Interaction of threat expressions and eye gaze: an event-related potential study

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The current study examined the interaction of fearful, angry, happy, and neutral expressions with left, straight, and right eye gaze directions. Human participants viewed faces consisting of various expression and eye gaze combinations while event-related potential (ERP) data were collected. The results showed that angry expressions modulated the mean amplitude of the P1, whereas fearful and happy expressions modulated the mean amplitude of the N170. No influence of eye gaze on mean amplitudes for the P1 and N170 emerged. Fearful, angry, and happy expressions began to interact with eye gaze to influence mean amplitudes in the time window of 200–400 ms. The results suggest early processing of expression influence ERPs independent of eye gaze, whereas expression and gaze interact to influence later ERPs. *NeuroReport* 24:813–817 © **2013 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

NeuroReport 2013, **24**:813–817

Keywords: emotional expression, event-related potential, eye gaze, face perception

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Received 29 April 2013 **accepted** 20 June 2013

Introduction

Discrimination – distinguishing faces from objects such as houses and cars – and biological movement – detection of emotional expression and eye gaze – are two important aspects of face perception [1]. Face discrimination is generally reflected by larger N170 (a negative temporal–occipital scalp deflection occurring 140–200 ms poststimulus that peaks around 170 ms) event-related potential (ERP) amplitudes for faces than objects [2]. The influence of expression and gaze on the N170 has been mixed. Emotional expression has increased the N170 amplitude [3–5], whereas other times it has not [6–9]; gaze direction has also increased the N170 amplitude [10–13], whereas other times it has not [14,15]. Although some studies have examined the influence of expression and gaze independently on the N170, the influence of expression and gaze interactions on the N170 has been virtually unexplored.

Klucharev and Sams [16] presented happy and angry faces with left, right, and straight gazes in an ERP study to participants who identified repetitions of gaze direction. Straight gaze had larger amplitudes than right gaze around 85 ms poststimulus, whereas happy expressions had larger amplitudes than angry expressions around 115 ms poststimulus. Expression and gaze interacted around 300 ms where angry expressions had larger amplitudes than happy expressions with straight gaze but smaller amplitudes for averted gaze. Their results suggest expression and gaze act independently around 100 ms and interactively around 300 ms to influence occipital ERPs.

The current study utilized happy, neutral, angry, and fearful expressions combined with left, straight, and right eye gaze directions and expands on Klucharev and Sams [16] by exploring how fearful and angry expressions interact with eye gaze to influence ERPs. It is important to understand how threat expressions such as anger and fear interact with eye gaze because various expression–gaze combinations convey different information. From an evolutionary perspective, fearful averted gazes should predict a more imminent threat than angry averted gazes while angry straight gazes should predict a more imminent threat than fearful straight gazes; fearful averted and angry straight gaze signal danger for the self, whereas fearful straight and angry averted signal danger for another.

Behavioral experiments have shown that participants are faster to identify an averted gaze when the expression is fearful compared with angry, and are faster to identify a straight gaze when the expression is angry compared with fearful [17]. In addition, participants are faster to identify angry and happy expressions with direct compared with averted gaze and are faster to identify fearful and sad expressions with averted compared with direct gaze [18]. Although these studies suggest that different combinations of threat expressions and gaze have significant influences on behavioral responses, it is unclear how threat expressions such as fear and anger interact with eye gaze to influence the N170 ERP.

Methods

Participants

Twenty-five participants consisting mostly of undergraduate and graduate students were paid \$20 to complete a 2-h experiment. Three participants were discarded because of depression (CED-D > 16) [19] and anxiety traits (STAI-A > 40) [20], one was discarded for poor behavioral performance and one for excessive eye movements; 20 participants were used in the final data analysis (age: $M = 25.2$ years, SD = 7.62; 19 right handed; one ambidextrous; 11 men). Participants gave written informed consent in accordance with a protocol approved by the CSU Institutional Review Board.

Materials

Eight faces (four men/four women) displaying happy, neutral, angry, and fearful expressions with left, straight, and right eye gaze directions were taken from the RafD database [21] for a total of 96 images and 12 experimental conditions. A Dell desktop computer (Dell Inc., Round Rock, Texas, USA) displayed stimuli using Stim^2 software (Compumedics NeuroScan, Charlotte, North Carolina, USA) that were cropped to display internal features (eyes, nose, and mouth area) within an oval surrounded by a black background contained within a rectangle of 170 × 210 pixels. All eight faces were scrambled for a condition to serve as a control for attention. Stimuli were manipulated with Gimp.

