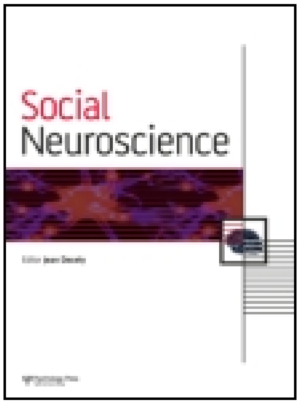

Social Neuroscience
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/psns20

Emoticons in mind: An event-related potential study

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Published online: 06 Jan 2014.

SOCIAL NEUROSCIENCE, 2014
Vol. 9, No. 2, 196–202, http://dx.doi.org/10.1080/17470919.2013.873737

Routledge
Taylor & Francis Group

Emoticons in mind: An event-related potential study

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It is now common practice, in digital communication, to use the character combination ":-)", known as an emoticon, to indicate a smiling face. Although emoticons are readily interpreted as smiling faces, it is unclear whether emoticons trigger face-specific mechanisms or whether separate systems are utilized. A hallmark of face perception is the utilization of regions in the occipitotemporal cortex, which are sensitive to configural processing. We recorded the N170 event-related potential to investigate the way in which emoticons are perceived. Inverting faces produces a larger and later N170 while inverting objects which are perceived featurally rather than configurally reduces the amplitude of the N170. We presented 20 participants with images of upright and inverted faces, emoticons and meaningless strings of characters. Emoticons showed a large amplitude N170 when upright and a decrease in amplitude when inverted, the opposite pattern to that shown by faces. This indicates that when upright, emoticons are processed in occipitotemporal sites similarly to faces due to their familiar configuration. However, the characters which indicate the physiognomic features of emoticons are not recognized by the more laterally placed facial feature detection systems used in processing inverted faces.

Keywords: Face perception; Digital communication; N170; Configural; Featural.

One of the first pieces of evidence to suggest that there are face-specific brain mechanisms was the finding that presenting stimuli upside down reduces recognition for faces more than for other objects (Yin, 1969). This effect of inversion on the recognition of faces has been found both when the faces are well known and unfamiliar (Collishaw & Hole, 2000; Farah, Wilson, Drain, & Tanaka, 1998). Hence, these behavioral results indicate that the face inversion effect is due to inversion disrupting the early stages of perceptual encoding of an image (Rossion & Gauthier, 2002). In particular, picture plane inversion of a stimulus disrupts configural processing of the image since inversion disrupts the configuration of the features that constitute the stimulus while leaving each feature readily identifiable. Hence, the finding that inversion reduces the recognition of faces more than other objects suggests that when upright, faces are readily perceived through configural processes while other objects tend to be perceived through featural processes. But, when inverted, both faces and objects are perceived featurally (Maurer, Le Grand, & Mondloch, 2002).

This distinctive effect of inversion on the perception of faces is also observable in the recording of electrophysiological activity in the brain that is measured at the scalp. The N170 event-related potential (ERP) is a negative going deflection in the electroencephalography (EEG) recording which occurs at around 170 ms after the onset of a stimulus (Bentin, Allison, Puce, Perez, & McCarthy, 1996) and which shows a reliable effect of face inversion in line with

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the behavioral results: inversion affects the N170 to faces more than to other objects (Eimer, 2000b; Rossion et al., 2000). This effect of inversion on the N170 is seen as an increased latency of the N170 for inverted faces and, somewhat counterintuitively, an increased amplitude of the N170 for inverted faces as well (Rossion & Jacques, 2008).

A change in the latency and amplitude of an ERP component following an experimental manipulation is always difficult to interpret because it may be explained by changes in multiple neural events (Luck, 2005), a general limitation that also applies to the effect of inversion on the N170 (Rossion & Jacques, 2008). However, multiple streams of evidence suggest that the increase in amplitude of the N170 for inverted faces is best explained by the presence of two dipole generators which are activated to a greater or lesser extent by faces in their upright and inverted orientation (Bentin et al., 1996; Bentin, Golland, Flevaris, Robertson, & Moscovitch, 2006; Sagiv & Bentin, 2001).

