The Meaning of the Virtual Midas Touch: An ERP Study in Economic Decision Making

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Abstract

The Midas touch refers to the altruistic effects of a brief touch. Though these effects have often been replicated, they remain poorly understood. We investigate the psychophysiology of the effect using remotely transmitted, precisely timed, tactile messages in an economic decision-making game called Ultimatum. Participants were more likely to accept offers after receiving a remotely transmitted touch. Furthermore, we found distinct effects of touch on ERPs evoked by 1) feedback regarding accepted and rejected offers, 2) decision cues related to proposals, and 3) the haptic and auditory cues themselves. In each case, a late, positive effect of touch was observed and related to the P3. Given the role of the P3 in memory-related functions, the results indicate an indirect relationship between touch and generosity that relies on memory. This hypothesis was further tested and confirmed in the positive effects of touch on later proposals.

Introduction

In order to effectively communicate, it is often important to accurately estimate the emotions of one's interaction partner. Our sense of touch has been shown to play a large role in establishing how we feel and act toward another person. For instance, after a soft touch, a request for a dime is more often granted (Kleinke, 1977), waiters who touch their customers get larger tips (Crusco & Wetzel, 1984), and people touching the bus-driver can expect free rides (Guéguen & Fischer-Lokou, 2003). The effect that people are more altruistic, in the sense that touch can elicit measurable generosity has been termed the Golden, or Midas, touch, after the mythological king who had been granted the gift to convert everything he touched into gold (Ovid, Metamorphoses XI).

Despite the apparent simplicity of the tactile sense, a touch involves a complex syndrome of social, psychological and physical aspects, and it may, therefore, not be too surprising that certainty regarding the neural underpinnings of the Midas touch remains absent in the literature. Touch may be our most intimate sense, so the warm act of reaching out to others may be reciprocated with kindness. Furthermore, hostility, nurturance, dependence, and affiliation are all social messages that can be conveyed through touch (Argyle, 1975). Human touch has also been suggested to evoke a sense of "proximity and establish the human connection" (Montagu & Matson, 1979), perhaps because our tactile sense is used as an embodied metaphor for social connectedness (Ackerman, Nocera, & Bargh, 2010)

Given the psychological complexity of the tactile sense, it is unlikely that a touch works its way to generosity as directly as the mythology of Midas implies. Indeed, studies showed that even the perception of touch varies according to social context. For instance, heterosexual male subjects who received a "sensual touch" in the MRI scanner showed different patterns of activity in their somatosensory cortex if they believed that the source of the touch was a male, rather than a female, even though the touch was always administered by a female (Gazzola et al., 2012). In regard to the neural aspects of interpersonal touch, recent research has shown that different patterns of brain activation can differentiate between the more perceptual and the more social aspects of tactile sensation (Gallace & Spence, 2010; Rolls et al., 2003).

Despite the social richness of touch, communication media have traditionally relied on the senses of sight and sound. However, in the recent years that have seen a decline of face to face communication in favor of interaction via telephone, email, instant messaging, social networks, and so on, it has become an important consideration to enhance a sense of social presence in communication. Mediated, virtual touch was a technology developed to facilitate a sense of psychological closeness in the lack of physical proximity. Hoggan, Stewart, Haverinen, Jacucci, and Lantz (2012) first implemented the technology in mobile telephony and found that users would communicate a variety of messages with mediated touch, rather than simply closeness or positive affect. This might be expected as previous studies demonstrated that stimuli from vibrotactile technologies are processed similarly to real physical contact (Haans, de Nood, & IJsselsteijn, 2007). Thus, even though a warm, human touch may appear quite different from the buzzing sensation involved in a mediated touch, there are indications that the impact of a virtual touch is of the same magnitude of an unmediated touch in a evoking helping behavior (Haans & IJsselsteijn, 2009). Mediated social touch thus seems to offer a valid as well as promising alternative to investigate the social, cognitive and psychophysiological effects of touch without other confounding communicational cues (see also Haans & IJsselsteijn, 2006; Lewis, Derlega, Shankar, Cochard, & Finkel, 1997).

The effort to empirically establish the extent to which touch affects communication inspired the present study.

Present study

In order to better understand the interplay between touch and communication, we started with a hypothesis based on the Midas touch, predicting that people who receive a remote touch behave more generously than people who do not. As mentioned, the study of remote touch becomes more and more relevant in its own right due to the continuing technological trends of integrating haptic signals in mobile communication, but there were additional benefits to studying remote, as opposed to direct, tactile signals. First, it allowed us to disentangle the commonly confounding effect of a confederate's presence on the Midas touch effect (cf. Lewis et al., 1997). Second, by using a well-known paradigm from game theory, we were able to examine the effect of touch on immediate acceptance (compliance, as in Kleinke, 1977) as well as on later generosity (as in Crusco & Wetzel, 1984). Third, it allowed us to investigate the psychophysiological correlates of cognitive and affective processes during pre-defined moments in the communication, which we will define in more detail below.