EEG recording

Electroencephalography (EEG) data was acquired with a SynAmps Amplifier and NeuroScan Quickcap (Compumedics NeuroScan) utilizing 19 electrodes (Fz, Cz, Pz; left: Fp1, F3, F7, C3, T7, P3, T5, O1, and coinciding right electrodes) placed according to the international 10–20 system with the factory ground (midline anterior to Fz) and reference (midline between Cz and Pz). Two electrodes under the outer canthi of each eye monitored eye movements. Data were acquired with a sampling rate of 500 Hz with an online bandpass filter of 0.1–50 Hz at 24 db/octave. Impedances were kept less than 11 kΩ for all electrodes.

Procedure

Participants sat about 1.5 ft from the computer screen and completed a paradigm [22] originally used to examine changes in the configuration of facial features. This paradigm was adapted to examine how changes in facial expression and eye gaze influence ERPs related to face perception in the current study.

Trials began with a black screen (1500 ms), a fixation cross (300 ms), and a neutral face (700 ms). Next, a black screen (500 ms) preceded the target stimulus (1000 ms); targets were the same identity as the first neutral face but from one of 12 experimental conditions. Participants were instructed to watch the presentation of faces in pairs and to press the '1' button within 1000 ms whenever a scrambled face appeared as the second face; they were not informed about expression/gaze changes. Six blocks each consisting of 112 trials were presented; eight presentations of each condition (× 12 = 96) and two presentations each of the eight scrambled faces (16).

Analysis

In the behavioral task, participants correctly pressed '1' within 1000 ms of a scrambled face being presented 84% of the time. One participant was discarded for poor performance (53% identification).

Raw EEG data were cut into epochs (– 100 to 600 ms) and subjected to artifact correction (± 110 μV) on all electrodes; average number of accepted trials per condition per participant was 34 of 48 (71%). One participant was discarded for excessive eye movements (28% accepted). Baseline correction and an offline dual bandpass filter of 0.1–30 at 24 db/octave were applied before rereferencing to the grand average. Grand averages for 12 experimental conditions consisted of three gaze directions for each expression. ERPs were also collapsed across gaze to show main effects of expression.

The main electrodes of interest were over temporal–occipital regions; T5, T6, O1, O2. The main time windows of interest were 30–80, 80–140 ms (P1), 140–200 ms (N170), and 200–400 ms. Analyses of variance (ANOVAs) on participants' grand mean amplitudes were conducted using a 3 Gaze (left, straight, right) × 4 Emotion (happy, neutral, angry, fearful) × 2 Electrode (temporal, occipital) × 2 Hemisphere (left, right) repeated measures design. α-Levels were set at $\alpha = 0.05$ for ANOVAs and a Bonferroni corrected $\alpha = 0.008$ for post-hoc *t*-tests.

Results

30–80 ms

No main effects or interactions of Gaze or Emotion occurred in this time window (P's > 0.09).

80–140 ms

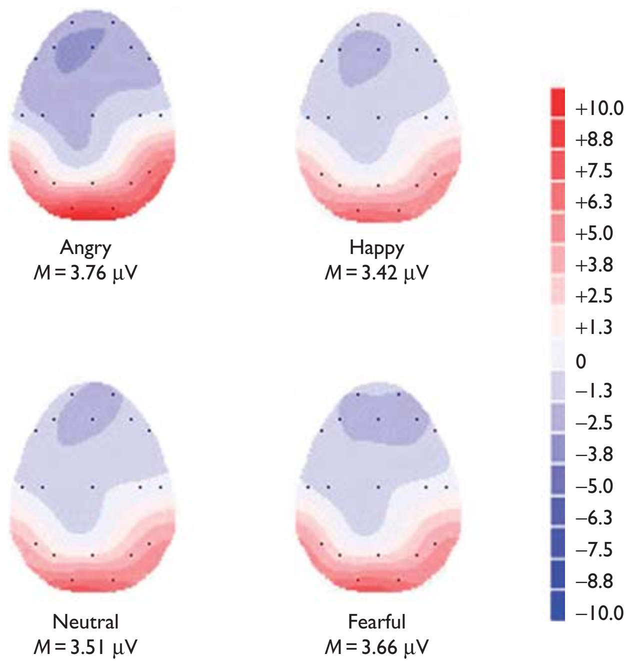
A main effect of Emotion occurred [$F(3,57) = 2.82$, $P = 0.047$]. Post-hoc *t*-tests showed that angry mean amplitudes ($M = 3.76$ μV) were significantly larger than happy ($M = 3.42$ μV; angry vs. happy, $P = 0.004$; Fig. 1) and marginally larger than neutral ($M = 3.51$ μV; angry vs. neutral, $P = 0.028$), whereas fear ($M = 3.66$ μV) was marginally larger than happy ($P = 0.04$). An Emotion × Electrode interaction [$F(3,57) = 4.01$, $P = 0.012$] was characterized by larger occipital amplitudes than temporal for all expressions (P's < 0.001) with angry occipital having significantly larger amplitudes than happy occipital ($P = 0.002$) and marginally larger than fear occipital ($P = 0.058$) and neutral occipital ($P = 0.02$) electrodes. Finally, an Emotion × Hemisphere interaction [$F(3,57) = 3.09$, $P = 0.034$] was characterized by angry expressions having marginally larger right hemisphere amplitudes ($P = 0.015$) than left with no other expressions showing hemispheric differences (P's > 0.2); additionally, angry right hemisphere amplitudes were significantly larger than happy right ($P = 0.006$) and marginally larger than fearful right ($P = 0.054$) and neutral right hemisphere