ERPs recorded directly from the cortical surface have identified regions within the occipitotemporal cortex that produce a larger negative going waveform at around 200 ms to whole faces than parts of faces or inverted faces, which suggests that they are primarily involved in the configural processing of faces (Allison, Puce, Spencer, & McCarthy, 1999; McCarthy, Puce, Belger, & Allison, 1999). Lateral to these cortical areas are regions that produce a larger amplitude response to face parts than whole faces making them a putative place of feature processing (McCarthy et al., 1999). However, the orientation of the regions related to configural processing is perpendicular to the recording sites at the scalp from which the N170 is recorded, while the regions involved in feature processing, especially those in the posterior upper bank of the occipitotemporal sulcus (OTS) and in the inferior temporal (IT) gyrus are arranged such that the dipoles extend readily through the scalp sites at which the N170 is maximal. Hence, it is likely that the N170 recoded at the scalp is affected by both configural and featural information but that due to the nature of cortical folding at ventral sites, the generator associated with featural information contributes more to the N170 component (Bentin et al., 1996).

Consistent with these physiological and behavioral findings, Sagiv and Bentin (2001) propose that the increase in amplitude and latency of the N170 to faces when they are inverted occurs because upright faces are processed configurally which inhibits the feature processing system. But, when faces are inverted the feature processing system is activated which produces the larger amplitude N170 by nature of its physical location and a longer latency N170 by nature of it taking more time to extract featural information from the visual scene.

That the effect of inversion on the scalp recorded N170 is so reliable makes it a useful tool for investigating the degree to which a stimulus is processed featurally or configurally. In the current experiment, we use this metric to assess the processing of a stimulus which is increasingly prevalent in written communication: the smiley face emoticon.

The emoticon used to denote a smiling face, written in the form ":-)", was first placed in a post to the Carnegie Mellon University computer science general board by Professor Scott E. Fahlman in 1982 (Associated Press, 2007). It was initially intended to alert the reader to the fact that the preceding statement should induce a smile rather than be taken seriously. It has since become a ubiquitous presence in screen based writing with many variations on these character combinations used to indicate different emotions.

The frequency with which the smiley face emoticon is used suggests that it is readily and accurately perceived as a smiling face by its users. Yet the process through which this recognition takes places is unclear. The components that are used to create the percept of a face are actually typographic symbols which do not carry any meaning on their own as a pair of eyes, a nose and a mouth. Indeed, removed from their configuration as a face, each of the symbols carries a specific meaning for the punctuation of the surrounding text.

This implies that the encoding of the smiley emoticon as a face occurs through configural processes rather than featural processes. If this is the case, then inversion of the emoticon should reduce the amplitude of the N170. Removed from their configuration as a face, the symbols representing the physiognomic features should revert to their meaning as a colon, a hyphen and a closed parenthesis and so fail to activate either the configural or feature-based face-specific cell populations in extrastriate and IT areas that are the source of the N170.

In the following study, we test this hypothesis by comparing the N170 to canonically arranged and inverted emoticons, natural faces and strings of typographic characters that do not carry any meaning beyond their use as punctuation.

METHODS

Participants

This study was approved by the Human Research Ethics Committee of the University of South

Australia. Twenty right-handed participants aged 18–32 years (six male) took part in the experiment. All participants were free from an uncorrected impairment in eyesight or hand movement, a personal or a family history of any psychological or genetic disorder or a period of unconsciousness in the last 5 years.

Stimuli

Participants were shown pictures of canonically arranged and inverted faces, emoticons in the form ":-)" and nonrepresentational character combinations (henceforth known as characters) in the form "*/.". Inversion of the stimuli was conducted by rotating each image by 180 degrees. Hence, canonically arranged faces were presented with the eyes at the top and inverted faces with the eyes at the bottom. Canonically arranged emoticons were presented with the eyes on the left and inverted emoticons with the eyes on the right. Sixty stimuli in each category were shown along with 30 pictures of flowers which were always presented upright. Faces were half male, half female and all showed a happy expression. These were taken from the Karolinska Directed Emotional Faces (KDEF IDs AF 01 to 30 HAS and AM 01 to 30 HAS; Lundqvist, Flykt, & Öhman, 1998). Emoticons and characters were typed in 60 different typefaces (fonts). All stimuli were shown on a gray background and were 5 cm by 7 cm on the monitor as shown in Figure 1.