In the interactive decision making game of Ultimatum (Güth, Schmittberger, and Schwarze, 1982), participants are asked to share an amount of money. One player, the *proposer*, may offer fair and unfair divisions of money to share between him/herself and another player, the *responder*. The latter has the ultimate power to accept, resulting in a payout for both that is consistent with the offer, or reject, resulting in neither player receiving anything, the offer. Although it may seem irrational, proposers seldom offer very unfair offers, while responders typically reject unfair offers, thus preferring monetary loss to facing unfairness (Van 't Wout, Kahn, Sanfey, & Aleman, 2006). Consistent with the view that cold, economical utility does not fully account for behavior, neuropsychological findings show this game to recruit both cognitive and emotional centers of the brain (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003).

Event-Related Potentials

In order to better understand the role of touch on decision making, we used event-related potentials (ERP) in the Ultimatum game to evaluate the cognitive and affective effects of tactile stimulation. In general, we expected touch to influence later, higher-level processing rather than early, sensory-level, and, thus focused on the N2 and P3 components of the ERP. The N2 is a component with a latency of around 250 ms and a source that has been located in the anterior cingulate cortex (Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003). As the amplitude of the N2 has previously been associated with response inhibition and cognitive control (Folstein & Van Petten, 2008; Spapé, Band, & Hommel, 2011), we used it here to investigate the effects of tactile stimulation on subsequent attentional processes. The N2 has also been related to the occurrence of negative evaluations more broadly in its capacity of feedback-related negativity (FRN). The FRN refers to the often-repeated observation that the N2 is enhanced as a result of negative feedback (Gehring & Willoughby, 2002), particularly when monetary losses are involved. In the Ultimatum game, it has been demonstrated that even just observing an unfair offer elicits a similar effect (Boksem & De Cremer, 2010).

A secondary event related potential that was expected to be affected by touch concerned the P3. The P3 is a common component elicited by meaningful stimuli, after a latency from about 300 ms, and a distribution over either the frontal (the "novelty" P3a, e.g. (Friedman, Cycowicz, & Gaeta, 2001; Snyder & Hillyard, 1976) or the parietal regions (the classic P3b, Chapman & Bragdon, 1964). Traditionally, the P3 was studied in oddball paradigms (Squires, Squires, & Hillyard, 1975), in which infrequent and attended rather than frequent and ignored, stimuli evoked particularly strong P3s. These aspects of expectation and attention suggested that the P3 is related to higher-order cognitive functions and studies since have shown the P3 to be involved in the psychological functions of stimulus-encoding, or response-processing time (Verleger, 1997), attention allocation (Polich & Kok, 1995), the contextual updating of memory (Donchin & Coles, 1988). However, while the precise role of the P3 remains unclear, it is generally assumed to be related to late, cognitive processing, often involving functions of memory (Polich, 2007).

Studies investigating the psychophysiological response to feedback and perceived fairness have sometimes shown effects on the P3 as well as the FRN. Hajcak, Holroyd, Moser, & Simons, (2005), for instance, noted that although the FRN is equal for expected and unexpected negative outcomes, the P3 is amplified in cases of unexpected feedback. This has been taken to indicate that the FRN is related to a more automatic evaluation of the stimulus, while the P3 involves a further processing which would be required to affect a future change in behavior. Consistent with this dissociation in terms of immediate evaluation and delayed appraisal, Wu and colleagues used the Dictator (Wu, Leliveld, & Zhou, 2011) and Ultimatum (Wu, Zhou, van Dijk, Leliveld, & Zhou, 2011) game to demonstrate that social distance affects early, fairness appraisal – and therefore the FRN – whereas social comparison is only later – during the P3 – of significance.

Considering these distinct interpretations of the N2 and P3 in the literature, we measured both potentials, both at the responder stage as well as the proposer stage, to test three distinct hypotheses concerning the role of touch in decision making. If a touch caused compliance, we predicted increased conflict, resulting in greater N2 amplitudes after touch during the responder stage. Conversely, if a touch generally positively affected emotional appraisal, we predicted attenuated FRNs following touch-preceded negative feedback during the proposer stage. Finally, if touch generally had a more indirect effect, requiring memory and perhaps increasing the meaningfulness of the stimuli, the P3 in both the proposer and responder stages should be increased.

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In addition to the investigation of these hypotheses, we explored the effect of offer size on somatosensory-evoked potentials (SEPs) and auditory evoked potentials (AEPs) elicited by the first tactile and audio messages. Previous studies showed that viewing positive, emotional images enhanced the P50 of deviant tactile stimuli (Montoya & Sitges, 2006). We expected that high offers presented immediately prior to the stimulus might serve as a similar motivational context. In the present study, tactile stimuli were not differentiated in terms of their commonality and occurred at a fixed rate of 1/3 in terms of probability, yet given the discussed role of touch in communication, they might have been construed as more task-relevant than auditory stimuli nonetheless. Thus, we explored the degree to which offers modulated the SEPs as well as AEPs. Because only the first tactile or audio message could be construed as informative, and because evoked potentials of subsequent messages would likely show confounds with preceding ones, we used only the first in the series of three stimuli to compute the average of the evoked potentials.

