Negative Sentence		Positive Sentence		Negative sentence		Positive Sentence		Negative sentence	
ERP	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
P1	5.14	3.0	4.64	2.83	5.31	3.06	4.96	2.98	6.43	4.16	6.28	4.54

N170 *Amplitude*. There was no main effect of sentence valence, $F(1, 25) = .24$, $p = .629$, $n_p^2 = .009$, nor an effect of hemisphere $F(1, 25) = 2.09$, $p = .161$, $n_p^2 = .077$ (Figure 5).

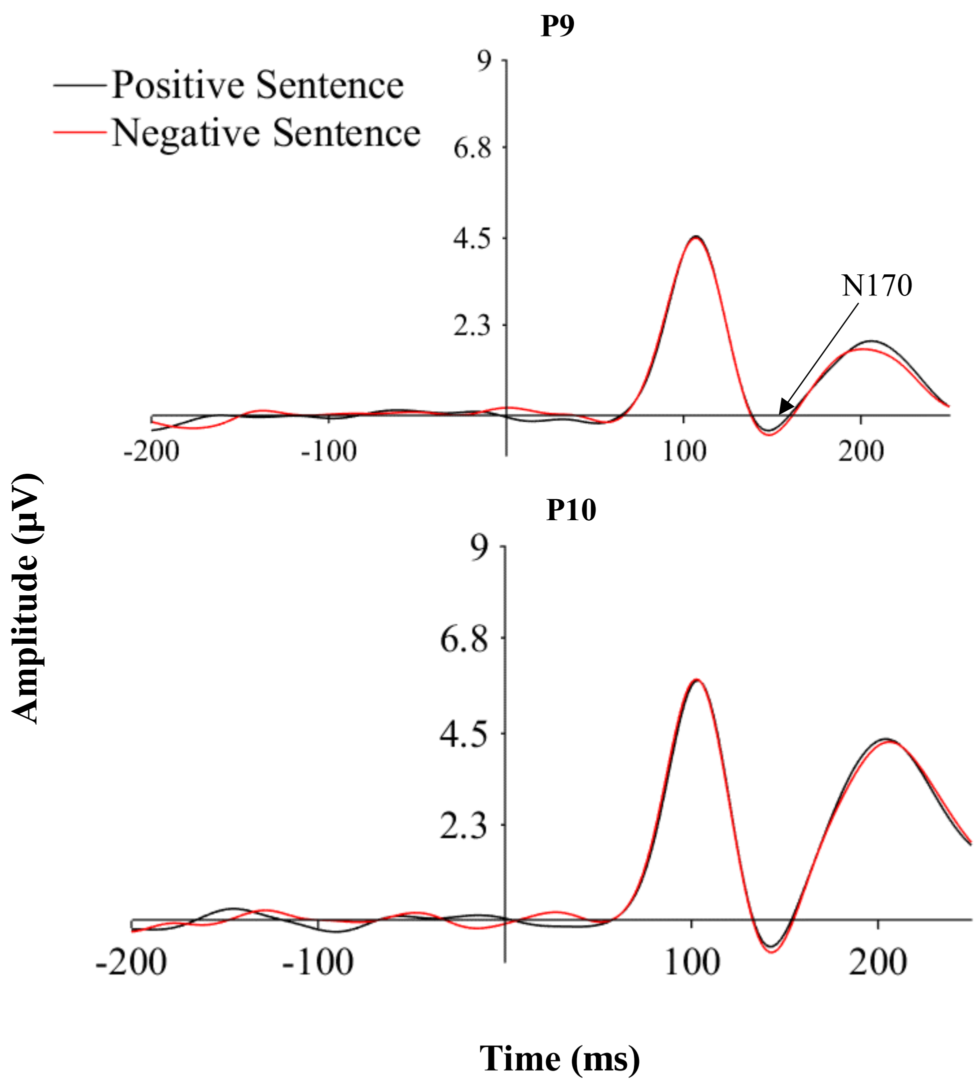

Figure 5 ERP waveforms reflecting the N170 in response to the neutral face following positive and negative sentences. No differences between sentence type is seen on either left hemisphere (top) or right hemisphere (bottom).

