# Effects of touch on emotional face processing: A study of event-related potentials, facial EMG and cardiac activity

Spapé12, M.M., Harjunen23, & Ravaja234, N.

1. Department of Psychology, Liverpool Hope University

2. Helsinki Institute for Information Technology, Aalto University

3. Aalto University, School of Business

4. University of Helsinki, Department of Social Research

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Correspondence: Michiel M. Spapé

Liverpool Hope University

Department of Psychology

Hope Park

L16 9JD

Liverpool

United Kingdom

[spapem@hope.ac.uk](mailto:spapem@hope.ac.uk)

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## Abstract

Being touched is known to affect emotion, and even a casual touch can elicit positive feelings and affinity. Psychophysiological studies have recently shown that tactile primes affect visual evoked potentials to emotional stimuli, suggesting altered affective stimulus processing. As, however, these studies approached emotion from a purely unidimensional perspective, it remains unclear whether touch biases emotional evaluation or a more general feature such as salience. Here, we investigated how simple tactile primes modulate event related potentials (ERPs), facial EMG and cardiac response to pictures of facial expressions of emotion. All measures replicated known effects of emotional face processing: Disgust and fear modulated early ERPs, anger increased the cardiac orienting response, and expressions elicited emotion-congruent facial EMG activity. Tactile primes also affected these measures, but priming never interacted with the type of emotional expression. Thus, touch may additively affect general stimulus processing, but it does not bias or modulate immediate affective evaluation.

## Introduction

Touch is well-known to affect emotions and cognition. Early research focused on the critical role of touch in the formation of social bonds that is necessary for the emotional development of both humans (Spitz, 1945) and other primates (Harlow, 1958). This idea, of a deep relationship between touch and closeness remains current in the conceptualization of touch, with recent studies suggesting that the degree of allowed touch can predict the closeness of a relationship (Suvilehto, Glerean, Dunbar, Hari, & Nummenmaa, 2015), and that the degree of actual touch can predict functional connectivity of the social brain (Brauer, Xiao, Poulain, Friederici, & Schirmer, 2016). However, even a brief, seemingly trivial touch can positively bias emotions. In a landmark study by Fisher, Rytting, & Heslin (1976), people were shown to appreciate a library better if they had previously been touched upon receiving a new membership card. Further studies suggested that the action of touching, possibly by signaling a positive social bond, not only increases affiliation but can result in social compliance, yielding tangible gains after tactile interactions, such as higher tips for waiters, free dimes for strangers and free bus-rides for potential passengers (Crusco & Wetzel, 1984; Guéguen & Fischer-Lokou, 2003; Kleinke, 1977). As such outcomes had a clear financial value, the effect became commonly known as the *Midas* *touch*, after the famous Phrygian king from Greek mythology, whose touch could transform anything into solid gold.

Although the effect continues to be replicated in various settings (Dolinski, 2010; Haans & IJsselsteijn, 2009), there have been varying, even conflicting, explanations as to which social, affective, and cognitive functions elicit it. In the social domain, Henley (1973) observed more interpersonal touch from men to women than vice versa and suggested that touch may signify warmth towards one who has a lower social status than the sender (Henley, 1973). Psychologists have suggested that touch, innately or as formed through childhood, is intrinsically a positive reinforcement, and may thus directly cause positive affect (Hornik, 1992). Touch may also act as an embodied cue that symbolizes similarity between a sender and a receiver, thus leading to more positive attitudes towards the sender (Smith, 2008). For instance, being touched by an outgroup member has been found to reduce implicit negative attitudes towards ethnic minorities (Seger, Smith, Percy & Conrey, 2014). Neither hypothesis explains, however, the fact that touch does not consistently lead to positive effects and can even yield negative outcomes (Dolinski, 2010). Of course, in social psychological experiments, the physical characteristics of touch are rarely controlled, making it possible that positive and negative evaluations simply follow pleasant and unpleasant haptic parameters. Furthermore, studies generally focused on consequences of touch that follow minutes after the event, leaving it impossible to guess whether touch immediately and directly alters affective appraisal and cognitive processing. Event related potential techniques have been demonstrated to be invaluable in providing information when examining the temporal dynamics of human cognition and emotions (Hajcak, MacNamara, & Olvet, 2010), but have thus far rarely been applied when it comes to touch.

*Effects of tactile stimuli on emotional processing*

Recently, Schirmer et al. (2010) showed direct effects of tactile modulation on emotional processing. They presented emotional stimuli from the international affective picture system (IAPS; Lang, Bradley, & Cuthbert, 1997) while participants occasionally received a touch. Interestingly, they found similar effects whether a touch was applied by a friend, applied by a tactile device but attributed to a friend, or applied by a tactile device and attributed to a computer. In each condition, touch was found to alter the event related potentials to visual stimuli, suggesting the tactile effects were independent of the source of the stimulation. Early potentials were found to be amplified after touch, regardless of the emotionality of the picture, possibly indicating that touch enhances visual attention. However, these effects were replicated after replacing the touch with a simple auditory stimulus, so it could be argued that the mere presence of a stimulus in an irrelevant modality may have influenced (e.g. primed) visual stimulus processing. Of more interest, therefore, were the effects on late potentials: tactile, but not auditory primes (although these were not directly contrasted), were found to amplify the difference between negative and neutral emotional pictures. This suggests that touch modulates emotional processing, making recipients more attuned to the affective part of the message.

In a study by our own group (Spapé, Hoggan, Jacucci, & Ravaja, 2015), vibrotactile stimuli were presented (applied using a device but attributed to another person) before the onset of emotional stimuli. Here, instead of images from the IAPS database, touch was presented before the onset of symbolic cues (smiley faces) that conveyed winning or losing in a decision making paradigm. To investigate the effect of the tactile primes on emotion, we measured the feedback related negativity (FRN), an ERP component that has been related to evaluative appraisal ( Cohen, Elger, & Ranganath, 2007). Touch had some positive effects on decision making (accepting offers) and the FRN, but these were found to be indistinguishable from the effects of auditory control primes. Thus, we concluded that the tactile primes had no direct influences on the affective evaluation of subsequent information. However, touch was found to amplify the late component of the P3 wave of both negative and positive cues, which we interpreted as potentially reflecting enhanced encoding into memory. In order to investigate this hypothesis, we analyzed how tactile communication in one trial influenced decision making in the next, and observed patterns suggesting that touch modulated reciprocating and generosity. Thus, touch was found to not immediately or automatically affect emotional evaluation, but instead has a general influence on cognition that may bias later interpretation and decision making.