Method

Participants and Deception

Twenty-six female and 22 male pairs of participants, aged 24.16 ± 3.94 took part in the experiment. Sixteen pairs indicated affinity prior to the experiment and were assigned to the group of *friends*. The remaining 32 were randomly assigned to the groups of *strangers* or *computer*. Fourteen participants (six male, eight females; seven friends, four strangers, three computer) were excluded from the analysis for accepting >95% of the offers or showing signs of noticing deception. The pairs met in a common waiting area where they also signed an informed consent. They were then randomly assigned and brought to separate rooms, situated ca. 25 meters from one another. There, the participants read further instructions and played a few test-rounds of the experiment while the setting up of the equipment took place. They were also informed that the co-actor in the experiment would be their *friend*, the *stranger*, or the *computer*. Participants in the *friends* and *strangers* groups were fully debriefed immediately after the experiment and informed of the deception: no communication between them and their assigned pair took place. Pairs in the *computer* group were already informed, although the nature of the algorithms was not disclosed. During debriefing, we asked participants about their experiences during the experiments, without already mentioning the presence of the deception. In response, some participants volunteered that they felt apprehensive ("the other seemed to respond randomly") or noticed the deception ("my friend would never behave like this"). These participants were excluded from analysis. After these informal questions, all participants were debriefed and the deception was fully disclosed.

Stimuli and Apparatus

Auditory and vibrotactile stimuli were sine or square waves of 500 ms in duration with 10 ms stochastic fade-in and out and a pitch of 250 Hz. Control – silent – stimuli were created as audio files, but amplified to 0 dB. Audio stimuli were presented at a comfortable listening level via computer speakers at a distance of ca. 50 cm. Tactile stimuli were presented using two ATAC C2 Tactors (*www.atactech.com/PR_tactors.html*). Stimuli were presented three times (see Figure 1), at an inter-stimulus interval of 500 ms. The C2 Tactor is a small linear vibrotactile actuator and is resonant at 250 Hz. They were strapped using an elastic band, which was placed centrally on the palm of both hands. The task was presented on a flat-screen 17" TFT monitor in 1024 x 768 pixel resolution and a refresh-rate of 60 Hz. The timing of stimulus presentation, recording of reactions and synchronization with the EEG equipment were achieved using E-Prime 2.0.10.242 (Psychology Software Tools, Sharpsburg, PA) running under Windows XP SP2 on two Intel based desktop PCs. Synchronization of the two computers was achieved via serial communication.

EEG Recording and Pre-Processing

Two QuickAmp (BrainProducts GmbH, Gilching, Germany) amplifiers recorded EEG at 1000 Hz from 30 Ag/AgCl scalp electrodes, positioned using EasyCap elastic hats (EasyCap GmbH, Herrschin, Germany) on 30 equidistant electrode sites of the 10% system excluding FT9/FT10 with AFz serving as ground and initial reference. Prior to all analyses, EEG was rereferenced to the common average reference. Electro-oculographic (EOG) activity was recorded near the left eye using two unipolar electrodes placed respectively 1 cm inferior to the pupil and 1 cm lateral to the outer canthi. Offline preprocessing of the EEG and EOG included bandpass filtering at 0.1<Hz<80 and the application of a notch filter at 50 Hz. The artifact correction was based on an independent component analysis (ICA) using the runica algorithm in EEGLAB (Delorme & Makeig, 2004), after which artifactual components were rejected using visual inspection. EEG was then reconstructed from the remaining components. Further analysis was carried out in Brain Vision Analyzer (BrainProducts GmbH, Gilching, Germany), and included a low-pass filter at 40 Hz and segmentation into 1 s epochs, time-locked to 200 ms preceding the onset of critical stimuli. An automatic, threshold-based artifact rejection procedure was then applied, removing all epochs with amplitudes beyond 40 μV or peak differences greater than 60 μV. Averages over proposer and responder ERPs were calculated only if at least 16 epochs remained after artifact rejection; otherwise the participant was excluded from analysis. The resulting ERPs and critical differences were on average based on 54.2 ± 8.1 epochs per modality condition in the responder analysis and 26.3 ± 3.3 epochs per modality-by-acceptance combination in the proposer analysis. Given the more exploratory nature of the additional analysis concerning auditory- and somatosensory evoked potentials, we opted here for a more liberal inclusion criterion of 12 epochs, corresponding with an average of 16.8 ± 2.9 epochs per modality-by-offer-size combination.