Summary. This critical manipulation check ensured there were no pre-existing differences in processing the auditory context on neutral face processing, or carry-over effects from previous trials.

3.2.2 Emotional Faces.

Mean amplitudes and standard deviations for all ERP components in response to the emotional face are presented in table 9.

Table 9 Mean amplitudes (μV) and Standard Deviations (SD) for each condition during the presentation of the emotional face.

			Condition							
			Positive Sentence				Negative Sentence			
			Happy Face Expression		Angry Face Expression		Happy Face Expression		Angry Face Expression	
ERP	**Electrode**		Mean	SD	Mean	SD	Mean	SD	Mean	SD
P1										
	PO3	70-100ms	1.71	1.53	1.18	1.11	1.75	1.75	1.50	1.12
		100-130ms	2.24	2.13	2.27	1.52	2.36	1.97	2.58	1.85
	POz	70-100ms	2.08	1.56	1.42	1.47	2.19	1.55	1.80	1.56
		100-130ms	2.36	2.08	2.19	1.66	2.42	1.71	2.56	1.56
	PO4	70-100ms	2.33	1.76	1.91	1.62	2.72	1.55	2.21	1.67
		100-130ms	2.84	1.77	2.73	1.62	3.11	1.61	3.09	1.70
N170										
	P9, PO9, P7, PO7		-5.05	3.54	-4.34	3.35	-5.05	3.62	-4.24	3.28
	P10, PO10, P8, PO8		-8.32	4.26	-7.32	3.48	-8.17	4.44	-7.28	3.54
EPN										
	P9, PO9, P7, PO7	200-300ms	-2.87	2.47	-3.15	2.62	-2.98	2.39	-3.20	2.71
		300-400ms	-2.99	3.04	-3.37	3.03	-2.93	2.93	-3.16	3.16
		200-300ms	-3.99	3.02	-4.28	2.88	-4.04	3.06	-4.38	2.89

	P10, PO10, P8, PO8	300-400ms	-3.91	3.27	-4.28	3.35	-4.04	3.43	-4.29	3.44
Negative LPP counterpart										
	P9, PO9, P7, PO7	400-500ms	-2.25	2.68	-2.91	2.94	-2.29	2.73	-2.72	3.09
		500-600 ms	-1.72	2.17	-2.52	2.46	-1.72	2.09	-2.44	2.67
	P10, PO10, P8, PO8	400-500ms	-3.69	2.68	-4.18	3.06	-3.77	2.94	-3.95	3.13
		500-600 ms	-3.29	2.45	-4.17	2.63	03.32	2.44	-4.06	2.77
LPP										
	FCz	400-500ms	.617	2.20	1.28	2.33	.610	2.44	.725	2.01
		500-600 ms	.058	2.41	.755	2.12	.220	2.58	.412	1.99

P1. A main effect of electrode was found, $F(1,25) = 4.33$, $p = .025$¸ $n_p^2 = .265$, such that amplitude at PO4 was significantly larger relative to both PO3 ($p = .032$) and POz ($p = .008$). PO3 and POz did not differ ($p = .476$)

The main effect of time was significant, $F(1,25) = 17.03$, $p < .001$¸ $n_p^2 = .405$, with amplitudes largest in the 70-100ms time range (M = 2.56) relative to the 100-130ms time range (M = 1.90).

The main effect of sentence was marginally significant, $F(1,25) = 3.33$, $p = .080$¸ $n_p^2 = .118$, with negative sentences (M = 2.36) eliciting an enhanced positivity relative to positive sentences (M = 2.10; Figure 6 top). And the main effect of face expression was marginally significant, $F(1,25) = 3.51$, $p = .073$¸ $n_p^2 = .123$, with happy faces (M = 2.34) eliciting an enhanced amplitude relative to angry faces (M = 2.19; Figure 6 bottom).

The face expression by time interaction was significant, $F(1,25) = 19.9$, $p < .001$¸ $n_p^2 = .443$, such that happy faces elicited an enhanced amplitude in both time windows relative to angry faces, whereas angry faces only saw an enhancement in the first time window.