Both studies conclude that touch affects emotions to some extent, but strictly speaking, this inference is premature. In the first study, negative affect evoking pictures were contrasted with non-emotional stimuli, making it unclear whether touch affected arousal – which can result from positive and negative images alike – or perceived emotionality. The second study similarly focused on the positive/negative dimension of emotion by solely contrasting negative (losses) and positive (gains) conditions. This dimension, valence, is of course important in describing emotion but cannot singularly account for the emotional spectrum (Schlosberg, 1954). More importantly, because of the simple contrasts in the studies, it cannot be inferred whether the effects of touch concern a bias of valence evaluation, or a more general facilitation of cognitive processing. For example, a suddenly appearing stimulus in an irrelevant modality can facilitate an early phase of the response selection stage, an effect which is commonly known as the accessory stimulus effect (Hackley & Valle-Inclàn, 1999).

In order to investigate whether qualitatively different emotional dimensions are distinctly affected by tactile stimulation, emotional face stimuli could be more informative than economic or IAPS stimuli. Emotional faces have long been the focus of much emotion research (Ekman & Friesen, 1976), resulting in some consensus on how different emotional expressions affect event related potentials and peripheral psychophysiological activity. In terms of the former, event related potentials have been related to distinct stages of cognitive processing. As for the latter, measurements of facial electromyography and electrocardiography have long been known to provide reliable information on the later consequences of affective evaluation.

*Early processing of emotion in faces*

The temporal accuracy of EEG has proven remarkably informative in the study of emotion processing. Early research showed that from 170 ms, a dissociation in the visual evoked potential emerges which distinguishes between faces and other visual stimuli (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Seeck & Grüsser, 1992). This face-sensitive potential came to be called the vertex positive potential (VPP, maximal over frontal electrodes) or N170 (minimal over lateral parietal P7/P8), depending on the reference (Joyce & Rossion, 2005). The consistency across studies and the timing of the potentials, being well before potentials that are strongly affected by task-relevance, such as the P300 (Polich & Kok, 1995), suggested the VPP/N170 are task-independent and possibly pre-attentive (Cauquil, Edmonds, & Taylor, 2000). In that way, it is associated with an early, automatic visual facial pattern recognition process and the operation of the fusiform face area that fMRI studies commonly associate with face identification (Itier & Taylor, 2004b; Watanabe, Kakigi, & Puce, 2003) although the degree of face-specificity of the N170 remains debated (Itier & Taylor, 2004a; Thierry, Martin, Downing, & Pegna, 2007).

Interestingly, several studies suggest that information regarding the emotion of the facial expression is either parallel to, or precedes the identification of the stimulus as a face. That is, earlier findings provide evidence that identification of threat occurs almost at the same time as the face selective activity, with such stimuli incurring an early, negative shift at around 230 ms (Vanderploeg, Brown & Marsh, 1987). It was later found that multiple arousing or threatening emotional expressions (e.g. anger) incur this negativity near the N200 (Balconi & Pozzoli, 2003; Sato, Kochiyama, Yoshikawa, & Matsumura, 2001; Schupp et al., 2004). A more recent study showed that under conditions of limited attentional resources, the emotional modulation may even happen prior to the identification of faces. Thus, Luo, Feng, He, Wang, & Luo (2010) observed greater frontal N1s and posterior P1s for fearful than happy faces, as well as stronger VPPs for both fearful and happy than neutral faces (but see Eimer, Holmes, & McGlone, 2003; Herrmann et al., 2002). The extreme immediacy of these effects has been taken to indicate that facial emotions may be extracted even pre-attentively, before conscious processing. While the field continues to debate the degree of control over facial expression perception (Palermo & Rhodes, 2007), it is clear that emotional processing of a facial expression starts early, and probably before the image is identified as a face.

*Late processing of facial emotions*

While facilitating the early processing of stimuli that indicate threat may be an adaptive trait (Fox, etc), positive facial expressions tend to have stronger effects in later potentials. According to Luo et al. (2010), an initial stage of emotional face processing consists of extracting the coarse emotional content in order to identify threat while the more fine-grained emotional content becomes only relevant at a relatively late (ca. 300 ms) stage. Their definition of this late stage is indicated by an N300 over lateral sites that is more pronounced for fearful than neutral expressions, while simultaneously a positivity starts to affect the event related potential, distinguishing the happy from the neutral expressions. The latter effect may reflect the P3, a general longer-lasting positive potential over centro-parietal sensors from 300 ms onwards, which has been related to functions of late perceptual processing, or early memory (Polich, 2007). A variety of studies have shown the P3, and in particular its later aspect, the late positive potential (LPP) to be amplified for positively valenced stimuli such as happy expressions (Schupp et al., 2004, Luo et al. 2010), and pictures of beloved others (Langeslag, Jansma, Franken, Van Strien, 2007). However, as the P3 has long been known to be affected by stimulus relevance (Sutton, Braren, Zubin, & John, 1965), it is not clear whether the late effects reflect an intrinsic effect of valence, or are more related to the specific task and motivation (Olofsson, Nordin, Squieira & Polich) as the direction of the effects depends on the task (Pastor et al., 2008).

*Peripheral psychophysiology of facial emotions*

After the emotional evaluation of face stimuli by the brain, they elicit distinct reactions in our facial muscles and heartrate. Positive affect has generally been shown to result in activity over the zygomaticus major (ZM, smiling) muscle area, while negative affect has been associated with activity over the corrugator supercilii (CS, frowning) area (Fridlund & Cacioppo, 1986). Perceiving an emotion in another person may also induce the congruent feeling in oneself, and/or mimicking of the emotional expression, an effect that is sometimes referred to as emotional contagion (Hatfield, Cacioppo, & Rapson, 1993) or linkage (Levenson & Gottman, 1983; Spapé et al., 2013). Perception of emotional expressions thus has predictable consequences: smiling eliciting activity over the ZM and disgust over the levator labii superioris alaeque nasi (LN, nose-wrinkling) muscle areas (Blairy, Herrera, & Hess, 1999). Finally, negative emotional expressions, such as angry and fearful faces, have been shown to result in enhanced attentional alertness, associated with the brief, parasympathetically-mediated, deceleration of cardiac activity (Bradley, 2009; Jönsson & Sonnby-Borgström, 2003). This so-called orienting response is followed by increased sympathetic control indexed by cardiac acceleration (Bradley, Codispoti, Cuthbert & Lang, 2001). Contrary to the simple fight-or-flight type of response, cardiac acceleration results both from stimulating negative and positive events and is thus related to the stimulus arousal rather than valence (Balconi, Vanutelli, & Finocchiaro, 2014; for a review see Kreibig, 2010).