Procedure

Participants within pairs were randomly assigned the initial role of proposer or responder in a sequential decision-making game of Ultimatum. As schematically illustrated in Figure 1, in each trial, the proposer divided €0.30 between him/herself and the other player. By pressing the left or right key, respectively, the proposer could reduce or increase the offer by €0.02. He or she then indicated their choice of a “poke” to be sent along with their offer by pressing a numbered key. The poke was a reference to modern social networking vernacular and constituted an audio (keys 1/2), vibrotactile (3/4) or silent (5) tone. By pressing a number, a sample presentation would be played to the proposer to make their choice clear. Pressing the Enter key finalized the offer. They were asked to avoid eye movements and to keep their eyes fixed on the centrally presented fixation cross-hair. After 3.5 s, the “responder’s” pokes were presented to the proposer. Following, after 6.5 s, the acceptance or rejection of the responder was indicated by showing a happy or sad smiley faces for 1 s. Acceptance of the offer was randomized at a probability of .5 acceptance. However, to avoid participants noticing the deception, very extreme generous offers (25:5, 27:3, 29:1) had increased likelihood of being accepted (respectively p = .75, .83, .93) while very extreme negative offers (5:25, 3:27, 1:29) had a decreased likelihood of being accepted (.25, .17, .07).

While the proposer was deciding upon an offer, the responder was asked to memorize which buttons corresponded to accepting/rejecting offers (randomized between trials to be the Q or P key). Then, a fixation was shown for 0.5 s before being replaced by the offer. After 3.5 s, the “proposer’s” pokes were presented. Participants were asked to withhold their response until the pokes stopped playing and to press the prepared button only after a prompt (after 6.5 s). Following, after 1 s, they were asked to also make a choice of poke. The computers were then resynchronized, and the next trial would start for both participants, with the roles of responder and proposer switched. The entire experiment, excluding preparation and instruction, lasted ca. 90-100 minutes in total, with a self-timed break after every 120 trials.

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Analysis

Based on the visual inspection of the grand averages for proposer and responder trials and the literature on the FRN, N2, and P3, we defined four peaks for the responder and three for the proposer analysis, and we carried out automatic peak detection to calculate latency and magnitude of individual peaks. For the proposer, P1 and P3 were the highest positive voltages in the latencies 100–250 ms as well as 250–600 ms following the onset of the feedback display, and N2 was the lowest negative voltage in the latency 170–350 ms. For the responder, the analysis was aligned to the onset of the decision cue. Here, P1 and P3 were defined as positive peaks in the ranges of 150–250 ms and 500–900 ms, respectively. Two, possibly distinct, negative peaks in the N2 range (250–550 ms) were observed and defined in the analysis as early ($N2^E$) and late ($N2^L$) components with latencies of, respectively, 250–350 and 400–550. Greenhouse-Geisser adjustments were applied where Mauchly’s test showed the assumption of sphericity being violated. Behavioral measures of probability of acceptance for the responder and amount offered for the proposer were analyzed in relation to the preceding modality of poke. Note that the analysis focuses on the participants in either their proposer or responder role. The “responder behavior” section, for example, thus concerned the trials in which the participant received offers, even though these were presented as if coming from the proposer.

Design

The experiment consisted of 360 trials—180 proposer and 180 responder trials. Participants received no prior information regarding the number of trials. For both proposer and responder trials, separate ANOVAs were conducted for each peak. Because audio and tactile signals cued the onset of the feedback display for proposers and the decision screen for responders, we carried out additional analyses with the silent condition excluded: only if a specific effect was significant for both the analysis *with* and that *without* the control condition were the modality effects considered significant. For the proposer, mixed design ANOVA analyses were conducted regarding decision (accept vs. reject, occurring randomly at 50%) and modality of poke (silence vs. touch vs. audio, occurring randomly at 33%) as within subject factors and the group (stranger, friend and PC) as a between subjects factor. For the responder, the design was similar but involved offer size (low – 5:25, 7:23 or 9:21 ct – medium, 11:19 or 13:17 ct – or high – 15:15, 17:13, 19:21 or 21:9 ct), instead of decision. The distribution of N2 and P3 components tended to suggest fronto-central localizations for N2 and either frontal or parietal distributions for the P3. Thus, a 7 level factor was included in all ERP analyses to account for the electrode site: F3, Fz, F4, FC1, FC2, Cz and Pz.

The deception in the randomization of conditions, types of offers, and acceptance of offers, was required because pilot testing showed that subjects often chose the same modality of poke as well as the same type of (reasonably fair, ca. 13:17) proposal, and they usually accepted proposals. This would limit the analysis to only the most likely combinations of conditions because a sufficient number of epochs for each design cell is needed to make ERP analysis meaningful.

