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ARTICLE

Alpha suppression over parietal electrode sites predicts decisions to trust

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ABSTRACT

Decisions to trust help form the basis of relationships and society yet little is known about their neurophysiology. We told participants they were playing a coin toss game with a trustworthy and an untrustworthy person and measured their neural activity with EEG as they decided whether to trust those fictitious interaction partners. Target people ostensibly correctly reported the outcome of a coin toss on 66% of trials. Behaviorally, participants probability matched and chose to trust the reported coin flips from each profile equally by the end of 100 trials. Electrophysiologically, there were reliable differences in the pattern of oscillatory activity in the alpha band (8-13Hz) over parietal electrode sites 1–3 s prior to their trust decisions. Specifically, for trustworthy profiles, there was greater alpha suppression for trust decisions vs. distrust decisions. Conversely, for untrustworthy profiles there was greater alpha suppression for distrust decisions vs. trust decisions. This differential activity (trust minus distrust) also predicted the number of trust decisions made. Our results indicate that the intentions to trust people form very early in the processing stream and manifest as alpha suppression over parietal cortex.

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Introduction

Overview

Trust is a willingness on the part of the trustor to be vulnerable to the trustee, because the trustor expects the trustee will perform a specific action (Mayer, Davis, & Schoorman, 1995). According to the model proposed by Mayer et al. (1995), the behavioral expression of trust is co-influence by trust in the relevant party as well as the perceived risk involved in the behavior. This trust, or willingness to put one’s outcomes in the hands of the trustee, develops early during the information processing stage and is co-influenced by the facial features of an individual (Oosterhof & Todorov, 2008) and through multiple interactions with the individual (Rudoy, 2009). Over time, a more nuanced perception emerges that is based on that individual’s ability, benevolence, and integrity toward the trustee (Mayer et al., 1995). The goal of the current paper is to identify the neural signatures that are associated with the initial impressions of the trustworthiness of the individual and maintenance of this information during repeated interactions in a trust task.

The temporal resolution of EEG offers a useful tool for investigating the neural processes associated with perceptions of trustworthiness. To date, several researchers have used the event-related potential (ERP) technique to investigate trust decisions (Boudreau, McCubbins, & Coulson, 2009; Leng & Zhou, 2014; Long, Jiang, & Zhou, 2012; Peterburs, Suchan, & Bellebaum, 2013). The two ERP components that have been linked to trust decisions are the P3 and the feedback-related negativity (FRN). The P3 (see Polich, 2007 for a comprehensive review) is most often associated with categorization and decision making (Mecklinger & Ullsperger, 1993; respectively; see Nieuwenhuis, Aston-Jones, & Cohen, 2005). In the context of trust research the P3 component has been found to be larger when participants share common interests with the trustee (Boudreau et al., 2009). Additionally, Long et al. (2012) had participants judge whether four target individuals correctly reported the outcome of a coin toss over the course of 100 trials each. They showed that the P3, time-locked to the feedback on whether the participant’s decisions was correct or not, was larger if they decided to trust the target compared to when they chose to distrust the target, and that this difference (trust-distrust) was larger if the outcome was a gain rather than no-gain. Long et al. (2012) argued that these differences in P3 amplitude arose because the target had violated their expectations on a given trial based on the assumption that participants actively maintained information about the trustee and reward structure across the task.

The feedback-related negativity (FRN) is another ERP component that appears in trust related EEG research.
In a probabilistic reinforcement task with two options, the FRN was shown to be sensitive to reward expectancy and modulated neural responses to wins (Cohen, Elger, & Ranganath, 2007). When these decisions offer different levels of rewards (.05 cents or .10 cents), the larger potential reward results in a larger amplitude FRN (Bellebaum, Polezzi, & Daum, 2010). In a task where participants were asked to guess whether a subsequent card value would be higher or lower than the current card, amplitude of the FRN is more negative after receiving incorrect response feedback (Sato et al., 2016). Similar to the P3 results previously reviewed, the amplitude of the time-locked FRN in trust paradigms is more positive when the outcome results in a gain (Long et al., 2012). Together with the P3 component, these FRN results suggest dynamic maintenance of information regarding the trustee and the dynamics of reward processing during the coin flipping trust task developed by Long and colleagues.