*Present Study*

In the present study, we set out to investigate whether simple, tactile stimuli change subsequent processing of emotional expressions as measured by their effects on ERPs and peripheral psychophysiology. To find out if tactile primes biased emotional evaluation, as opposed to a more general type of stimulus-processing, we used four different types of emotional expression. The study principally focusses on whether tactile primes interact with the quality of the emotion, operationalized as the interaction between the type of emotional expression and the type of prime. In order to control for other priming effects, we employed both a control condition without prime, and a control condition with a similar prime, but delivered via a different modality.

Firstly, if touch amplifies the affective content directly, as would be expected from the observations by Schirmer et al. (2010), one would expect interactions between emotional expression- and prime-type already at an early ERP stage, for example resulting in touch amplifying the difference between the N170s for angry and happy facial expressions. In contrast, if, as we suggested (Spapé et al., 2015), touch affects only the significance of the emotional stimulus, then the primes may have additive effects on early stimulus processing, but may interact only with emotional content (i.e. the type of expression) at a later stage.

Secondly, if touch induces positive affect, as is the traditional interpretation of the Midas Touch effect, one should predict a bias towards a more positive evaluation of facial expressions. Accordingly, one would predict tactile primes to increase ZM muscle activity in response to happy faces, but to decrease CS and LN activity in response to negatively valenced facial expressions. Similarly, one could predict negative expressions related cardiac deceleration to be attenuated as a result of touch. However, if, as another theory of touch suggests, touch acts as an embodied cue related to interpersonal similarity (Smith, 2008), one would predict touch to facilitate mimicry of all facial expressions. Specifically, this predicts emotion-congruent facial muscle activity to be amplified after touch: increased ZM activity in response to happiness, corrugator supercilii (CS) activity in response to anger and fear, and levator labii superioris alaeque nasi (LN) activity in response to disgust (Fridlund & Cacioppo, 1986). Finally, if touch increases visual attention to emotional stimuli (Schirmer et al., 2010), or modulates the significance of stimuli (Spapé et al., 2015), one could expect generic effects of touch on corrugator supercilii and the orienting response, resulting from enhanced attention (Bradley, Codispoti, Cuthbert, & Lang, 2001). For the former, if the emotional salience is processed further, one should expect emotion-specific interactions to occur at the facial EMG level, while for the latter, emotional and tactile effects could be additive factors.

Note that the aim of the present study is not necessarily to falsify a *null-hypothesis*: The effects of emotional expressions (and to some extent, of priming) are well known. The critical aim is to find out at what time, if any, touch selectively modulates emotion, for which reason effect sizes could be more informative than significance.

## Methods and materials

*Participants*

Seventeen female and twenty-four male, right-handed undergraduate students from Aalto University and the University of Helsinki volunteered to take part in the study in exchange for money. They were 24.7 ± 3.9 years old on average. The experiment was conducted in accordance with the ethical guidelines laid out in the Declaration of Helsinki, and approved by the Ethical Board of Aalto University. Participants received full briefing regarding their rights – including their right to withdraw from the study at any time without fear of negative consequences – and signed informed consents prior to the experiment. The data from one (female) participant were removed from the analyses due to a technical problem.

*Stimuli*

Presentation of stimuli, recording of behavior, and synchronization with EEG equipment over the parallel port was done using E-Prime 2.0.10.353 (Psychology Software Tools Inc, Sharpsburg, PA), running on Windows XP. Images from the commonly used “Pictures of Facial Affect” (Ekman & Friesen, 1976) were used as visual source material. Of these, we used only those happiness, fear, anger and disgust images that could be combined with a neutral expression of the same face (16 on average). Images were 320x480 pixels, presented at a distance of ca. 60 cm on a 48 x 30 cm LCD screen running at a 1024x768 resolution and a refresh rate of 60 Hz. The images were shown in the center of a gray screen, against a black window of 340x540 pixels which also occluded the top 60 pixels of the source material, as they include identifying information. Primes always used the same audio waveform as source: a 100 Hz square wave form of 500 ms in duration with a gradual fade-in of 10 ms and fade-out of 350 ms. A C2 tactor (<http://www.atactech.com/PR_tactors.html>) was used to present the prime in the vibrotactile domain. This device operates via a moving magnet linear actuator, with a vibrating contact area of 7 mm, surrounded by an additional, shielded area of 23 mm. It was strapped using elastic tape to the volar surface, in the centre of the palm of the right hand. A computer speaker, positioned to the right of the LCD screen, presented the same stimulus as audio at a level of ca. 50 dB (at the distance of the participant to the speaker). The same stimulus was presented over both channels, but completely attenuated in order to provide a silent, control condition with commeasurable timing characteristics.

*Procedure and design*

Participants began the experiment immediately after reading experiment instructions and viewing a demonstration of the experiment by the laboratory assistant. As schematically portrayed in figure 1, trials started with a fixation cross presented to the center of the screen for 400 ms, which participants were asked to fixate on. A face with a neutral expression then replaced the cross. After a randomized interval of 300-600 ms, the prime was presented. Then, after a randomized stimulus onset asynchrony of 650-1000 ms, the neutral expression was replaced by an image of the same person, now wearing an emotional expression. Participants were asked to not respond until after the face disappeared, which occurred 1000 ms later. They were then instructed to use their left hand and Z and X keys and their right hand and N and M keys to indicate the emotion of the face.

[-- FIGURE 1 about here --]

Participants completed four blocks of 120 trials. The emotional expression-response mapping between anger, disgust, fear, happiness on the one hand and the Z, X, N and M keys on the other, was randomized every block with a Latin square design to avoid confounds with lateralized activity. Since this could induce confusion upon having to adjust to the new response mapping, we provided 4 training trials at the beginning of every block, during which participants received full feedback as to their speed and accuracy. In the subsequent 120 testing trials per block, feedback was only provided if participants responded too early (before face disappeared) or too late (>2000 ms). Such trials that provoked feedback, as well as the training trials, were excluded from analysis.

The study used a within subject design with factors emotion (anger, disgust, fear and happiness) and prime (touch, tone, silent) randomized within every 12 trials, with 10 repetitions for each of the 4 blocks, resulting in a maximum of 40 trials per design cell for the analysis. Participants took ca. 40 minutes to complete the entire series of 480 trials of the experiment.

*Recording*

A BrainProducts QuickAmp (BrainProducts GmbH, Gilching, Germany) recorded EEG at 1000 Hz from 32 Ag/AgCl electrodes placed on sites over FP1, FP2, F7, F3, Fz, F4, F8, FT9, FC5, FC1, FC2, FC6, FT10, T7, C3, Cz, C4, T8, TP9, CP5, CP1, CP2, CP6, TP10, P7, P3, Pz, P4, P8, O1, Oz and O2 using an elastic cap for standardization (EasyCap). We used the average reference both during recording and all steps in the analysis, as it is most commonly used in face and emotional expression perception studies (Joyce & Rossion, 2005). Two bipolar electrodes were placed 1 cm lateral to the outer canthi of the left and right eyes to capture horizontal eye movement activity (HEOG), and two similar electrodes 1 cm superior and inferior to the left eye for vertical eye movements and eye-blinks (VEOG). The electro-cardiogram (ECG) was recorded using a bipolar pair of disposable adhesive electrodes, one placed near the manubrium and the other near the ninth left rib. The facial electromyogram (fEMG) was recorded with bipolar electrodes on sites overlying the left zygomaticus major (ZM), corrugators supercilii (CS) and levator labii superioris alaeque nasi (LN) muscle regions. All data were recorded at a sample-rate of 1000 Hz and a hardware filter at 0.01 Hz.