Procedure

Participants were seated in a darkened, sound attenuated room approximately 60 cm from the monitor that presented the stimuli. EEG was recorded using a modified Quickcap (Compumedics Neuroscan, Charlotte, NC, USA). Sixty-four silver/silver-chloride electrodes were arranged according to the 10–20 system (American Electroencephalographic Society, 1994). Reference was at the tip of the nose and ground at FPZ. Vertical and horizontal eye movements were recorded in bipolar channels with electrodes 1 cm above and below the left eye and from the outer canthus of each eye.

Continuous EEG was recorded using a Synamps II amplifier (Compumedics Neuroscan) that sampled the analog signal at 1000 Hz with an analog bandpass filter between 0.1 and 100 Hz. Impedance at each electrode was reduced to below 5 KΩ at the start of the experiment. Stimuli subtended 5.1° by 7.3° of visual angle and were presented for 500 ms with an inter-stimulus interval that varied randomly between 1700 and 1900 ms.

Participants were instructed to press the response button with the index finger of one hand when they saw a flower. The hand used was counterbalanced between participants.

Electrophysiology

The continuous EEG was epoched from 150 ms before to 900 ms after the onset of each stimulus and baseline corrected to the pre-stimulus period. Deflections due to eye blinks were identified and corrected using a subtraction algorithm (Semlitsch, Anderer, Schuster, & Presslich, 1986). In addition, epochs with amplitudes larger than ±100 μV were excluded from the analyses. Participants with conditions in which less than 30 epochs were available were excluded from the analyses. This resulted in a final sample of 17 participants.

The epochs for each category of canonically arranged and inverted faces, emoticons and characters were averaged for each participant. These epochs were filtered at 30 Hz with a 12 dB/oct falloff. The N170 was identified as the most negative point between 130 and 200 ms and the peak amplitude and latency of this point was found for each stimulus category for each participant.

Statistical analysis

The peak amplitude and latency of the N170 were analyzed using a three way ANOVA for stimulus category (face, emoticon, character), orientation

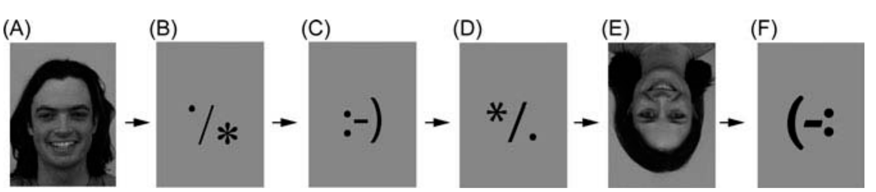

Figure 1. Stimulus sequence showing faces canonically arranged (A) (KDEF ID: AM01HAS) and inverted (E) (KDEF ID: AF01HAS), emoticons canonically arranged (C) and inverted (F), and characters canonically arranged (D) and inverted (B).

(canonically arranged, inverted) and hemisphere (left, electrode P7; right, electrode P8).

RESULTS

Amplitude

There was a main effect of stimulus category for the amplitude of the N170 ($F(2, 32) = 26.435$, $p < .0001$) in which emoticons ($M = –4.08$ µV, SD = 4.47) produced a larger N170 than both characters ($M = –0.19$ µV, SD = 3.92, $t(16) = 9.65$, $p < .0001$) and faces ($M = –2.22$ µV, SD = 5.56, $t(16) = 3.74$, $p = .02$), and faces produced a larger N170 than characters ($t(16) = 3.03$, $p < .0001$). This was qualified by an interaction between stimulus category and stimulus orientation ($F(2, 32) = 10.78$, $p < .0001$) in which inversion increased the amplitude of the N170 for faces (canonically arranged: $M = –1.29$ µV, SD = 6.64, inverted: $M = –3.16$ µV, SD = 4.96 $t(16) = 2.53$, $p = .02$) but decreased the N170 for emoticons (canonically arranged: $M = –5.08$ µV, SD = 4.85, inverted: $M = –3.08$ µV, SD = 4.38 $t(16) = 3.51$, $p = .03$). The amplitude of the N170 produced by characters was unaffected by inversion. There were no main effects or interactions involving hemisphere.