The interaction between sentence valence and face expression was insignificant.

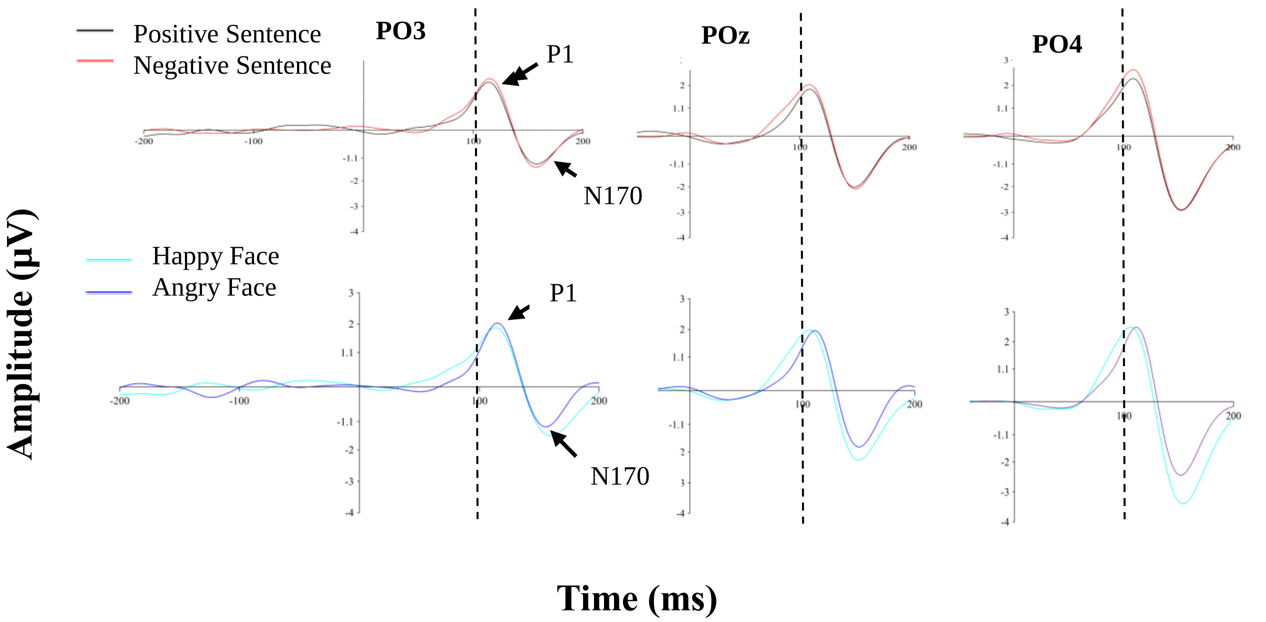

Figure 6 Mean P1 amplitude recorded to the emotional face averaged across all 26 participants at electrodes (a) PO3 (b) POz, and (c) PO4. Sentence type (top) with negative sentences (red) demonstrating an enhanced P1 amplitude relative to positive sentences (black). Additionally, enhanced P1 amplitudes were found for angry faces (dark blue) relative to happy faces (light blue). An N170 is also apparent on these sites, although no analyses were conducted there.

N170. There was a main effect of hemisphere, $F(1, 26) = 11.180$, $p = .003$, $n_p^2 = .309$, whereby the amplitude in the right hemisphere (M = -7.77, SD = 3.84) was significantly enhanced relative to the left hemisphere (M = -4.670, SD = 3.39).

There was also a main effect of face expression, F(1, 25) = 19.122, $p < .001$, $n_p^2 = .433$, whereby happy faces had a significantly enhanced peak (M = -6.648, SD = 3.08) relative to angry faces (M = -5.794, SD = 2.45; see panel ‘a’ on figure 7). No other effects were found.

N170 Latency. There was a significant main effect of face expression, $F(2,24) = 42.10$, $p < .001$, $n_p^2 = .637$, with faster latencies for happy (M = 172.92ms, SD = 1.50) than angry face expression (M= 182.83ms, SD = 12.91; see panel ‘a’ on Figure 7).