*EEG preprocessing*

EEG and EOG were pre-processed off-line with a high-pass filter at 0.2 Hz and a 50 Hz notch filter. The artifact correction procedure made use of the infomax algorithm based independent component analysis (ICA) as implemented in EEGLAB (Delorme & Makeig, 2004). To optimize ICA decomposition, we first filtered the data between 1 and 80 Hz, and segmented data centering on the face stimulus, including 2.1 s before and after onset. Extreme amplitudes (>500 μV, ca. 4.4%) were removed to reduce, in the subsequent ICA decomposition, the likelihood of components selectively accounting for rare artefacts with high variance. Following ICA, we inspected the activity, frequency spectrum and topography of components and visually classified components as artefactual (related to eye-movements, eye-blinks, etcetera) or clean (EEG related). The EEG was reconstructed by applying the thus obtained weights to the unfiltered, continuous data and projecting only the artifact-free components to the electrode level. The artefact-corrected data was further processed in Brain Vision Analyzer 2 (BrainProducts GmbH, Gilching, Germany). This included applying an IIR filter to the data (0.2 – 40 Hz) and epoching the data, again centering on face stimulus onset, but now including 200 ms of baseline and 800 ms of data following the presentation of the emotional expression. Epochs were rejected for suspect activity if any of the channels considered in the analysis (see ERP measurements) had amplitudes exceeding 35 µV or a difference between maximum and minimum value exceeding 55 µV. This procedure removed ca. 10.6 ± 13.9 % of epochs, so that ERPs – averages of the epochs for each of the 12 combinations between prime and emotion – were computed over 35.8 ± 5.6 trials in total.

*ERPs*

In order to avoid “cherry picking”, we defined points of interest based on the grand average visual evoked potential of the emotional expression stimuli regardless of the preceding prime. As early components tend to be much shorter and more affected by particularities in laboratory setups, we defined the temporal windows of interest for early components based on the data, and for later components based on the literature.

Windows for early components were defined by calculating the standardized (mean / SE) evoked potential for F3, Fz, F4, C3, Cz, C4, P7, P3, Pz, P4, P8, O1, Oz, and O2 in every 10 ms between stimulus onset and 250 ms. Then, the local peaks were detected, around which the surrounding window with a threshold of T(40) > 4 was taken as the interval for N1/P1, VPP/N170 and P2. An N1 was found in frontal sites (strongest over Fz at 110-120 ms, T = -8.21), in contrast with a P1 in lateral-temporal and occipital sites (at 110-120 ms, P8: T = 8.24, O1: T = 6.26). We thus defined the N1/P1 as the local maximum in P8 between 90 and 130 ms. Following, a VPP/N170 was found: maximal over frontal sites (F3: T = 10.23 at 170-180 ms, Fz: T = 9.82 at 170-180 ms) and most negative over lateral posterior sites (P7: T = -8.69 at 170-180 ms, P8: T = -11.85 at 180-190 ms). The window for the N170 was therefore defined as the minimal value between 150-210 ms over P8. A subsequent P2 was observed slightly after the N170, characterized by positivity in central parietal channels (Cz: T = 14.94 between 210-220 ms, Pz: T = 9.26), for which reason the latency between 180 and 250 with maximal value in Cz was used. Following detection of the component within the thus defined relevant channel and window of interest, its latency was used to extract the amplitude for all electrodes. Windows for late components were based on Eimer et al. (2003), who used mean amplitudes between 220-315, 320-495 and 500-700 ms post-stimulus.

The analysis of ERPs extended the basic design of *emotion* and *prime* with a factor *area*, based on Eimer et al. (2003), with *area* defined as the average across electrodes within predefined regions: frontal (F3, Fz, F4), central (C3, Cz, C4), parietal (P3, Pz, P4), lateral posterior (P7, P8) and lateral occipital (O1, O2). For N1/P1 and N170/VPP – being components with opposing polarities – we used all areas, whereas for the P2 only central (C3, Cz, C4) and parietal (P3, Pz, P4) areas were included. For late components of the ERP, the analysis was extended to a four-way repeated measure design with *emotion*, *prime*, *area* (all five regions), and *time* (220-315, 320-495 and 500-700 ms) as factors. Throughout all analyses, Greenhouse-Geisser corrections were applied wherever sphericity assumptions were violated.

*EMG, ECG*

The continuous EMG data were filtered using a 7 Hz high-pass filter, rectified using the Hilbert transform to obtain the envelope (Myers et al., 2003) and normalized with the log-transform to reduce outlier effects. Continuous ECG signals were band-pass filtered 2-100 Hz, with a notch filter between 46-54 Hz. Following, a peak-detection algorithm was used to detect the latencies of heartbeats as local, globally stable, maxima (MATLAB code available at cognitology.eu/source/mig\_ContECGToIBI.m), and interpolating rare intervals in which no heartbeats were detected. Resulting heartbeat latencies were then spline-interpolated to inter-beat interval (IBI) by time signal. Means for IBI and EMG over three areas were then calculated over four 1 s bins following the emotion onset, with the average activity in the 1 s interval preceding the emotion subtracted. The repeated measures ANOVA on IBI included time, as the orienting response affects ECG in a strongly time-locked manner (Graham & Clifton, 1966). Effects of emotion on facial EMG are less consistent in time, but can be distinguishable in terms of their localization. As some expressions affect multiple muscle areas simultaneously (Ravaja, Turpeinen, Saari, Puttonen, & Keltikangas-Järvinen, 2008), we added *area* as a factor to the EMG analysis. One repeated measures ANOVA tested the effects of *prime*, *emotion* (anger vs. happiness vs. disgust vs. fear) and *time* (1st vs. 2nd vs. 3rd vs. 4th s) on IBI*.* Another tested the effects of *prime*, *emotion* and *area* (CS vs. LN vs. ZM) on EMG activity.