There are at least two limitations of using the FRN and P3 to examine how initial impressions of trustworthiness influence trust decisions. First, the FRN and P3 results have primarily been linked to feedback regarding the outcome of trust decisions rather than to the decision itself. Thus each of these feedback signals are likely more important in determining how our decisions to trust a target evolve over time, but do not necessarily reflect on our initial impression of the target’s trustworthiness. Furthermore, these components reflect the violation of an anticipatory state that is assumed to be determined by features of the trustee (i.e., is this a trustworthy person) but this assumption has yet to be examined in any detail. A second more methodological limitation is that in order to obtain a reliable ERP, even for large components such as the P3, one must average over a large number of trials (e.g., Long et al., 2012 averaged across roughly 200 trials in each condition). The general rule of thumb is to use a minimum of 30 observations per experimental condition (Luck, 2014). Because the present study examines how initial impressions of trustworthiness impact trust decisions, it is unclear whether averaging across dozens of ERPs will be sufficient to overcome the ERP’s low signal-to-noise ratio.

Measures of oscillatory dynamics provide a powerful alternative to ERPs that tend to be more stable when averaging across few observations. For example, differences in oscillatory patterns can be obtained within a single subject by comparing as little as 20 seconds from one condition to 20 seconds from another condition (e.g., Varnum, Blais, & Brewer, 2016). Oscillatory measures also allow us to accurately assess durations of information processing in time-frequency space thought to reflect anticipatory states where participants (i.e., the trustee) are likely maintaining information about the trustee.

We identified two potential oscillatory signals that may help mediate trust decisions. First, activity in the alpha band (8–13 Hz) over parietal cortex has been implicated in attention (Klimesch, 2012). Specifically, a decrease in the strength of alpha power (i.e., desynchronization) is associated with cognitive selectivity and improved performance on discrimination tasks via focused attention to information stored in memory. Klimesch (2012) also notes that decreased alpha power occurs during retrieval from long term memory and decreases in alpha power are linearly related to increases in information integration. Thus, when faced with a trust decision it is possible that retrieval of information about the trustee will be associated with decreased alpha power when the information retrieved is consistent with subsequent behavior. In this sense, decreased alpha power may reflect the relative match between initial evaluations of the reputation or trustworthiness of the trustee and the decision to either trust or distrust that trustee. That is, decreases in alpha power may occur when the intention to distrust or trust the trustee is formed and this decision is consistent with whether the trustee is exhibiting behaviors that should signal untrustworthiness or trustworthiness, respectively.

Second, activity in the so-called mu band (8–13 Hz) over central electrode sites that has been tied to mirror-neuron functioning (Pineda, 2009) also seems likely. Specifically, mu suppression is often found with respect to intragroup empathy processes (e.g., Gutsell & Inzlicht, 2010, 2013; Rieckensky et al., 2015; Varnum et al., 2016). The hypothesis from this line of research here is that subjects who interact with targets that are more “like them” (i.e., Christians) will show greater mu suppression than targets who are less like them (i.e., Muslims).

The current study

This study had two aims. The first was to replicate Long et al. (2012) and determine whether the consequences of trust decisions, as measured by the FRN and P3, differed as a function of target trustworthiness. The second was to identify whether and oscillatory signals, specifically partial alpha and central mu, predicted the decision to trust. To better associate these time-frequency components with anticipatory states that mediate trust decisions we manipulated trustee features and we hypothesized that changes in these features would create shifts in anticipatory states and trust behavior. Hall, Cohen, Meyer, Varley, and Brewer (2015) reported that religious costly signaling influences trust behavior for both in-group and out-group trustees (costly signaling; Sosis & Alcorta, 2003). Specifically, Christian subjects were more likely to trust
an individual who costly signals (donating time or money to their church or mosque), regardless of their religious affiliation (i.e., Muslim or Christian). In our prior research (Hall et al., 2015) we have measured and covaried prejudice against Muslims and shown that it does not change the pattern of results or the magnitude of the results. We therefore did not measure prejudice in this study. In the present study we provided information about fictional trustees in target profiles in order to manipulate group membership and costly signaling to examine the extent to which parietal alpha and/or central mu mediate decisions about trust. We recruited self-identified Christian subjects and had them interact with persons who they thought were Christian (in-group) or Muslim (out-group), and who costly signaled (wearing religious garb and volunteering for causes associated with their religion) or did not costly signal (no religious garb and did not volunteer). To preview the results, we found that decreased alpha power was associated with trust decisions when the trustor viewed a profile of a trustee that costly signals and distrust decisions when the trustor viewed a profile of a trustee that does not costly signal.