Results

Responder behavior

Repeated Measures ANOVAs on acceptance rates, measured as the proportion of accepted offers, revealed a significant effect of offer size, $F(2, 150) = 206.42$, $p < .001$, $\eta^2 = .73$, with high offers (97% ± 1%) > medium offers (81% ± 2%) > low offers (43% ± 3%). No significant effect of group was found, $p > .1$, but the group did interact with offer size, $F(4, 150) = 3.58$, $p < .02$, $\eta^2 = .09$, with acceptance rates to low offers from *strangers* being lower. A small, significant effect of modality was observed, $F(2, 150) = 3.11$, $p < .05$, $\eta^2 = .04$, indicating a Midas Touch- like effect (see Figure 2A). Post-hoc comparisons revealed, however, that touch elicited higher acceptance rates than control, $t(77) = 2.60$, $p < .02$, but not than audio.

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Responder ERPs

Repeated measures ANOVAs for the effects of electrode, modality of poke, group, and offer size on the earlier N2[e] showed significant main effects of the electrode, offer size, and modality, *F*s > 6, $p < .003$, and a significant interaction between offer size and the modality, $F(4, 69) = 2.79$, $p < .04$, $\eta^2 = .14$. However, after removing the control condition from the analysis, the modality showed neither a main-effect nor an interaction effect, *p*s > .06. The N2l was similarly affected with a significant main effect of electrode, $F(6, 67) = 34.74$, $p < .001$, $\eta^2 = .76$, but not modality, $F(2, 71) = 0.71$, $p > .4$. Modality interacted significantly with electrode, $F(12, 61) = 3.99$, $p < .001$, $\eta^2 = .44$, and entered a three-way interaction with group-by-electrode, $F(24, 122) = 1.76$, $p < .03$, $\eta^2 = .25$, but neither effect remained significant after the removal of the control condition, *p*s > .2.

Similar analyses on the P3 revealed significant main effects of electrode, offer size and modality, *F*s > 6, *p*s < .003, and an interaction between modality and electrode, $F(12, 61) = 6.62$, $p < .001$, $\eta^2 = .56$. After removal of the control condition, the interaction with the electrode was rendered insignificant, $p > .05$, but, unlike in the N2 analyses, the effect of the modality of the poke remained significant, $F(1, 72) = 7.83$, $p < .007$, $\eta^2 = .10$. As shown in Figure 3, the P3 amplitude was found to be particularly enhanced after tactile stimulation.

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Proposer Behavior

Given the effects of touch on the P3, and the association between the P3 and memory, we hypothesized that the tactile stimulation of the preceding trial (i.e. when the current proposer was a responder) might carry over onto the next trial, affecting the proposed offer size. To test this, we carried out an analysis on the proposed offer with N-1 modality, N-1 offer size and group as factors. Group affected offer size, $F(2, 75) = 6.06$, $p < .004$, $\eta^2 = .14$, as did N-1 offer size, $F(2, 150) = 79.87$, $p < .001$, $\eta^2 = .52$, with offers to *friends* and offers after high offers being the highest. N-1 modality had no main effect, $p > .6$, but it did enter in a significant 3-way interaction, $F(5.92, 222.03) = 2.32$, $p < .04$, $\eta^2 = .06$. To better understand this effect, separate ANOVAs were conducted for each group, revealing for the *computer* group no effects of N-1 modality, *p*s > .5, for the *friends* group an interaction with offer size, $p < .03$, $\eta^2 = .38$, and for the *strangers* group both a main effect, $p < .007$, $\eta^2 = .32$, and an interaction with offer size, $p < .02$, $\eta^2 = .39$. As can be observed in Figure 2B, generosity was found to be strongly, positively related to preceding offers. However, only with strangers did touch generally have a positive effect on generosity, whereas with the group of friends, touch only affected proposals positively after high offers but adversely after low offers.

Proposer ERPs

Repeated measures ANOVAs for the effects of electrode, modality, group, and acceptance on the N2 revealed a significant effect of electrode, $F(6, 67) = 26.28$, $p < .001$, $\eta^2 = .70$, but no other main effect, *p*s > .1. The interaction between electrode and acceptance was found significant, $F(6, 67) = 7.32$, $p < .001$,

$\eta^2 = .40$, with rejection resulting in an FRN-like pattern with negativity over frontal electrodes (F3, Fz, F4, FC1, FC2) but positivity over centro-parietal sites. Modality also interacted with electrode, $F(12, 61) = 4.11$, $p < .001$, $\eta^2 = .45$, but not anymore after removal of the control condition, $p > .3$. Similar analyses on the P3 showed significant main effects of electrode, acceptance, and modality, *p*s < .001, but not of group, $p > .3$ [FOOTNOTE 1]. Furthermore, modality interacted with electrode, $F(12, 61) = 7.36$, $p < .001$, $\eta^2 = .59$, and acceptance, $F(2, 71) = 4.35$, $p < .02$, $\eta^2 = .11$. After removal of the control condition from the analysis, the interaction between modality and acceptance remained significant, $F(1, 72) = 7.52$, $p < .008$, $\eta^2 = .10$. As can be seen from Figure 4, the difference between accepted and rejected offers in terms of P3 was largest after tactile stimulation.