($P = 0.048$). No main effect or interactions of Gaze occurred (P's > 0.13). This demonstrated an early influence of angry expressions on P1 mean amplitudes independent of eye gaze.

140–200 ms

A main effect of Emotion occurred [$F(3,57) = 8.68$, $P < 0.001$; Fig. 2]. Post-hoc t-tests showed that fear ($M = -0.31\,\mu\text{V}$) and happy mean amplitudes ($M = -0.31\,\mu\text{V}$) were larger than angry ($M = 0.40\,\mu\text{V}$; fearful vs. angry, $P < 0.001$; happy vs. angry, $P < 0.001$) and neutral ($M = 0.28\,\mu\text{V}$; fearful vs. neutral, $P < 0.001$; happy vs. neutral, $P < 0.001$); no differences between angry/neutral or fear/happy emerged (P's > 0.4). No other effects or interactions involving Gaze and Emotion occurred (P's > 0.2). This demonstrated an influence of expression independent of eye gaze such that fear and happy expressions led to larger mean N170 amplitudes than neutral and angry expressions.

Fig. 1

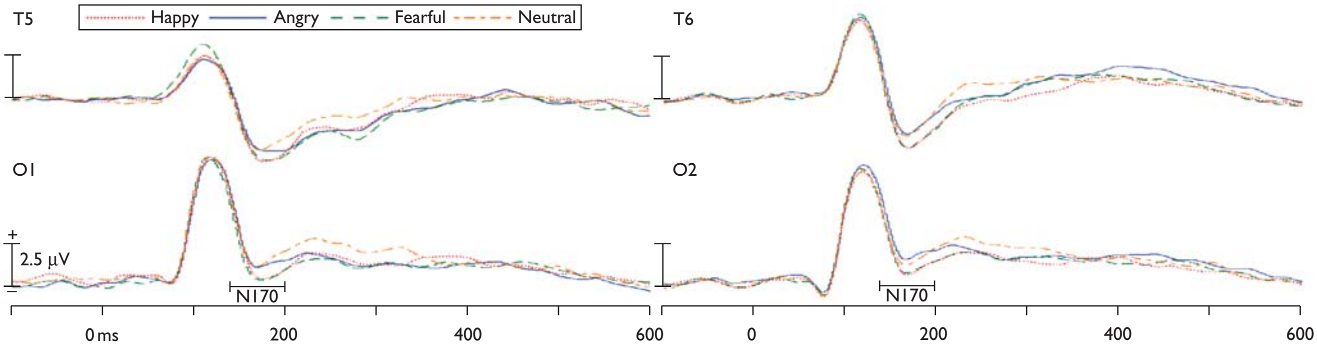


Topographic plots collapsed across gaze showing main effect of Expression for 80–140 ms time window. Angry expressions were significantly larger than happy expressions and marginally larger than neutral expressions over temporal–occipital areas.