EPN. There was a main effect of face expression, $F(1, 25) = 5.31$, $p = .030$, $n_p^2 = .175$, such that angry faces had an enhanced negativity (M = -3.765, SD = 2.39) relative to happy faces (M = -3.47, SD = 2.25; see panel ‘b’ on Figure 7). All other factors and interactions remained insignificant.

Negative LPP counterpart. There was a main effect of hemisphere $F(1, 25) = 5.67$ $p = .025$, $n_p^2 = .185$, such that there was an enhanced negativity in the right hemisphere (M = -3.804, SD = 2.63) relative to the left hemisphere (M = -2.322, SD = 2.46).

There was a main effect of face expression $F(1, 25) = 26.45$ $p < .001$, $n_p^2 = .514$**,** such that angry faces had an enhanced negativity (M = -3.37, SD = 2.09) relative to happy faces (M = -2.76, SD = 1.93; see panel ‘c’ on Figure 7)

There was a significant interaction between time and face expression $F(1, 25) = 11.21$ $p = .003$, $n_p^2 = .310$**.** Follow up t-tests demonstrated that happy faces had a significant amplitude change across time (400-500ms: -2.99, SD = 2.20; 500-600ms: M = -2.51, SD = 1.79), whereas angry faces did not, resulting in larger emotion differences across time, $t(1, 25) = 2.64$, $p = .014$.