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Audio- and Tactile-Evoked Potentials

In addition, we explored the effects of offer size on auditory- and tactile evoked potentials, aligned to the onset of the first tone (windows averaged between 70–160, 180–280, 280–400, and 400–800 ms) or vibration (regions 40–100, 100–200, 200–400, and 400–800 ms) in responder trials. Separate ANOVAs for each window with offer size and electrode (Fz, FC1, FC2, Cz, CP1, CP2, and Pz) as factors revealed no significant effect involving offer size or group for audio ERPs, *p*s > .05. Tactile ERPs, conversely, showed in the regions 200–400 and 400–800 ms, significant main effects of offer size, *F*s > 5, *p*s < .006. Additionally, effects of group on tactile ERPs were observed in the regions 100-200, 200-400 and 400-800, *p*s < .04. Overall, as can be observed from Figure 5, the results show a late (from ca. 300 ms) positivity in the tactile-, but not audio-, evoked potentials with medium and high offers.

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Discussion

The Midas touch refers to the effect that people, after being touched, are more likely to engage in altruistic, generous, or compliant behavior (Crusco & Wetzel, 1984). Previous studies have indicated that a Midas Touch could even occur in a virtual setting, such that after a computer-mediated, remote touch, people are more likely to offer a helping hand (Haans & Usselsteijn, 2009). Unlike in most studies, we employed virtual, mediated touch and investigated the effects of haptic communication in a controlled setting, featuring the Ultimatum game to provide empirical indicators of compliance—the proportion of accepted offers—and generosity—the amount offered for sharing. The mediated setting of the experiment allowed us to forego the use of confederates and control for the normally confounded effects of touch and the distance between communicating parties. Furthermore, commensurable control conditions with auditory messages allowed us to form conclusions regarding the haptic dimension of the Midas touch itself. Finally, investigation of the ERPs elicited by decision cues and feedback displays as well as the somatosensory-evoked potential provided insights on the cognitive significance of touch in communication.

In the introduction, we identified three key hypotheses concerning the role of touch in communication. A touch would be considered “gentle” if it would positively influence emotions, increasing generosity and compliance alike, while also reducing the impact of negative outcomes (indicated by the FRN). Likewise, a “forceful” touch should increase compliance but not necessarily generosity, and this type of touch could incur an amount of decision conflict (indicated by the N2). Finally, the “meaningful” touch depends critically on the operation of memory (indicated by the P3), enabling the context in which the touch takes place to critically affect later generosity rather than immediate compliance.

The results of the experiments revealed that touch affected compliance in the Ultimatum game. However, the effect size was small, and no clear difference was observed between haptic and audio messages, suggesting that there is a benefit of receiving a message over receiving none. In terms of EEG, a touch prior to receiving negative feedback did not affect the FRN any more than audio, either, so in terms of the predictions in the introduction, there is no evidence for a “gentle touch.” Likewise, receiving a touch before responding to offers did not amplify or affect the N2. The hypothesis of a “forceful touch” would predict additional attentional costs or cognitive conflict to occur with low offers and touch. Since such costs in the literature have been associated with effects on the N2, which was, in the present study, not observed, this argued against the hypothesis of the “forceful touch.”

Interestingly, both for proposers who received negative feedback and for responders who dealt with offers, receiving a touch just before these episodes amplified the P3 component of the ERP. Given the history of the P3 as a component critically involved in processes of memory (Polich, 2007), this could be taken as evidence for a more indirect effect of touch on cognition, as part of the hypothesis of the “meaningful touch.”

This hypothesis was explored and verified in two additional ways. First, if a touch triggers processes involving memory, then a touch after a less important event should be encoded to a lesser extent than a touch after a more important event. By investigating the audio- and tactile-evoked potentials, we found—uniquely for tactile-evoked potentials—enhanced P3s after increased offers. This suggests that unlike with audio, simple tactile messages are perceived differently, depending on the context. Second, if indirect, *later* effects of touch are suspected, one should predict effects on future generosity, rather than on immediate compliance. It was confirmed that after receiving a touch, participants were, indeed, found to be more willing to offer more money to the other.

Previous studies can provide a framework for understanding the more complex, indirect, memory-dependent effect of touch on cognition. It has been found, for example, that repeating a vibrotactile stimulus enhances performance if a paired visual stimulus is simultaneously repeated, suggesting that the touch can act as an episodic retrieval cue (Zmigrod, Spapé, & Hommel, 2009). In the present study, tactile signals preceded by high offer sizes elicited different somatosensory-evoked potentials than those preceded by low offer sizes: in a way, the touch is "felt" differently, depending on the signifier. This can be related to the somatic marker hypothesis, which holds that body signals—particularly from the more peripheral system—act as markers that are ultimately perceived as perceptible feelings (Damasio, Everitt, & Bishop, 1996; see also Bechara & Damasio, 2005 for an economic application of the model).