## Results

Reactions occurring during the training period and slow reactions were excluded from all analyses. Erroneous reactions were removed from the analysis of reaction times (RTs) only. Repeated measures ANOVAs were conducted separately for behavior, EMG, ECG, early ERP amplitudes and late ERP area averages. All analyses had *emotional expression* (anger vs. disgust vs. fear vs. happiness) and *prime* (silent vs. audio vs. touch) as factors. Extensions of this basic design – for example, if an analysis also included a factor to estimate differences across areas – are mentioned in their particular description. Our interest primarily concerned interaction effects between touch and emotional expression, so for the sake of brevity, we omit a detailed report of each individual effect or possible post-hoc comparison. However, an overview of contrasts of interests and effect sizes, for emotional expression, touch and their interaction on behavior, EMG, ECG, early and late ERPs is provided below (see table 1).

[ TABLE 1 about here ]

*Behavior*

Participants generally responded accurately (92.3 ± 0.6 % correct), and quickly (566 ± 20 ms). We tested whether *emotional expression* and *prime* affected overt behavior, in terms of error rates (percentage erroneous) and reaction time (RT). A cut-off value of <1250 ms in latency was used to remove outliers from the RT analysis. Following, significant effects of *emotional expression* were observed for RT, F (2.67, 106.92) = 81.27, p < .0001, and error rates, F (2.19, 85.48) = 36.81, p < .0001. Happiness provoked fastest and least erroneous responses (459 ms, 0.7 %) followed by fear (572 ms, 3.7 %), disgust (589 ms, 12.4%) and anger (642 ms, 14.0%). *Prime* did not significantly affect errors, p > .9, but did affect RT, F (1.94, 75.76) = 4.21, p = .02, with audio (562 ± 20 ms) and touch (573 ± 20 ms), eliciting faster responses than silent (563 ± 20 ms) conditions. No interactions were significant, *F*s < 0.9, *p*s > .5.

*EMG*

Similar ANOVAs, but with *area* (CS vs. ZM vs. LN muscle group) added, on EMG activity gave significant main effects for *area*, F (1.99, 77.42) = 12.77, p < .001, and *prime*, F (1.31, 51.20) = 20.04, p < .0001, but not *emotional expression*, p > .3, with stronger facial muscle activity over ZM muscles, and after audio primes. *Emotional expression* and *area* significantly interacted, F (1.64, 63.95) = 15.48, p < .0001, with stereotypical effects of anger and fear (increasing CS), disgust (increasing CS and LN), and happiness (increasing ZM while decreasing CS). *Prime* also interacted with *area*, F (1.36, 53.21) = 12.12, p < .001. This effect was found to be mainly the result of differences in the baseline of the LN muscle: already in the first 1 s, a stronger decrease in LN activity was observed. This was found to be related to the tactile primes eliciting an immediate short burst of activity prior to the onset of the face which resulted in a difference in baseline (see Figure 2). However, *prime* neither interacted with *emotional expression*, nor modulated the *emotional expression*-by-*area* interaction, *F*s < 1.3, *p*s > .3.

*ECG*

For IBI, the effect of *time* (1st, 2nd, 3rd, 4th second following the emotional stimulus) was added to the basic design. This showed significant effects of *time*, F (1.73, 67.52) = 37.53, p < .0001, and *emotional expression*, F (2.72, 105.94) = 4.97, p < .004, but not *prime*, p > .1. The effect of time showed a cardiac deceleration (9.3 ms) in IBI in the first two seconds, suggesting a general orienting response. *Time* also interacted with *emotional expression*, F (3.24, 126.51) = 4.83, p = .003, and with *prime*, F (3.84, 149.83) = 2.79, p = .03. The effect of *emotional expression* could be described as mainly due to an amplified deceleration occurring particularly in the third bin with anger (14.0 ± 1.8 ms). The *prime*-by-*time* interaction showed a more pronounced deceleration after touch in the 2nd second (9.4 ms) than silent (8.0 ms) or tone (8.0 ms), followed by tones showing a stronger re-acceleration in the 4th second (4.1 ms) than after silent (1.5 ms) and touch (1.4 ms). The latter part, being the stronger effect, is described in Table 1. Neither the *prime*-by-*emotional expression, —*nor the three-way—interaction was significant, *F*s < 0.8, *p*s > 0.5.

[ FIGURE 2 about here ]

*N1/P1*

In three repeated measures ANOVAs with *area* (frontal, central, parietal, lateral-temporal and occipital), *emotional expression* (anger, disgust, fear and happiness) and *prime* (touch, tone and silent) as factors, *area* significantly affected P1/N1, F (1.61, 64.25) = 41.63, p < .0001, while neither of the other main effects was significant, *p*s > .07. However, *emotional expression* significantly interacted with *area*, F (5.55, 216.26) = 4.04, p = .001, as did *prime*, F (3.19, 124.35) = 7.07, p < 0.001. The effect of *area* showed negativity over frontal areas (N1) and positivity over occipital ones (P1). The interaction effect could be described as indicating an enhanced N1/P1 for faces showing disgust, with amplified negativity over central (-0.82 μV vs. -0.61, -0.53, and -0.51 for respectively anger, fear and happiness) areas as well as amplified positivity in occipital (2.52 μV vs. 2.01, 1.76 and 1.97) areas. *Prime* likewise affected both potentials, with touch amplifying (by 0.20 μV), and auditory primes attenuating (by 0.22 μV) the N1 over fronto-central areas in contrast with silent conditions. The P1, over lateral-temporal and occipital areas, was likewise attenuated after auditory primes (by 0.30 μV) but not after touch (0.05 μV, *ns*). However, neither the *prime*-by-*emotional expression*, F (4.87, 189.72) = 0.90, p > .5, nor the three-way interaction, F (7.97, 310.87) = 0.51, p > .8, was significant.

*N170 / VPP*

Similar repeated measures ANOVAs on the N170 / VPP amplitude showed significant main effects of *area*, F (1.31, 51.10) = 127.38, p < .0001, and *emotional expression*, F (2.83, 110.35) = 13.13, p < .0001, but not *prime*, F (1.92, 74.95) = 2.35, p > .1. Faces expressing happiness showed strongest negativity (-1.41 μV) vs. disgust, fear and anger (-1.22, -1.19 and -1.04 μV respectively). However, both *prime*, F (3.85, 150.07) = 9.44, p < .0001, and *emotional expression*, F (4.56, 177.66) = 14.33, p < .0001, significantly interacted with *area*, suggesting the effect was localized. Comparing the effects largely showed the same effects, but in inverse order, consistent with the idea that the N170 and VPP components have similar functional meaning, but are reversed in polarity (Joyce & Rossion, 2005). The N170, as measured over lateral-temporal areas, was amplified after fear (-7.71 μV), followed by happiness (-7.33 μV), disgust (-6.97 μV), and anger (-6.53 μV). In terms of primes, the N170 was enhanced after auditory primes (-7.42 μV), followed by touch (-6.92) and silent (-7.06). The same pattern of the effect of emotional expression and prime could be observed on the VPP, strongest present over frontal areas, with greatest positivity after fear (3.65), followed by happiness (3.50), disgust (3.24) and anger (2.97); and after auditory (3.69), followed by silent (3.28 μV) and tactile (3.05 μV) primes. Again, neither the *prime*-by-*emotional expression-*, F (5.52, 215.40) = 0.65, p > .6, nor the three-way-interaction, F (8.83, 344.22) = 0.49, p > .8 was significant.