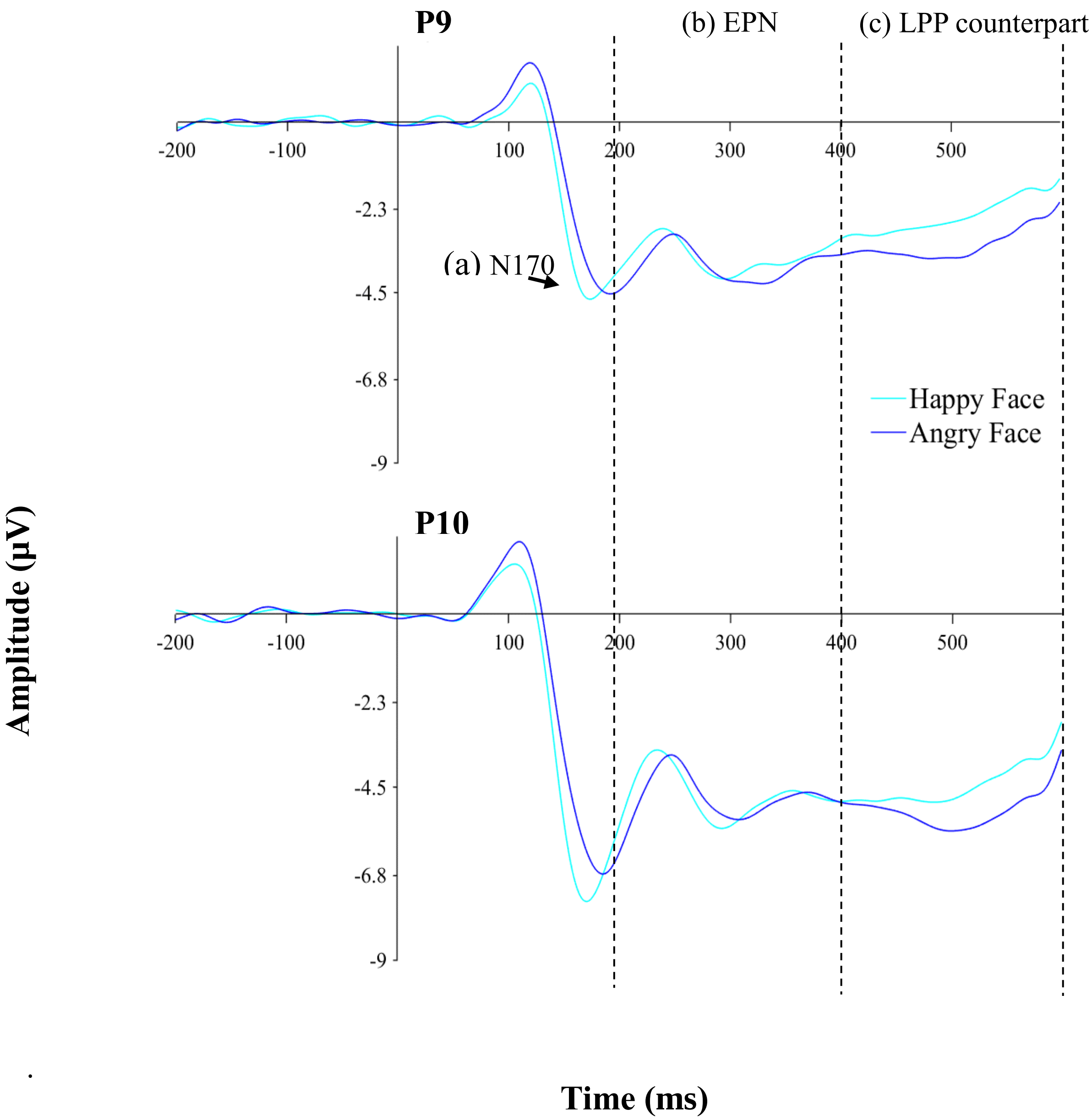

Figure 7 Mean amplitude across (a) N170; (b) EPN; and (c) negative LPP counterpart for happy faces (dark) and angry faces (light) across the 26 participants. The majority of participants displayed peak amplitude differences across P1 (left hemisphere) and P10 (right hemisphere), consequently these electrodes were selected for demonstrations.

LPP. A main effect of face in the opposite direction to the negative counterpart was found, $F(1,25) = 8.06$, p = 009, $n_p^2 = .244$, such that angry faces had an enhanced amplitude relative to happy faces (figure 8).