Another possibility is that the relative scarcity of information encoded in a single vibrotactile signal necessitates the reliance on memory. A single visual display can convey countless different impressions, and we can discern countless different audio tones—let alone chords—but we can distinguish a mere five to eight different vibrotactile pulses if frequency and intensity are combined (Sherrick, 1985). Meanwhile, the relative scarcity of haptic interfaces suggests that it is a rare occurrence, indeed, that people are required to interpret tactile signals absent associated action or complementary sensory information. Therefore, paradoxically, the inherent meaninglessness of touch necessitates our cognition to fill in the blanks: who was the source, and what does he/she mean by the touch?

What follows is a discussion of the importance of the "meaningful touch" for the interdisciplinary field of psychophysiology. While previous studies focused largely on the psychophysiology of touch in isolation, the present communication paradigm underlines the importance of touch as a mediator of subsequent psychophysiology, and conversely, of social context as a mediator of tactile perception. Next, we will describe how the study may inform the field of behavioral economics. Finally, as the study was originally inspired by the potential applicability of touch in mobile communication, we conclude with a brief discussion of the importance of the present study for the field of human computer interaction.

Psychophysiology

The study of tactile ERPs goes back to somatosensory-evoked potentials. Applying electrical shocks was found (Giblin, 1964) to result in measurable, early potentials related to the activation of the primary somatosensory cortex, which provides an important diagnostic tool in neurological and surgical settings. In terms of cognition, it has been found that consciously perceived sensations can be dissociated from those we remain unaware of after ca. 100 ms (Schubert, Blankenburg, Lemm, Villringer, & Curio, 2006). Further processing of tactile stimuli has shown strong similarities across modalities, with the P3, in particular, receiving much attention. The P3 is typically studied in oddball paradigms, and it has been found that unpredictable and rare locations of tactile stimulation yield stronger P3 components (Nakajima & Imamura, 2000), which has been used in the design of tactile brain-computer interfaces (Brouwer & Van Erp, 2010).

The present study was designed largely on the hypothesis that a tactile message would influence subsequent FRN through modulation of the reward expectation. It has previously been observed that a negative deflection in fronto-central sites is elicited by displays that inform participants of their inaccurate performance (Miltner, Braun, & Coles, 1997), indicating—like error-related negativity—the working of a reinforcement based learning system (Holroyd & Coles, 2002). In terms of learning, however, the FRN has been found to only depend on the evaluation of the outcome, based on the probability, rather than the magnitude (Cohen, Elger, & Ranganath, 2007; Hajcak, Moser, Holroyd, & Simons, 2006). Thus, if a touch would directly modulate the reward expectation, it should reduce the FRN.

As our findings demonstrate that the FRN itself is not affected by touch, it should be concluded that mediated touch does not affect immediate evaluation (or expectation Kobza, Thoma, Daum, & Bellebaum, 2011), even though it may modulate subsequent action. It has previously been found that both the FRN and P3 are enhanced if the participants will adjust their own behavior (Zhou, Yu, & Zhou, 2010). Of the two components, the FRN has been found to not necessarily predict explicit, rule-based adjustment of actual behavior (Chase, Swainson, Durham, Benham, & Cools, 2011), and that the P3 may be a better candidate potential to indicate explicit, memory-based, decision making based on, for example, social comparison, fairness norms (Wu, Zhou, et al., 2011) as well as empathy (Wang et al., 2014). Thus, the findings of the present study that relate tactile stimulation, the subsequent P3 toward later generosity, rather than directly between touch and evaluation or touch and immediate decision making, converge with the literature suggesting the utility of the P3 as a marker of late, contextual processing (Wang et al., 2014; Wu, Leliveld, et al., 2011).

Economics and Human Computer Interaction

Even though the assumption of economic rationality has already been challenged by many previous studies (for the prospect theory, see Kahneman & Tversky, 1979), the present results are intriguing also from the perspective of economics. That is, the findings show that, as a result of such factors as (mediated) touch, choice behavior may further diverge from rational Bayesian maximization of expected utility (Naqvi, Shiv, & Bechara, 2006). Thus, not only do social and affective factors play a role in determining the outcome in economic behavior, but additionally does the medium in which the communication takes place.

Although current communication media still mostly rely on the senses of vision and hearing, the results are also relevant to human computer interaction research. Haptic feedback in human computer interaction has traditionally been applied, for example, to improve perception in user interfaces or as a form of guidance in navigation tasks (Hoggan, Brewster, & Johnston, 2008; Tsukada & Yasumura, 2004). Recent studies have investigated whether haptic feedback can support remote interpersonal communication, showing that such feedback is often assigned a variety of different meanings (Hoggan et al., 2012). In this article, the finding that mediated haptic communication may result in a more altruistic style of interaction has implications for technological design choices aimed at improving (mediated) interpersonal communication. Furthermore, the ERP-based approach of the study contributes a novel method of evaluation for human computer interaction research, which, in this area, usually relies on retrospective, subjective reports. The study demonstrates the efficacy of the approach, establishing in an objective way not only that a (e.g., tactile) signal is sensed by the user, but also to which degree its further processing influences the user's affect and modulates future decision making. We demonstrate the efficacy of the approach, and we hope that it will inspire future research.