*P2*

A repeated measures ANOVA with *area* (central vs. parietal), *prime* and *emotional expression*, showed significant main effects of *area*, F (1, 39) = 50.14, p < .0001, and *emotional expression*, F (2.63, 102.71) = 4.62, p = .006, but not *prime*, F (1.86, 72.58) = 2.27, p > .1. *Area* and *emotional expression* significantly interacted, F (2.78, 108.43) = 6.88, p = .0004, as did *area* and *prime*, F (1.96, 76.48) = 5.93, p = .004. For *emotional expression*, the effect showed amplified P2s over central areas with fear (3.68 μV) and happiness (3.62 μV) compared to anger (3.37 μV) and disgust (3.31 μV) while activity over parietal areas was stronger in anger (1.37 μV) and fear (1.30 μV) than in disgust (0.90 μV) and happiness (0.87 μV). *Primes* showed stronger effects in central areas, with higher amplitudes after auditory (3.66 μV) and silent (3.58 μV) than tactile (3.24 μV) primes. Again, the interaction between *prime* and *emotional expression* and the three-way interaction were both non-significant, *F*s < 0.8, *p*s > .5.

*Later components*

A repeated measures ANOVA, with *time* (220-315, 320-495 and 500-700 ms), *area* (frontal, central, parietal, lateral-temporal and occipital), *emotional expression* (anger, disgust, fear and happiness) and *prime* (touch, tone and silent) as factors, showed significant effects of *time*, F (1.53, 59.82) = 66.97, p < .0001, area (1.61, 64.19) = 50.33, p < .0001, *emotional expression*, F (2.44, 95.24) = 12.48, p < .0001, and *prime*, F (2, 78) = 5.84, p = .005. *Prime* interacted with *area*, F (3.57, 139.04) = 32.49, p < .0001, and this interaction was significantly modulated by *time*, F (5.29, 206.24) = 3.80, p = .002. *Emotional expression* interacted with *area*, F (4.11, 160.19) = 10.80, p < .0001, and *time*, F (3.64, 141.92) = 15.32, p < .0001. Here, too, the three-way interaction between *time*, *area* and *emotional expression* was significant, F (6.41, 249.79) = 10.80, p < .0001. A complete description of how the main effects of emotion and primes are distributed in time and topography is provided in Figure 3. However, of main importance for the present study was that no evidence for an interaction between *emotional expression* and *prime* could be found, *F*s < 1.2, *p*s > .3.

[ FIGURE 3 about here ]

## Discussion

This study investigated whether touch modulates emotional face processing. In order to control for generic cognitive effects of cross-modal primes, such as might be expected from a forewarning cue or an accessory stimulus effect (Hackley & Valle-Inclán, 1999; Swallow & Jiang, 2010), we contrasted tactile primes with both no-cue and auditory cue conditions. That is, if a touch is merely an accessory stimulus, it should have similar consequences to other task-irrelevant primes, while hypotheses considering touch a special, inherently emotional form of stimulus predict distinct differences between tactile and auditory primes.

The affective responses to emotional faces were strong and in line with previous studies. The observed effects on facial EMG activity reflected the well-established phenomenon of facial mimicry: the response in the corrugator supercilii (CS) was most pronounced after negative expressions and that in the zygomaticus major (ZM) after happy expressions (Hess & Blairy, 2001). Faces displaying expressions of disgust, however, did not affect the levator labii superioris alaeque nasi (LN). Finally, an increased cardiac deceleration indicated a parasympathetically mediated orienting response to threatening (angry) faces (Bradley, 2009).

The event related potentials to the emotional faces likewise replicated some two decades of research on EEG responses to facial emotions. In particular, the N1, indicated in preliminary visual attention (Hillyard, Hink, Schwent, & Picton, 1973; Näätänen & Michie, 1979), was amplified after disgust. The N170/VPP, commonly seen as specific to face perception (Bentin et al., 1996) was stronger in response to expressions showing fear or happiness. The P2, previously indicated as relating to anxiety (Holmes, Nielsen, & Green, 2008), was here also amplified after fearful faces. Finally, the P3/LPP, previously shown to be related to positive affect (Gable & Harmon-Jones, 2010; Pastor et al., 2008), but sometimes also to negative affect (An et al., 2003), was amplified with expressions showing happiness, relative to other emotional expressions.

Cross-modal cues also affected responses to the visual stimuli. Auditory and tactile stimuli facilitated forced choice reaction times to subsequently shown faces, consistent with the accessory stimulus effect (Hackley & Valle-Inclán, 1999). Touch furthermore reduced CS activity, possibly indicating a relaxation of concentration (Barral et al., 2015), but did not affect ZM activity, suggesting it did not necessarily result in an affective response. It did, however, elicit LN activity to a surprisingly strong degree. Since this effect was shown to be in response to the touch itself, thus preceding the emotional expression, and since the effect was much larger than the emotional effects on LN, we conclude that the effect is unlikely to have a cognitive or affective cause. Instead, we speculate that previous suggestions of cross-modal pathways between touch and smell (Dematte, Sanabria, Sugarman, & Spence, 2006) give rise to a tactile-LN reflex. Be that as it may, in sum, auditory and tactile primes seemed to affect stimulus evaluation in general – as a general facilitation of cognitive processing – but in no measurement under consideration was an interaction between emotional expression and prime observed. Thus, it does not appear that touch automatically changes emotional evaluation, for example by increasing empathy – an old (Fisher et al., 1976) but still relevant (Gallace & Spence, 2010) conceptualization – as this would predict that touch should elicit facial mimicry (Sims, Van Reekum, Johnstone, & Chakrabarti, 2012).

Likewise, almost all ERP components that were affected by emotional expression were also found to be affected by primes, but not in any clear or interacting way. Thus, touch increased the N1, replicating Schirmer et al. (2010), and reduced the VPP (though not necessarily the N170) as well as the P2. A frontal part of the P3 response was reduced for touch and enhanced for sound, whereas a later (possibly P3b) response was found similarly amplified after both types of primes. Finally, the late positive frontal negativity (possibly inversely related to the late positive complex, Picton & Stuss, 1994; Sutton & Ruchkin, 1984) was found reduced for touch compared to control and sound. The LPP in particular has recently become the focus of psychophysiologists, some of whom explicitly consider it a motivational (Gable & Harmon-Jones, 2010; Schupp et al., 2000) or emotional (Brown, van Steenbergen, Band, de Rover, & Nieuwenhuis, 2012; Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012) correlate. However, given that no ERP component showed any interaction with the emotional identity of faces, the evidence does not point toward the primes biasing emotional face processing.