Method

Participants

Christian participants were recruited in the present study to assess how costly signaling impacts in-group vs. out-group differences in trust decisions. A total of 91 participants were recruited from the introductory psychology research participation pool at Arizona State University in accordance with their IRB recommendations. Of these, N = 52 (26 females) self-identified as Christian at both the time of recruitment and at the time of the experiment. Data from the remaining 39 participants (that self-identified as Agnostic or Atheist at the time of the experiment) were not examined further.

Procedure

The present study was a 2 (Costly Signaling: Signal versus No Signal) x 2 (Trustee Religion: Christian versus Muslim) mixed-factorial design, but the specific implementation prevented us from examining the interaction as a fully within-subject contrast (see below). The four target profiles associated with each condition (see Figure 1 for a sample) were created and each participant interacted with two in a Coin Toss Game.

To determine the neural correlates of a trust decision, we first had 26 Christian participants play against the two targets that were designed to be relatively more and relatively less trustworthy, a Christian who costly signaled (“Christian Signal target”; CC) compared to a Muslim who did not costly signal (“Muslim No Signal target”; MN). Under this scenario, theories regarding in-group/out-group status and costly signaling both predict that the Christian Signal target would be more trustworthy than the Muslim No Signal target. We then conducted literature-guided exploratory analyses on these data to determine potential regions and signals of interest.

Next, a new group of 26 Christian subjects played against two targets that correspond with the other 2 cells of a 2 × 2 design: a Muslim Signal target (MC) and a Christian No Signal (CN) target. We focused on the regions and signals identified on the first 26 participants to determine whether in-group/out-group status or costly signaling was driving performance.

Coin toss game

The trust task used in this experiment was modeled after one used by Long et al. (2012). In our version of the task participants were told that they would be playing a Coin Toss game with other participants somewhere else in the building.

At the beginning of the experiment a picture was taken of the participant for use in the profile that they subsequently generated. Participants then provided information about their name, major, favorite food, favorite color, and their religious and spiritual beliefs. From this we generated a profile which the participant saw, and informed them that this was the information the other person would see. The participant then viewed the profile from the other (fictional) individual and told they should use that information to help them make decisions.
accurate trust decisions if they were assigned the role of trustor (in reality the participant was always playing against a computer).

All participants were instructed about the two potential roles they might have, that of the reporter (trustee) or the receiver (trustor). The reporter’s job was to flip a coin and report the outcome to the receiver. The outcome could have been true (e.g., result of coin flip was heads and the reporter reported heads to the receiver) or false (e.g., result of coin flip was heads and the reporter reported tails to the receiver). The receiver was tasked with judging whether the reporter was telling the truth (Trust) or attempting to deceive them (Distrust). In our task the participant always played against the computer (thinking they were playing against another real person, the reporter) which was honest 66% of the time. As previously stated, participants always played the role of the receiver and were tasked with trying to correctly decide whether they should trust or distrust the coin flip report. To incentivize the participants, they were told that if they could correctly guess the outcome (correctly guess if they should trust or correctly guess if they should distrust) of 80% of reported flips they would be awarded $5 per profile. However, at the end of the study, all participants were compensated $10 regardless of task performance.