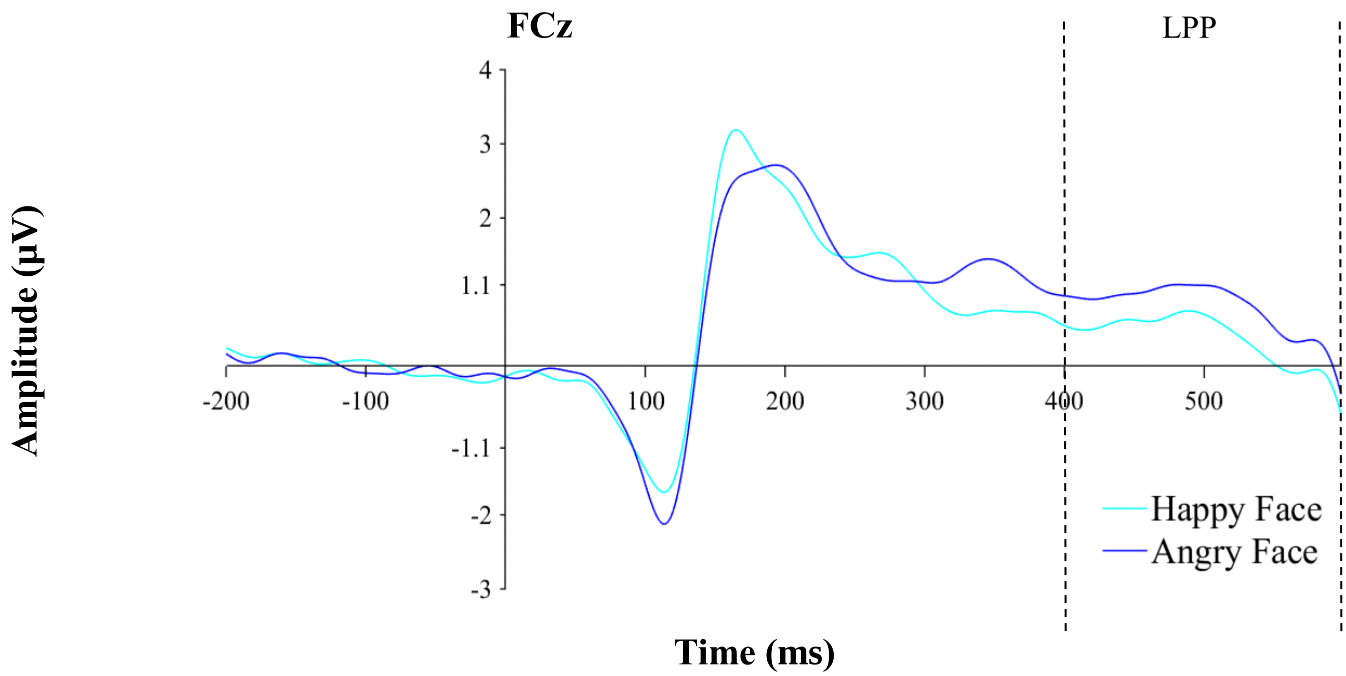

Figure 8 LPP measured traditionally at frontal sites (FCz). The resulting positivity wave is enhanced in the opposite direction for face expressions compared to the negative LPP counterpart, such that angry face expressions (dark) are enhanced relative to happy faces (light). The negative LPP counterpart and traditional LPP show similar effects, with polarity reversed, due to the average reference used in this study.

Chapter 4: DISCUSSION:

` The overarching goal of this study was to examine the effect of a situational auditory context prime on the processing of emotional faces, using a set of newly developed auditory stimuli.

This study began with the validation of positive and negative auditory sentence primes to identify sentences that would elicit happy and angry facial expressions. The results of this validation allowed for the use of more ecologically valid situational auditory sentences, which as far as we know have never been used in an ERP study examining audio-visual integration in social cognition. This study not only presented auditory context primes, but was also designed to reflect a neutral face dynamically changing in response to the auditory sentence, to either a happy or angry facial expression. The combination of these design features allowed for a relatively more ecologically valid experimental design of a person's facial expression reacting in response to a situation. This design reflected a scenario in which a participant heard about an experience (i.e. He just won the basketball game for his team), and saw a neutral face dynamically change in response to the situation, as would be seen in more realistic social experiences.

Behaviourally, congruency between sentence valence and the resulting facial expression facilitated increased accuracy for congruent relative to incongruent trials, and enhanced reaction time speed for happy faces following a congruent positive prime, consistent with previous behavioural findings within the literature (de Gelder & Vroomen, 2000; Diéguez-Risco et al., 2013; Herring et al., 2011). This effect of congruency suggests there may be a matching process between the expected reaction, and the perceived reaction from a social partner.

The facilitation of reaction times and accuracy suggests that auditory information cannot be ignored by the perceptual system. This finding is interesting based on participants subjectively reporting not always paying attention to the auditory sentence. Accuracy data demonstrated an effect of congruency, such that both happy and angry faces were modulated by the congruency of the sentence that preceded it, such that congruent trials were significantly more accurate than incongruent trials. The reaction time data similarly demonstrated a congruency finding for happy faces. This congruency effect aligns with research on dichotic listening tasks in which information from an unattended ear can still impact cognition and perception (Ball & Zuckerman, 1992; Jancke, Specht, Shah, & Hugdahl, 2003). Here we show in a social cognition paradigm, that auditory social cues are critical in social cognition. The significant congruency effect in reaction time data for happy faces stands in stark contrast to the lack of a congruency effect for angry faces. As touched on in the introduction, it may be that people are far more familiar with happy expressions than angry expressions – rendering happy expressions more amenable to our congruency manipulation. Additionally, this may be due to angry sentences being perceived as rendering a *sad* response, relative to angry. This alternative interpretation of the sentence meaning (i.e. sad relative to angry) was subjectively reported, and may be modulating the congruency effect for angry faces.

At the neural level, effects on the P1, N170, and LPP showed larger amplitude differences in the right hemisphere. Additionally, no effect of sentence prime was seen on any ERPs measured in this study, with all neural modulations occurring in response to the facial expression. The lack of integration between sentence prime and face expression is likely a result of the experimental design; any processing of auditory information occurred during the presentation of the neutral face, with all face expression changes occurring after. It is likely the auditory information *was* integrated with visual processing, based on the congruency effect seen at the behavioural level, but was not picked up on the ERPs measured in this study. The integration would have occurred during the presentation of the neutral face, however no modulation of sentence type was found on these ERPs due to no visual change in the face that would align or misalign with the congruency manipulation. While this study hoped to capture the top-down priming effects of auditory information on subsequent facial expressions, it is likely this processing is already complete during the three seconds in which the neutral face is on the screen. Consequently, all processing of auditory information is complete before the neural indices measured to the emotional face expression.