Although a lack of a significant effect is no proof of its absence, it should be noted that our study had a relatively large sample size, and consistently shows a clear lack of any effect of tactile primes modulating emotional expression across behavior, ERPs, EMG and cardiac activity. Indeed, looking at the effect sizes of the interaction terms across the sixteen measures in the present study, we find that on average, only 1.8% of the variance can be accounted for by the effect of priming on emotional face processing. To put that into perspective, the effects of emotional expression and type of priming on their own accounted for respectively 27.1% and 19.5%. This has important implications for the sample size of replication studies, but more importantly, this means that the explanatory value of the hypothesis that touch biases emotional evaluation is limited. Indeed, it would be hard to align the size of any of the psychophysiological effects with the Midas Touch literature. For example, Gueguen & Fischer-Lokou (2003), show the likelihood that a request for a free ride increases by 20 percentage points after being “encouraged by a tactile contact”, and in a meta-analysis, Haans & IJsselsteijn (2009) computed an average effect size across studies of 15.9%.

However, one might argue that the “touch” employed in the present study does not sufficiently convey a real, human touch. Schirmer et al. (2010), for example, used a pressure based device to deliver tactile primes that generally had a long (5 s) duration. On the other hand, upon contrasting real, human touch with mechanical touch from a device either (believed to be) operated by a human, or starting randomly, they themselves noted very little effect of the “humanity” of the touch. Furthermore, the duration of the touch presented in the current study is not particularly short with regards to the Midas Touch literature, which favors a single (see footnote 1) short type of touch: Fisher, Rytting & Heslin (1976), for example, specifically trained confederates to achieve tactile stimulations of durations exactly equal to those in the present study. Thus, there is little a-priori evidence that long durations or human haptic parameters are required to cause emotional modulation, suggesting the argument is raised purely because no emotional modulation was observed.

A more serious argument relies on the lack of neutral emotional display. One might argue that our lack of neutral faces could cause all cross-modal effects to be equal amongst different emotions: perhaps a touch does not make a threatening face more threatening, but merely makes all faces more emotional? This interpretation would be possible, but only if emotions would bias facial stimulus-related components in similar ways. However, ERP studies have demonstrated that emotional face processing follows a more complex timeline. For example, fearful faces were found to amplify early (N1) responses, before (N170) the generic emotional response (Luo et al., 2010; Zhang, Luo, & Luo, 2013). However, here we find the reverse pattern: touch enhanced the N1, but not the N170.

Another interpretation is that cross-modal primes influence visual attention, but not necessarily immediately the emotional impact of this stimulus. This interpretation would be consistent with one suggested by Schirmer et al. (2010), who, remarking upon the similarity between tactile and auditory effects on emotional stimulus processing, suggested they might enhance “the sensory salience or emotional significance of accompanying pictures”. As the quality or valence of the emotional picture, as contributed in the present study, did not interact with the prime, the conclusion must be that the sensory salience rather than emotional processing is affected.

Still, it is important to note that even though touch does not seem to immediately alter emotional evaluation, it is possible that touch may still induce a late type of emotional effect on decision making. For example, if a touch enhances sensory salience, it could improve encoding to memory, thus making it more likely that any affective content is retrieved. Thus, in our previous work on the Midas Touch, we initially expected tactile primes to modulate affective appraisal and, consequently, the feedback related negativity (Spapé et al., 2015). This was not observed: Touch enhanced the late positive potential regardless of affective content. Consistent with touch as biasing stimulus significance, we related this effect to a persons’ relationship with the sender of the touch and the degree of fairness of economic offers, and showed the touch could still bias decision making at a subsequent phase of the experiment. Principally, this means that a touch does neither act necessarily as an embodied cue for interpersonal similarity, nor does it automatically bias ongoing affect and thereby improve emotional evaluation. It seems instead more likely that a touch acts firstly by focusing attention and secondly via a complex network that uses cultural expectations in the interpretation of the event.

In other words, a touch does not immediately make everything seem better. It is, however, possible that a touch may facilitate attention towards a stimulus, making it more likely we will remember the event. Or, in terms of the Midas Touch: A waiter’s touch may not make their smile appear warmer, but it might help you remember the event. It does not reduce the cost of your dinner, but you still will think twice before you fail to tip.

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## Figure Captions

**Figure 1: Trial procedure.** A fixation was presented for 400 ms before a face stimulus was displayed. The face always wore a neutral expression and was presented for 950-1600 ms. While this visual stimulus was still being shown on the screen, a touch, a tone or a silent control prime was presented. Then, the face’s expression changed to one of four emotions. The emotional expression was always presented for 1000 ms, only after which participants were asked to indicate the displayed emotion using a keypress.

**Figure 2: Effects of emotion (left panels) and primes (right panels) on facial EMG and ECG.** Portrayed are mean (per second) evoked logarithmic normalized EMG activity over Zygomaticus major (ZM, “smiling”), Corrugator supercilii (CS, “frowning”) and Levator labii superioris alaeque nasi (LN, “nose wrinkling”) muscle groups. For ECG, averages are shown for the average change in inter-beat interval (IBI) in ms (i.e. deceleration is plotted upwards). Error bars denote standard errors of means.

**Figure 3: Effects of emotion (left panels) and primes (right panels) on ERPs.** Portrayed are grand averages, pooled over frontal (F3, Fz, F4), central (C3, Cz, C4), parietal (P3, Pz, P4), lateral-temporal (P7, P8) and occipital (O1, Oz, O2) electrodes. The analysis of early potentials (N1/P1, N170/VPP and P2) used peak amplitudes at the latencies indicated in the left panel. For late potentials, average amplitudes were used over three distinct intervals (220-315, 320-495 and 500-700 ms).