After being shown the opponent’s profile they began the Coin Toss game (see Figure 1 for progression of a single trial). A small pilot study determined that 50 trials per profile provided an optimal balance between having enough observations to measure the oscillatory EEG neural response to trust and distrust decisions and still being influenced primarily by the subjects’ initial impression of the profile. Nonetheless, we opted to run 100 trials per profile (i.e., 200 total per person) hoping this would yield a reliable P3/FRN signal to replicate the findings from Long et al (who used 400 total trials) who showed that the P3 and FRN were sensitive to outcome valence following trust choices in the more rapport-based decisions of trust. Although the pattern of results for the P3 and the FRN were similar to Long et al. (2012) we do not discuss them further because the effects associated with costly signaling and religion were non-significant (ps > .20).

**EEG data collection**

**Electroencephalography (EEG)**

Activity was recorded from 30 scalp locations, referenced to the linked mastoids, using silver/silver-chloride (Ag/AgCl) electrodes attached to an elastic cap (Neuromedical Supplies Inc.) and a Neuroscan amplifier with the Neuroscan recording software. Horizontal eye movements and eye blinks were monitored with two pairs of bipolar electrodes positioned medially at the outer canthi, and above and below the left eye, respectively. All impedances were kept below 5 kΩ. EEG activity was recorded at 1000 Hz and filtered from DC to 100 Hz. Continuous analog-to-digital conversion of the EEG and stimulus trigger codes were performed on-line by the Neuroscan acquisition interface system.

**EEG offline preprocessing**

Data were down-sampled to 250 Hz and filtered with a .1–30 Hz band pass filter. Next, ICA was used to identify ocular artifacts in the continuous EEG data. These ICA topographies were then used to remove the ocular components from the raw data. Finally, the data were decomposed into their time-frequency representation via wavelet convolution (e.g., Cohen & Donner, 2013). Specifically, the power spectrum of the EEG signal was multiplied by the power spectrum of the set of complex Morlet wavelets \( e^{i2\pi ft} \)/\( \sigma^2 \), where \( t \) is time, \( f \) is frequency, which increased from 2 to 40 Hz in 40 logarithmically spaced steps, and \( \sigma \) defines the width of each frequency band, set according to \( n/(2n\pi) \), where \( n \) is the number of wavelet cycles, and increased from 4 to 10 in logarithmic steps), and the inverse fast Fourier transform was then taken. This was performed on the individual trial data, not the ERP. From the resulting complex signal, an estimate of frequency-band-specific power at each time point was defined as the squared magnitude of the result of the convolution \( \{\text{real}(z(t))^2 + \text{imaginary}(z(t))^2\} \). All power values in the time-frequency representation were normalized to the average pretrial baseline power at each frequency band. We used a decibel (dB) transform for normalization [dB power = 10 × log10 (power/baseline)]. The baseline power was computed as the average power from −200 to 0 ms pretrial.

**EEG analyses**

To determine the statistical reliability of the data, randomization tests were conducted. Specifically, a time-frequency difference score (or correlation) map was computed by randomly shuffling the order of subtraction (order of rows) and computing a new map. This was done 1000 times and a voxel was considered significant if it was below the 2.5th percentile or above the 97.5th percentile (i.e., alpha of .05, two-tailed). These results were then cluster-corrected by examining size of the “significant” clusters that were obtained by chance for each of the 1000 hypothesis maps at each electrode. Finally, we took the 99th percentile for the size of those clusters and highlight regions with a black line that exceed this size (i.e., cluster-corrected at \( p < .05 \)).
Results

Behavioral analysis

The cumulative proportion of trust decisions over the course of the 100 trials is shown in Figure 2. In order to evaluate whether the trustor’s initial impression of the trustee affected their first trust decision (prior to feedback), we computed a chi-square analysis on the number of trust decisions for each of the four conditions on Trial 1 (CC: 24, MN: 21, CN: 22, MC: 21, \( \chi^2 < 1, p > .50, n_p^2 = .013 \)). Given that the average costly signaling effect size reported by Hall et al. (2015) was relatively small at \( n_p^2 = .047 \), we were not surprised that this analysis failed to yield a significant effect. Various other analyses (e.g., first 5 trials, grouping religion, grouping signaling) also failed to yield significant effects.