200–400 ms

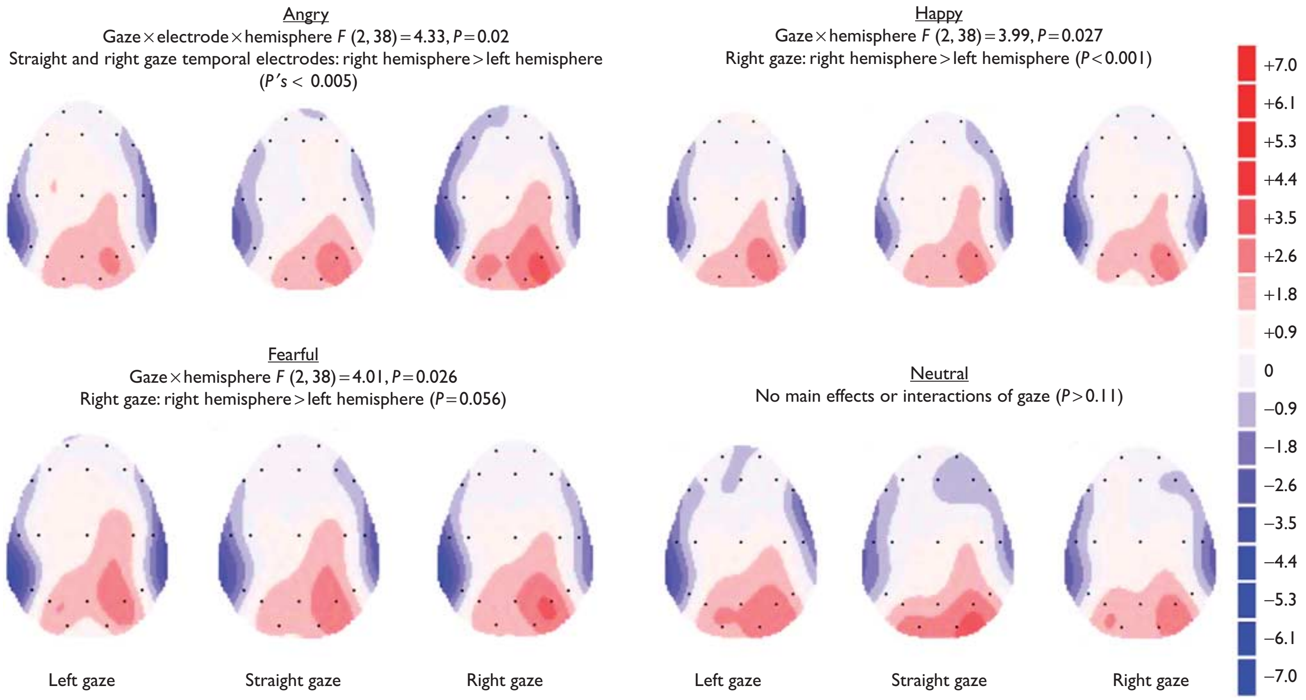
A main effect of Emotion occurred [$F(3,57) = 3.72$, $P = 0.016$]. Post-hoc t-tests showed that neutral ($M = 1.18\,\mu\text{V}$) and angry ($M = 1.03\,\mu\text{V}$) had significantly larger mean amplitudes than happy ($M = 0.59\,\mu\text{V}$; neutral vs. happy, $P < 0.001$; angry vs. happy, $P = 0.006$) expressions; neutral expressions were marginally larger than fear ($M = 0.65\,\mu\text{V}$; neutral vs. fearful, $P = 0.015$) with no other differences between expressions (P's > 0.08). There was also a Gaze × Emotion × Electrode × Hemisphere interaction [$F(6,114) = 2.76$, $P = 0.015$]. Follow-up ANOVAs were conducted on each Emotion using Gaze, Electrode, and Hemisphere as factors. Angry produced a Gaze × Electrode × Hemisphere interaction [$F(2,38) = 4.33$, $P = 0.02$; Fig. 3]. Post-hoc t-tests showed larger right hemisphere temporal electrodes amplitudes compared with the left for straight and right gazes (P's < 0.005) but not for left gaze ($P = 0.32$). Fear produced a Gaze × Hemisphere interaction [$F(2,38) = 4.01$, $P = 0.026$; Fig. 3]. Post-hoc t-tests showed that left and right gaze did not differ across hemisphere (P's > 0.5), whereas the right hemisphere was marginally larger than the left for right gaze ($P = 0.056$). Happy produced a Gaze × Hemisphere interaction [$F(2,38) = 3.99$, $P = 0.027$; Fig. 3]. Post-hoc t-tests showed larger right hemisphere amplitudes than the left for right gaze ($P < 0.001$), whereas no differences for left and straight gaze occurred (P's > 0.12). Neutral expressions produced no main

Fig. 2



Event-related potentials collapsed across gaze demonstrating main effects of expression for the N170 such that fearful and happy faces had significantly larger mean amplitudes than angry and neutral faces.