All main effects on the P1 were marginal at best, but a strong time window by face expression interaction emerged. Since all stimuli were controlled for low level factors, this effect may reflect differential emotion effects between happy and angry face expressions on the P1 amplitude. This study measured the difference between emotions on the rise and fall surrounding the peak of the P1, and not simply at the peak (around 100ms), which most studies typically measure. Based on this study, in which differences in P1 amplitude for happy and angry faces appeared between 100-130ms, previous studies exclusively examining the peak of the P1 may be examining differences too early, and consequently do not pick up a difference in amplitude to different emotions. The results of this study run counter to previous emotion effects found on the P1, in which negative emotions elicited an enhanced amplitude relative to happy and neutral face expressions (Pourtois et al, 2005; Rellecke, et al.,2012;Wijers and Banis, 2012). This study may have been underpowered, so more participants would be needed to determine if the main effects become significant before drawing any definitive conclusions. Although marginal, the enhanced amplitude to negative sentence valence is consistent with the previously observed enhanced P1 amplitude to negative environmental stimuli, potentially reflecting early attention capture for threat (Pourtois et al, 2005; Rellecke, et al.,2012;Wijers and Banis, 2012). The P1 was the only component that had marginal effects of sentence type. Since behavioural data did reflect a congruency effect, this marginal finding further supports the likelihood that all auditory information was processed during the processing of the neutral face, and any modulations (if any) on emotional face expression processing are occurring earlier than the P1.

Moving across the cortical processing timeline, the N170 demonstrated an enhanced negativity for happy faces relative to angry faces. This finding is unique relative to the majority of the face expression literature whereby angry faces are typically processed with an enhanced amplitude to happy faces (Rellecke, Sommer, & Schacht, 2012). This result also runs counter to previous interpretations that early ERPs are sensitive to threatening stimuli within the environment. Critically, these previous studies finding this opposing effect do not use primes in their paradigms, and instead presented isolated faces to participants. The present study was based on the procedures of Dieguez-Risko et al. (2013) who presented visual situational primes, such that participants read the sentence before being presented with a face to categorize. In their study, Dieguez-Risko et al., (2013) similarly found an enhanced negative amplitude to happy faces relative to angry faces. This suggests that providing context may change how faces are processed relative to when they are presented in isolation. However, neither Diegues-Risko et al. (2013), nor this study, presented faces in isolation as a comparison condition. Therefore, to establish the effect of an auditory prime on lab-based social processing, future studies should compare positive and negative auditory primes in comparison to no prime.

The N170 latency demonstrated a prolonged latency for angry relative to happy face expressions. This facilitated processing for happy faces is consistent with work suggesting happy face expressions are easily processed, potentially due to high frequency in the natural environment (Batty & Taylor, 2003). This may also be due to distinct configurable changes reflected in the smile, making happy faces easy to recognize (Russell, 1994). Since happy facial expressions have facilitated neural processing, this may be related to the faster reaction times for categorizing happy faces relative to angry faces seen in this paradigm.

The EPN and LPP in this study support the existing literature that angry faces are more negatively (EPN) and more positively (LPP) processed (Schacht & Sommer, 2009; Schupp, Junghöfer, Markus, Weike, & Hamm, 2003). Despite previous work finding an effect of congruency on the LPP (Herring et al., 2011; Hinojosa et al., 2009; Diguez-Risko, et. al., 2013), this study failed to replicate this result. This lack of congruency effect may be a result of participants not paying full attention to the sentences presented, and again may be due to auditory processing being completed before presentation of the emotional face. Alternatively, this lack of congruency effect may be a result of the experimental task. Participants were required to categorize the emotion of a facial expression, regardless of the sentence played before, making the sentence irrelevant to the task. Perhaps an interaction would have been seen in a congruency matching task, in which participants would match the emotion of the facial expression to the valence of the sentence (e.g Diéguez-Risco, et al., 2015).