Latency

There was also a main effect of stimulus category for the latency of the N170 ($F(2, 32) = 15.53$, $p < .0001$) in which faces ($M = 164.59$ ms, SD = 9.02) produced an earlier N170 than both emoticons ($M = 175.12$ ms, SD = 1.47, $t(16) = 6.43$, $p < .0001$) and characters ($M = 180.12$ ms, SD = 2.89, $t(16) = 4.21$, $p = .01$) but with no significant difference for latency between emoticons and characters ($p > .9$). In addition, there was a main effect of orientation for the latency of the N170 ($F(1, 16) = 5.32$, $p = .03$) in which canonically arranged stimuli ($M = 171.92$ ms, SD = 5.92) produced an earlier N170 than inverted stimuli ($M = 174.62$ ms, SD = 7.62). As with amplitude, these main effects for the latency of the N170 were qualified by an interaction between stimulus category and orientation ($F(2, 32) = 21.83$, $p < .0001$). However, for latency, only faces showed a significant effect of inversion in which canonically arranged faces ($M = 158.94$ ms, SD = 11.42) produced an earlier N170 than inverted faces ($M = 170.23$ ms, SD = 8.64, $t(16) = 5.04$, $p < .0001$). There were also were no main effects or interactions involving hemisphere for the latency of the N170. Grand average waveforms for each condition are shown in Figure 2.

DISCUSSION

In this study, we investigated the way in which the smiley face emoticon is processed as a face in the human brain by analyzing the N170 ERP associated with canonically arranged and inverted emoticons, along with natural faces and other typographic characters. We hypothesized that because the characters used to indicate the eyes, nose and mouth of emoticons do not carry any physiognomic information in their own right (but rather carry the information of a colon, a hyphen and an end parenthesis, respectively), emoticons must be recognized through a configural process that relies on the arrangement of the characters in their well-known form.

Consistent with this hypothesis, when emoticons were inverted, the amplitude of the N170 was reduced, suggesting that neither the configural face processing regions in the middle fusiform nor the more laterally placed face feature processing regions are activated as much by inverted emoticons and hence the arrangement of characters is less readily recognized as a face. This is in contrast to the effect of inversion on natural faces. Like numerous ERP studies of natural faces in nonclinical samples (for review, see Rossion & Jacques, 2008), we found an increase in the amplitude and latency of the N170 when faces were inverted. This is consistent with the hypothesis that when canonically arranged, faces readily activate configural processing regions of the occipitotemporal cortex which, by nature of their orientation, produce a smaller but earlier N170 at the scalp than the more lateral feature specific regions which are activated when faces are inverted and configural processing is no longer able to accommodate the image as a face (Bentin et al., 1996). That inversion did not affect the N170 to other characters is consistent with the finding that stimuli which do not carry any face-like meaning in their canonical arrangement or inverted orientation such as shoes, houses and chairs (Rossion et al., 2000) do not show inversion effects in the N170 because neither the configural nor featural face processing systems are activated in either orientation.

Somewhat counterintuitively, the N170 to canonically arranged emoticons was larger than to canonically arranged natural faces. This finding warrants further investigation. However, as a starting hypothesis, we propose that it may be because the