Fig. 3



Angry
Gaze × electrode × hemisphere $F(2, 38) = 4.33$, $P = 0.02$
Straight and right gaze temporal electrodes: right hemisphere > left hemisphere (P's < 0.005)

Happy
Gaze × hemisphere $F(2, 38) = 3.99$, $P = 0.027$
Right gaze: right hemisphere > left hemisphere ($P < 0.001$)

Fearful
Gaze × hemisphere $F(2, 38) = 4.01$, $P = 0.026$
Right gaze: right hemisphere > left hemisphere ($P = 0.056$)

Neutral
No main effects or interactions of gaze ($P > 0.11$)

Topographic plots for the 200–400 ms time window.

effects or interactions of Gaze (P's > 0.11). This showed that angry, fearful, and happy expressions began to interact with eye gaze in the 200–400 ms window.

Discussion

The finding of threat-expression ERP amplitude modulation replicates previous studies finding influences of anger and fear on P1 and N170 amplitudes [3–5] and studies finding no N170 amplitude modulation by eye gaze [13,14]. The novel finding of the current study is that angry and fearful expressions begin to interact with eye gaze in the 200–400 ms time window and that this interaction occurs only after independent expression influences on P1 and N170 mean amplitudes.

Klucharev and Sams [16] found no amplitude modulation in the N170 time window by expression, gaze, or expression/gaze interactions; expression and gaze influenced amplitudes during the P1 time window independently and began to interact around 300 ms in an explicit gaze processing paradigm. Eye gaze has influenced amplitudes of the N170 using both MEG [23] and ERP [13] implicit gaze processing paradigms utilizing checkerboard identification and watching the center of stimuli. Thus, explicit eye gaze processing [16] has modulated P1 amplitudes, whereas implicit gaze processing has modulated N170 amplitudes [13,23]. It is possible that the modulation of the P1 and N170 by threat expressions in the current study eliminated any eye gaze influences; previous studies finding gaze modulation of the N170 have not utilized emotional expressions in their design.

In addition, the influence of expression on N170 amplitudes is also unclear. Studies using implicit [6] and explicit [8] processing of emotional expressions have failed to influence N170 amplitudes, whereas other studies using implicit [3,4] and explicit [5] processing of expressions have modulated the N170. Thus, although there is evidence for the quick discrimination between emotional expressions from neutral expressions, the exact situations where expression modulates the N170 amplitude remain unknown.

The current study supports an interactive model of face processing where mechanisms perceiving biological motion such as emotional expression may interact with mechanisms responsible for initial face discrimination [1]. This interaction seems to occur on two different levels [16] where basic information from expression or gaze may influence early ERPs related to face discrimination such as the P1 and N170 on an independent level. This integration occurs on a basic level where no differentiation between specific expressions occurs, but rather a basic discrimination of emotional expression from neutral expression may occur [24]. At ∼300 ms temporal differences from expression–gaze interactions appear. This suggests that the mechanisms responsible for biological motion and face discrimination may interact on a limited basis for the quick detection of basic expression and gaze changes, whereas expression–gaze interactions are processed later downstream.

The idea that basic information from either expression or gaze is processed independently before being processed interactively would contradict the idea that early detection of different expression–gaze interactions would be an important evolutionary advantage. Thus, it may have been the case that quickly detecting changes in expressions was sufficient for our ancestors to survive; it may not have been necessary to quickly discern expression–gaze combinations. Accordingly, children show that at certain developmental stages, they match emotional expressions better than eye gaze direction; abilities that are equally present in adults [25]. This suggests that expression and gaze systems develop somewhat independently and that expression detection may take priority over gaze detection in some situations. This may also explain why no independent early eye gaze effects were found in the current study. Thus, although earlier processing of specific expression–gaze combinations such as fear averted or angry straight would be a plausible evolutionary advantage, quickly detecting simple changes in expression may have sufficed for our ancestors' survival.

Acknowledgements

This study was sponsored by the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) Program, NSF Grant SMA-1005199 to Edward L. DeLosh.

Conflicts of interest

There are no conflicts of interest.

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