From a communication point of view, one might wonder if the mediated "poke" in the present study is all that similar to a real human touch. Given that a deformation in the skin is generally perceived in similar ways, it is understandable that much of the human-computer interaction literature made this assumption implicitly or explicitly (Haans & IJsselsteijn, 2006; Haans & Usselsteijn, 2009; Hoggan et al., 2012; Park, Baek, & Nam, 2013). The present study demonstrates the validity of the assumption: a Midas Touch and a virtual Midas Touch show clear similarities in their behavioral outcomes. The type of touch itself has not been proven as important as other factors such as the remote party situation or the meaning given to the touch (cf. Haans & Usselsteijn, 2009; Hoggan et al., 2012). Again, we find clear parallels in the present study, which shows the context of the touch (e.g. the offer preceding the touch, or the perceived sender of the touch) to determine behavior and psychophysiology. Thus, rather than investigating the exact physical composition of a human touch and its synthetic simulations, the present study underlines the importance of providing context to haptic communications.

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Footnotes

Footnote 1. In fact, unlike others (Wang et al., 2014; Wu, Leliveld, et al., 2011), the study showed few significant effects of the relationship between participants on ERP potentials.

Figure Legends

Figure 1. Trial procedure with actual (straight line) and presented (dashed lines) timelines for proposers and responders. Participants were told that the responder received offers and pokes (small amplifier icons) based on the proposal (diagonal dashed line). Proposers would receive feedback in terms of pokes (rightmost dashed line) and acceptance (vertical dashed line) based on the responder's actions. However, proposals, pokes and responses were randomized in identity, while time-locked (as indicated by the straight line): the events were synchronized up until the feedback (for the proposer, 1000 ms) and the acceptance display (for the responder, 1000 ms and until response).

Figure 2: Behavioral results. Averages and standard errors (error bars) of responder's compliance (A) in terms of the percentage of accepted offers and proposer's generosity (B) in terms of the average offer made toward the responder. The latter is shown as a function of the group and the preceding offer.

Figure 3: Responder ERPs, averaged over F3, Fz, F4, FC1 and FC2, time-locked to decision cue. A: ERPs for decision cues following auditory, tactile and silent (control) stimulation. Negative voltages are plotted downward. B: Scalp topography of the average early (N2, 250-500) and late (P3, 500-900) difference ERP between the audio and silent condition (A-S), the touch and silent condition (T-S) and the difference between the two (T-A).

Figure 4: Proposer ERPs, averaged over F3, Fz, F4, FC1 and FC2, time-locked to feedback stimulus. A: ERPs for positive (accepted offers, straight lines) and negative (rejected offers, dashed lines) feedback following auditory (A) or tactile (T) stimulation. Negative voltages are plotted downward. B: Scalp topographies show the early (N2, 220-310) and late (P3, 340-440) average difference between

negative (rejected, r) and positive (accepted, a) feedback displays following silent (S, control), auditory (A) and tactile (T) stimulation.

Figure 5: Responder auditory- and somatosensory-evoked potentials. A: ERPs were averaged over Fz, FC1, FC2, Cz, CP1, CP2, and Pz, time-locked to the presentation of the stimulus. Negative voltage is plotted downward. B: Scalp topographies display the early (180-400) and late (400-800 ms) average difference between high and low (h-l) offers in the evoked potential.

Supplementary Figure 1: Responder ERPs. ERPs were time-locked to decision cues following auditory, tactile, or no (silent) signals. Negative voltages are plotted downward.

Supplementary Figure 2: Proposer ERPs. ERPs were time-locked to feedback displays indicating the participant's proposal was either accepted or rejected and followed auditory, tactile, or no (silent, not shown) signals. Negative voltages are plotted downward.

Supplementary Figure 3: Responder auditory and somatosensory-evoked potentials for low, medium and high offers. Evoked potentials were time-locked to audio, and tactile signals to investigate the effect of offers on evoked potentials. Negative voltages are plotted downward. Please note that the vertical scaling is different between auditory and somatosensory evoked potentials.

Tables

Table 1. *Summary of hypotheses*

Name	Function	Prediction
The forceful touch	Touch causes compliance	Increased N2 during decisions
The gentle touch	Touch causes positive affect	Reduced FRN/N2 with negative feedback
The meaningful touch	Touch requires memory	Increased P3 with decisions and feedback

Note. FRN = Feeedback Related Negativity