While this study added to the growing body of work examining the effect of an auditory context prime on face expression processing, what is less known is the developmental links associated with adult-level social cognition. The current study presented this paradigm to a arguably homogenous undergraduate sample, and consequently cannot determine when, within development, auditory information impacts cognition. Future directions should consider examining the effect of an auditory situational prime in children, who may be particularly sensitive to incoming auditory information, as they are learning and developing social cognition. Social development begins early in childhood, and continues across adolescence, thereby permitting individual experiences to impact social cognition (Blakemore & Choudhury, 2006). Early sensitivities to positive and negative information may impact adult level sensitivities. This question becomes important when considering the development of internalizing disorders such as anxiety and depression, which are characterized by a focus on negative information (Goldstein, Hayden, & Klein, 2015; Kuiper & Rogers, 1979).

This study was the first to present auditory situation context primes in the examination of face expression processing. Additionally, this paradigm uniquely presented dynamically changing facial expression within the confines of tightly controlled ERP study designs. Consequently, the results of this study need to be replicated and extended to determine how auditory situational cues impact social cognition. The validated auditory stimuli resulting from this work allow researchers to examine more realistic experimental designs involving ERP indices. Additionally, this work adds to the existing literature surrounding face expression processing.

Appendix

Appendix A.

Final sentences pairs separated by block

Block 1

Positive	Negative
She/He just won the ice skating competition.	She/He just lost the world cup final for her/his team.
She/He won the hardest music competition.	She/He just broke an amazing new vehicle.
She/He loves the new school she/he has to enroll in.	She/He just lost the best ballet competition.
She/He just won the basketball game for her/his team.	She/He jut crashed a fast and expensive new car.
She/He loves the football she/he got for her/his birthday.	She/He was annoyed by the basketball captain.
She/He won the final soccer game for her/his team.	She/He was annoyed by the new soccer captain.
She/He passed her very difficult English test.	She/He was annoyed by the teaching assistant.
She/He passed on of her/his many final exams.	She/He was punched by the coach after the big game.
She/He passed a very difficult science test.	She/He was punched by her teammate after the game.
She/He received the keys to her/his new vehicle.	She/He missed the vacation she/he always wanted.

Block 2

Positive	Negative
She/He just received the keys to her/his new cottage.	She/He just lost the ice skating competition.
She/He was hugged by her/his teammate after the goal.	She/He lost the hardest music competition.
She/He was accepted by the school she/he wanted.	She/He hates the new school she/he has to enroll in.
She/He raised the most money for the hospital.	She/He just lost the basketball game for her team.
Se/He earned the money for her/his dream vacation.	She/He hates the football she/he got for her/his birthday.
She/He loves the new city she/he has to live in.	She/He lost the final soccer fame for her/his team.
She/He loves the book she has to read for her/his class.	She/He failed her very difficult English test.
She/He won a very expensive brand new truck.	She/He failed one of her/his many final exams.
She/He just won a powerful new computer.	She/He failed a very difficult science test.
She/He loves the cell phone she/he got for her/his birthday.	She/He misplaced the keys to her/his new vehicle.

Block 3

Positive	Negative
She/He just won the world cup final for her/his team.	She/He just misplaced the keys to her/his new cottage.
She/He just bought an amazing new vehicle.	She/He was punched by her teammate after the goal.
She/He just won the best ballet competition.	She/He was rejected by the school she/he wanted.
She/He just won a fast and expensive new car.	She/He lost the most money for the hospital.
She/He was welcomed by the basketball captain.	She/He lost the money for her/his dream vacation.
She/He was welcomed by the new soccer captain.	She/He hates the new city she/he has to live in.
She/He was welcomed by the teaching assistant.	She/He hates the book she/he has to read for her/his class.
She/He was hugged by the coach after the big fame.	She/He crashed a very expensive brand new truck.
She/He was hugged by her teammate after the game.	She/He just broke a powerful new computer.
She/He won the vacation she/he always wanted.	She/He hates the cell phone she got for her/his birthday.

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