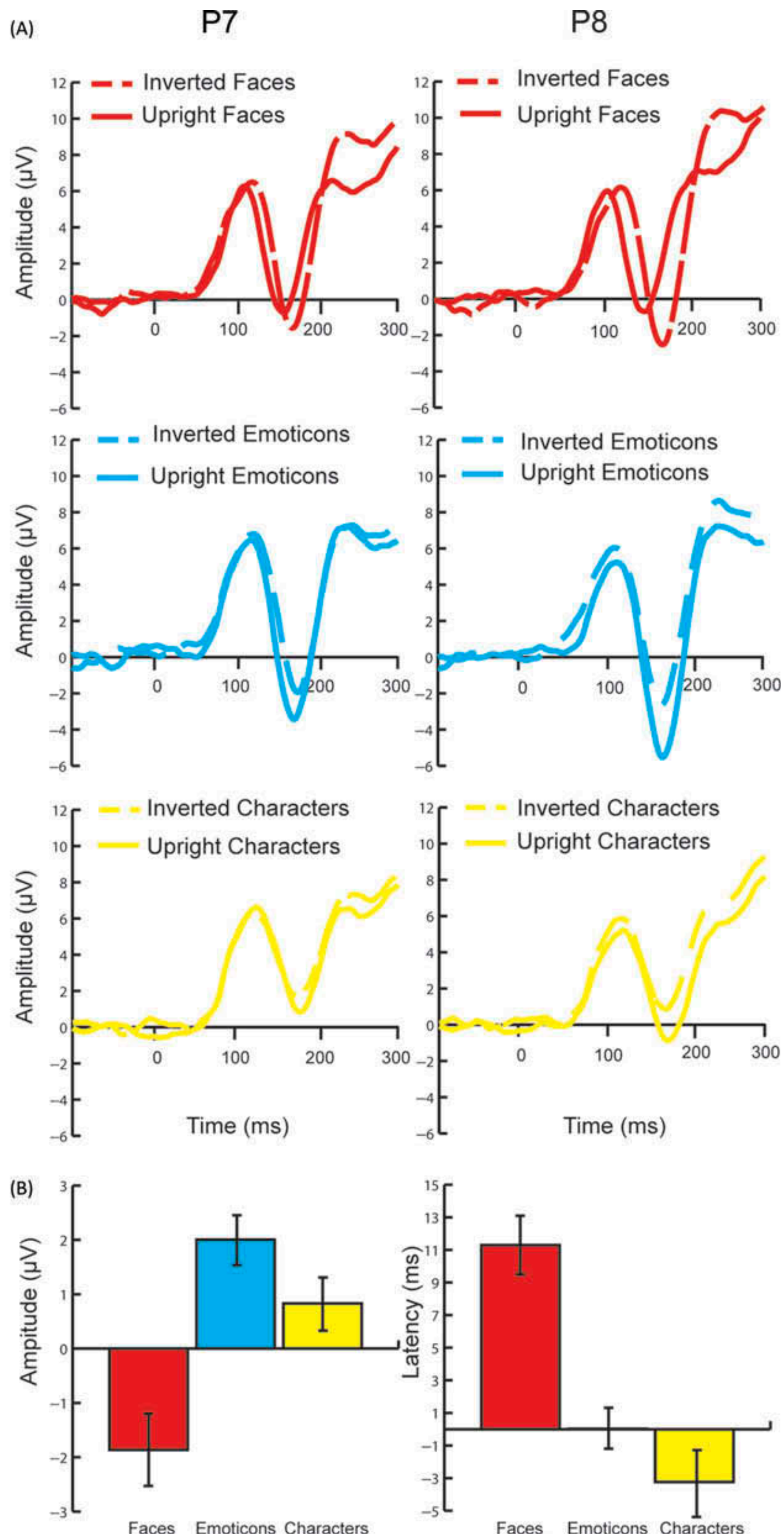

Figure 2. (A) Grand average waveforms for canonically arranged and inverted faces, emoticons and characters at electrodes P7 (left hemisphere) and P8 (right hemisphere). (B) Difference in amplitude and latency between canonically arranged and inverted faces, emoticons and characters.

emoticons captured participants' attention more than the natural faces which enhanced the amplitude of the N170 as has been found in previous studies of attention and the N170 (Churches, Wheelwright, Baron-Cohen, & Ring, 2010; Eimer, 2000a). Emoticons carry the connotation of colloquial communication and their sudden entry into the formal environment of an experiment in cognitive neuroscience may have created an incongruity which attracted the attention of participants more than the natural faces as has been found previously for incongruous stimuli (Schutzwohl, 1998).