EEG analyses

To identify the neural signals that precede a trust decision, we examined the difference in activity between to-be-trusted and to-be-distrusted decision that occurred starting at the “Sam is deciding” screen. We found a reliable burst of EEG power in the ~8–13 Hz range (i.e., alpha) approximately 1200–2000 ms after seeing the “Sam is deciding” screen over centroparietal electrodes. Interestingly, this manifested as an increase in power for the Christian costly-signaling profile (more trustworthy profile) and a decrease in power for the Muslim not costly-signaling profile (less trustworthy profile; see Figure 3). This signal was also positively correlated with the number of trust decisions for Christian signaling profiles and negatively correlated with the number of trust decisions for Muslim non-signaling profiles (Figure 4). Note that although there appears to be differences in mu activity on electrode C4, there tends to be more mu-suppression for the untrustworthy target (outgroup for the first N = 26 subjects and ingroup for the next N = 26 subjects).

Next, we wanted to use this pattern of results to determine whether the Hall et al costly-signaling hypothesis was driving performance or the ingroup/outgroup hypothesis. We did this by running a new group of N = 26 with a Muslim costly signaling target and a Christian no signaling target, so that we would essentially have a 2 × 2 design (Christian vs Muslim; costly signaling vs not). With respect to overall power, the burst of EEG power in the ~8–13 Hz range (i.e., alpha) approximately 1200–2000 ms after seeing the “Sam is deciding” screen over centroparietal electrodes does not survive our cluster-corrected threshold (see Figure 5). However, the pattern of data is similar in the sense that the Muslim costly signaling target looks more like the Christian costly signaling target, and the Christian not signaling target looks more like the Muslim not signaling target. Importantly, when we examine the correlation between power and the number of trust decisions, a clear pattern emerges: both costly signaling targets are positively correlated and both non costly signaling targets are negatively correlated with the centroparietal alpha activity (see Figure 6).

To examine this relationship further, we computed correlations between centroparietal alpha power and all the profiles either as a function of costly signaling or as a function of religion (see Figure 7). The results show that the correlation is driven by costly signaling across all time windows.

Discussion

In the present study we found that alpha band activity over parietal electrodes is related to the number of trust decisions the participant makes and is influenced by features of the trustee. Specifically, when the trustee is

![Figure 2](image-url) Figure 2. The cumulative proportion of trust decisions over the 100 trials for each of the four conditions. Error bars are not shown, but they are fully overlapping. Note that the curves asymptote at .66 indicating that subjects are probability matching.
engaging in religious costly signaling, the difference in the size of this signal for distrust minus trust decisions was positively related to the number of trust decisions. Conversely, when the target did not engage in religious costly signaling, this difference was negatively related to the number of trust decisions. We argue that the attention process this alpha signal is associated with likely facilitates the formation of a mental set or

**Figure 3.** Time-frequency plots at each electrode which represent the difference in distrust minus trust decisions for the Christian costly signaling target and the Muslim not signalling target. Areas enclosed by a black line are cluster-corrected at p < .05 (see methods).

**Figure 4.** The correlation between the time-frequency plots in Figure 3 and the number of trust decisions across individuals. Areas enclosed by a black line are cluster-corrected at p < .05 (see methods).
intention to trust that serves as an anticipatory state predictive of trust behavior.

Behaviorally, and replicating the behavioral results obtained by Long et al. (2012), the probability that our participants chose to trust the target matched the target’s rate of correctly reporting the outcome of the coin toss. That is, our participants probability matched over time. This finding supports the notion that

**Figure 5.** Time-frequency plots at each electrode which represent the difference in distrust minus trust decisions for the Muslim costly signaling target and the Christian not signalling target. Areas enclosed by a black line are cluster-corrected at p < .05 (see methods).

**Figure 6.** The correlation between the time-frequency plots in Figure 5 and the number of trust decisions across individuals. Areas enclosed by a black line are cluster-corrected at p < .05 (see methods).
multiple interactions with a trustee over time will influence trust decisions more so than evaluations based on initial impressions (i.e., information about costly signaling or group membership). Behaviorally, we did not obtain a costly signaling effect on trial 1. On the surface this observation appears inconsistent with Hall et al. (2015), but, as previously noted the effect size in Hall et al. (2015) is small. Thus, it is unsurprising that the behavioral findings in this study failed to conceptually replicate Hall et al. (2015) given the difference in paradigms wherein Hall et al. (2015) examined self-reported trust and here we examined likelihood of trusting a coin flip. We also failed to replicate the ERP findings in Long et al. (2012). However, we used fewer trials than Long et al. (2012) and were not interested in trust after many interactions. Instead, the present study aimed to evaluate how initial impressions based on costly signaling and group membership influenced trust. To answer this question, we examined patterns of oscillatory activity in the alpha band.