## Table

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 1 | | | | | | | | |  |  |  |
| *Effects of emotion and prime on behavior and physiology* | | | | | | | |  |  |  |  |
|  |  | Effect sizes () | | | Direction of Effects | | | | | | |
|  |  | Emotion | Prime | Interaction | Emotions | | | | Primes | | |
| Behavior | | | | | A | D | F | H | s | a | t |
|  | RT | .68\*\*\* | .09\* | .02 |  | | | | 2 | 1 | 1 |
|  | ERROR | .49\*\*\* | .00 | .01 | 3 | 3 | 2 | 1 | *ns* | | |
| EMG | | | | | | | | | | | |
|  | CS | .43\*\*\* | .09\* | .05 | 3 | 2 | 2 | 1 | 2 | 2 | 1 |
|  | ZM | .13\*\* | .01 | .01 | 1 | 1 | 1 | 2 | *ns* | | |
|  | LN | .03 | .30\*\*\* | .03 | *ns* | | | | 2 | 2 | 1 |
| ECG | | | | | | | | | | | |
|  | IBI | .11\*\* | .07\* | .02 | 2 | 1 | 1 | 1 | 1 | 2 | 1 |
| Early ERPs (area with highest amplitude) | | | | | | | | | | | |
|  | N1 (fronto-central) | .09\* | .26\*\*\* | .01 | 1 | 2 | 1 | 1 | 2 | 1 | 3 |
|  | P1 (occipital) | .12\*\* | .06 | .02 | 2 | 3 | 1 | 2 | *ns* | | |
|  | VPP (frontal) | .25\*\*\* | .33\*\*\* | .01 | 1 | 2 | 3 | 2 | 2 | 3 | 1 |
|  | N170 (lateral temporal) | .39\*\*\* | .18\*\*\* | .02 | 1 | 2 | 4 | 3 | 1 | 2 | 1 |
|  | P2 (central) | .12\*\* | .19\*\*\* | .02 | 1 | 1 | 2 | 2 | 2 | 2 | 1 |
| Late ERPs (area with strongest effect) | | | | | | | | | | | |
|  | 220-315 (frontal+) | .46\*\*\* | .18\*\*\* | .01 | 1 | 1 | 1 | 2 | 2 | 3 | 1 |
|  | 220-315 (occipital-) | .30\*\*\* | .38\*\*\* | .01 | 2 | 2 | 3 | 1 | 2 | 1 | 2 |
|  | 320-495 (central+) | .19\*\*\* | .30\*\*\* | .02 | 1 | 2 | 2 | 3 | 1 | 2 | 2 |
|  | 500-700 (lateral temporal-) | .45\*\*\* | .01 | .01 | 1 | 1 | 1 | 2 | *ns* | | |
|  | 500-700 (frontal-) | .10\*\*\* | .15\* | .02 | 2 | 2 | 1 | 1 | 2 | 2 | 1 |
| *Note.* RT = reaction time, error = error percentage, CS = corrugator supercilii, ZM = zygomaticus major, LN = levator labii superioris alaeque nasi, IBI = inter-beat interval. Direction of effects are on the main effects of emotion (first letter capitals denoting Anger, Disgust, Fear and Happiness) and primes (lower case letters denoting silent, audio, touch). Early ERPs are relative to peak polarity. Late ERPs are average amplitudes in bins with named midpoint. Effects are described as post-hoc comparisons after sorting the values in ascending order: RT A3 should be interpreted as reaction time in Anger being significantly higher than Disgust. *ns*: p > .05, \*: p < .05; \*\*: p < .01, \*\*\*: p < .001. | | | | | | | | | | | |
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## Footnotes

**Footnote 1**

A similar argument is that repeated exposure to tactile primes could have caused cutaneous habituation (Milne, Kay, & Irwin, 1991), and with the weaker sense of touch, a smaller interaction between prime and emotional expression might be expected. To explore this possibility, we contrasted the behavioral and physiological measures from the first half of trials with the second half in an additional analysis. As shown in the Supplementary Information, a main effect of time was observed for reaction times, error percentages, and late ERPs, as well as interactions between time and emotional expression, for error percentages and late ERPs. The error percentages showed mainly a floor effect towards 0% errors with higher gains for correctly classifying angry emotional expressions in the second half of trials. Conversely, late ERPs were found to have stronger effects of emotional expressions in the latter part of the experiment. Furthermore, as no interaction between time and the effect of primes on emotional expression was observed in any measure, we conclude that there is no evidence that habituation reduced priming effects on emotional face processing.

## Supplementary Information

**SI 1: Auditory / Tactile prime waveform**

**SI 2: Effect sizes as a function of time (first half of trials vs last half of trials).**

## Figure 1

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## Figure 2

C:\od\OneDrive - Liverpool Hope University\Pub\Papers\s(2016) Spape Harjunen Ravaja - Effects of touch on pictures of emotional faces\Figs\Figure 2.tiff

## Figure 3

C:\od\OneDrive - Liverpool Hope University\Pub\Papers\s(2016) Spape Harjunen Ravaja - Effects of touch on pictures of emotional faces\Figs\Figure 3B2.tif

## SI 2

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 2 | | | | | | | | |
| *Effect sizes as a function of time (first half of trials vs last half of trials)* | | | | | | | |  |
|  |  | Main Effects | | | Interactions | | | |
|  |  | 1. Emotion | 2. Prime | 3. Time | 1 x 2 | 1x3 | 2x3 | 1x2x3 |
| Behavior | | | | | | | | |
|  | Reaction time (ms) | .52\*\*\* | .06 | .26\*\*\* | .00 | .04 | .00 | .01 |
|  | Errors (%) | .66\*\*\* | .00 | .31\*\*\* | .03 | .18\*\*\* | .04 | .02 |
| EMG | |  |  |  |  |  |  |  |
|  | CS | .42\*\*\* | .10\* | .00 | .04 | .01 | .00 | .03 |
|  | ZM | .13\*\* | .02 | .00 | .02 | .01 | .01 | .05 |
|  | LN | .03 | .31\*\*\* | .00 | .03 | .01 | .07 | .03 |
| ECG | | | | | | | | |
|  | IBI | .12\*\* | .06\* | .00 | .02 | .02 | .02 | .03 |
| Late ERPs (area with strongest effect) | | | | | | |  |  |
|  | 220-315 (frontal+) | .10\*\*\* | .48\*\*\* | .27\*\*\* | .01 | .04 | .02 | .02 |
|  | 220-315 (occipital-) | .30\*\*\* | .38\*\*\* | .10\* | .01 | .05 | .03 | .02 |
|  | 320-495 (central+) | .35\*\*\* | .49\*\*\* | .29\*\*\* | .02 | .04 | .01 | .03 |
|  | 500-700 (lateral temporal-) | .26\*\*\* | .41\*\*\* | .04 | .01 | .12\* | .02 | .03 |
|  | 500-700 (frontal-) | .10\* | .55\*\*\* | .11\* | .02 | .07\* | .01 | .02 |
| *Note.* Values are effect sizes (). The effect of *time* concerns the contrast between the first half and second half of trials. CS = corrugator supercilii, ZM = zygomaticus major, LN = levator labii superioris alaeque nasi, IBI = inter-beat interval (ms). Numbers denote the type of interaction tested, e.g. 1x3 being the interaction between emotion and time. \*: p < .05; \*\*: p < .01, \*\*\*: p < .001. | | | | | | | | |
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