That emoticons are written such that the shape is rotated 90 degrees counterclockwise from the canonical orientation of a natural face raises an interesting question. This rotation disrupts the canonical configuration of the facial features. A rotation of 90 degrees (either clockwise or counterclockwise) has been shown to reduce behavioral accuracy and reaction times for face recognition as well as increasing the amplitude and latency of the N170 (Jacques & Rossion, 2007). Indeed, Jeffreys (1993) reported that the greatest modulation of the N170 was found by rotating faces by 90 degrees from their canonical orientation with little additional effect found for rotating faces a further 90 degrees to a fully inverted alignment. Yet, canonically aligned emoticons evoked a larger N170 than inverted emoticons despite the fact that inverted emoticons are removed from the canonical configuration of a natural face by the same amount as canonically arranged emotions (i.e., 90 degrees in a clockwise direction rather than a counterclockwise direction). This suggests that the configural processing of emoticons in their canonical orientation is based on a learnt association. This is consistent with the first posting of an emoticon on the internet being followed by the explanation "Read it sideways" (Fahlman, 1982). It is also consistent with the finding that previously meaningless stimuli which activate a small N170 produce a markedly increased N170 amplitude after participants learn that they represent parts of a face (Bentin, Sagiv, Mecklinger, Friederici, & von Cramon, 2002).

The null results for a main effect or interaction involving hemisphere are worth noting. There is a bias between the cerebral hemispheres in the processing of visual information such that the right hemisphere preferentially processes configural information while the left hemisphere preferentially processes featural information (Robertson & Delis, 1986), a phenomenon which is particularly strong in face perception (Bradshaw & Sherlock, 1982; Rhodes, Brake, & Atkinson, 1993). If the perception of canonically arranged emoticons involves predominantly configural processes, then it would have been reasonable to hypothesize that the N170 to canonically arranged emoticons would be larger and earlier over the right hemisphere than the left. However, several studies have failed to find an effect of hemisphere on the amplitude and latency of the N170 to faces or an interaction between hemisphere and orientation (Churches, Baron-Cohen, & Ring, 2009; Tanaka & Pierce, 2009). Of particular relevance to this study, Sagiv and Bentin (2001) did not find an interaction between stimulus, orientation and hemisphere when testing the effect of inversion on the N170 evoked by natural faces and schematic faces (which were hypothesized to be processed configurally when canonically arranged, much like the emoticons in this study).

Only one emotional expression was tested in the current study: happiness. Further research on the neural processing of emoticons can draw on the body of behavioral research investigating the perception of schematic faces expressing different emotions (e.g., Ohman, Lundqvist, & Esteves, 2001). In addition, only two orientations of each stimuli were tested: canonically arranged and inverted. A finer grained analysis of emoticon orientation would provide an interesting comparison to the work of Jacques and Rossion (2007), who presented participants with faces at 12 different angles of rotation and Milivojevic, Corballis, and Hamm (2008), who presented individual letters at 12 different angles of rotation.

The orthographic characters used to write English are phonographs and hence the semantic meaning must be decoded through an understanding of the speech sounds indicated by the characters. However, some of the characters used to write in logosyllabic languages, such as Chinese readily suggest their semantic meaning through their visual form. Hence, it is understandable that in people familiar with such scripts, logographs evoke a similar, though not identical, N170 to faces (Fu, Feng, Guo, Luo, & Parasuraman, 2012; Liu, Tian, Li, Gong, & Lee, 2009). Emoticons, like logographs, are readily understandable through their visual form and so represent a new way of communicating in written English. This study is the first to investigate the neural basis of this new medium of communication. The results show that while faces are recognized as faces when canonically arranged or inverted because both configural and featural mechanisms are able to process the image, emoticons are perceived as faces only through configural processes. When the configuration is disrupted (through a process such as inversion), the emoticon no longer carries its meaning as a face.

Original manuscript received 17 July 2013
Revised manuscript accepted 5 December 2013
First published online 7 January 2014

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