There was greater alpha desynchronization when a trustor decided to trust the trustee that costly signaled and when the trustor decided to distrust a trustee that did not costly signal. Thus, similar to the finding that greater desynchronization occurs for more integrated retrieved information (Klimesch, 2012), we found that greater desynchronization occurred when the intention to trust corresponded to trustworthy behaviors. By contrast, there were no differences in alpha desynchronization as a function of group membership. The differential alpha activity (distrust – trust) predicted the number trust decisions as a function of costly signaling alone. This is consistent with the notion that behaviors are more relevant than religious affiliation when determining who to trust (Hall et al., 2015).

Other researchers who examined the neural correlates of trust, trustworthiness, and trust behaviors have emphasized the role of mentalizing (inferring the thoughts, emotions, or intentions of others) in decisions to trust (Borum, 2010; Krueger et al., 2007; Stanley et al., 2012). Knowledge about the actions or beliefs of others may increase the accuracy of trust decisions through the creation of a mental set on the part of the perceiver, which we believe is represented in our data. Variables that directly influence trust will likely be given priority in determining which information (actions or belief)

Figure 7. Correlation between alpha power at PZ (averaged across multiple time ranges) and the number of trust decisions as a function of costly signaling (the two leftmost columns) and religion (the two rightmost columns). |rs| > .28, p < .05.
should receive attention first and be incorporated into this mental set. Behavioral expression of costly signals (e.g., donating time or money to your religious group) are often difficult to fake (i.e., costly) and serve as an indication of an honest commitment to a group (Sosis & Alcorta, 2003). By engaging in costly signaling (Sosis & Alcorta, 2003), a trustee can demonstrate that their actions are consistent with being a trustworthy person. Stated differently, costly signaling makes targets seem more predictable so that attention does not need to be maintained to consider the outcome of their unmonitored behaviors. Conversely, when target people fail to costly signal, they are perceived as less predictable and more engagement is needed to monitor their behaviors in order to render appropriate trust decisions.

According to Mayer et al. (1995), this congruence between actions and words influences whether a trustor decides a trustee has integrity, which in turn influences the perceived trustworthiness of a trustee. Additional information about costly signaling behaviors would thus provide knowledge of the trustees actions that signal integrity— one of the dimensions of trustworthiness. As a result, this information may be given priority over information about group membership. This is consistent with the interpretation of the data in the present study and with the findings in Hall et al. (2015).

The suspicion framework (Bobko, Barelka, & Hirshfield, 2014) also provides a useful context for framing our findings. This theory posits that there are three fundamental antecedents that lead one to be suspicious: uncertainty, increased cognitive processing, and perceptions of (mal) intent. In the context of our paradigm, that the fictitious reporter probabilistically tells the truth will lead the subject to be uncertain of his behavior. Furthermore, by interacting with the target on multiple trials allows the subjects to determine intent. In this paradigm, both of these should lead to an increase in cognitive effort when the reporter is doing things that violate the subjects’ expectations. This increase in cognitive effort is consistent with the differences in alpha suppression as a function of costly signaling that we observed. That said, our study was not designed with this framework in mind so this interpretation should be considered post hoc.

**Conclusion**

In the current study we utilized time-frequency techniques for analyzing EEG data to explore anticipatory states that precede decisions about whether or not to trust an individual. We found that power in the alpha band was functionally related to the number of trust decisions and was influenced by whether or not the target engaged in religious costly signaling. In preparing to trust or distrust a person, participants differentially focused attention to information stored in memory about that target’s trustworthiness. This result supports the hypothesis that mental representations of trustworthiness mediate decisions to trust and can be flexibly relied upon when evaluating upcoming target-person behaviors.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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