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# Psychological investigation of the "feeling of being seen through" in a non-clinical sample using an ERP paradigm

*Raymond C.K. Chan*[a,b,*,1], *Jia Huang*[b,c], *Ya Wang*[b,c], *Qi-yong Gong*[d]

[a]*Neuropsychology and Applied Cognitive Neuroscience Laboratory, Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China*
[b]*Neuropsychology and Applied Cognitive Neuroscience Laboratory, Department of Psychology, Sun Yat-Sen University, Guangzhou, China*
[c]*Life Sciences Faculty, Sun Yat-Sen University, Guangzhou, China*
[d]*Huaxi MR Research Centre, Department of Radiology, West China Hospital/West China School of Medicine, Sichuan University, Chengdu, Sichuan 610041, China*

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ABSTRACT

This study aimed to explore the validity of an experiment-based paradigm for assessing the suspicious thoughts in healthy volunteers and its corresponding neural process. Twenty-four pairs of healthy college students participated in this study and were randomly assigned to two experimental conditions: the informed (12 pairs) and the naive (12 pairs) conditions. EEG of one subject in each pair was recorded when the 'feeling of being seen through' was evoked. The findings showed a prominent positive deflection of the difference wave within the time window 200 ms–400 ms after stimuli presentation (0 ms) in the naive group. The ERP amplitude of frontal and central scalp sites was significantly different between high and low paranoia rating scores. These findings provide preliminary evidence on the use of an ERP paradigm to detect paranoid ideation or suspicious thoughts in non-clinical sample.


## 1. Introduction

The psychosis phenotype is generally thought of as a categorical entity. However, there is increasing evidence showing that psychosis exists in the population as a continuum of severity rather than an all-or-none phenomenon (Van Os et al., 2000). For instance, the existence of a psychosis continuum has been demonstrated in several large-scale community surveys, including US National Comorbidity Survey (Kendler et al., 1996), the Dutch NEMESIS study (Van Os et al., 2000), and a UK non-clinical population (Freeman et al., 2005). It is possible that paranoid ideation is almost as common as symptoms of anxiety and depression (e.g., Van Os and Verdoux, 2003; Johns et al., 2004).

For many people, thoughts that family members, friends or strangers might be hostile, or deliberately watching them, appear to be an everyday occurrence, usually referring to as phenomenon of "distant intentionality" (Braud, 1994) or "remote staring" (Braud et al., 1993a,b). The former phenomenon refers to relationship between the intentional efforts of one participant (the agent) and physiological changes in another remote person (the receiver), whereas the latter one refers to the ability people can detect someone staring at them or simply having an unusual "feeling of being stared". A most recent meta-analysis (Schmidt et al., 2004) study demonstrates that there is a significant effect, though small to modest, of these anomalies in non-clinical populations suggesting that

* *Corresponding author*. Neuropsychology and Applied Cognitive Neuroscience Laboratory, Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China.
E-mail addresses: rckchan@psych.ac.cn, rckchan2003@yahoo.com.hk, rckchan@hkucc.hku.hk (R.C.K. Chan).
[1] This author and his laboratory have moved to the Institute of Psychology of the Chinese Academy of Sciences.

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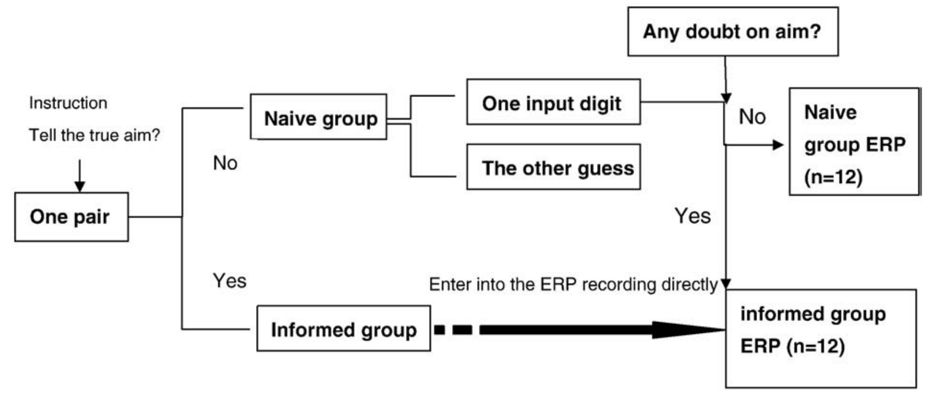


**Fig. 1 – Flow chart of the experimental procedure.**

the existence of these anomalies related to distant intentions cannot be ruled out.

However, most of the studies exploring the unfounded suspicion and paranoid ideation have been limited to clinical ratings or self-reported questionnaires (e.g., Fenigstein and Vanable, 1992; Freeman et al., 2005). Although the use of questionnaires is particularly useful to reflect the subjective experience of paranoid ideation and related construct, these methods lack methodological rigor that may complicate the investigation of such phenomena in non-clinical populations. The clinical validity and reliability of these rating scales or questionnaires are rarely explored. On the other hand, understanding of these subjective anomalies in non-clinical populations may facilitate the understanding of the delusion formation and maintenance in psychotic disorders. As stated above, traditional definitions of delusions that maintained that they were qualitatively different from normal beliefs has been challenged in terms of more recent phenomenological studies and randomized control trial studies that suggested delusions in patients with psychotic disorders might not be incurable (e.g., Brett-Jones et al., 1987; Chadwick and Lowe, 1990; Sensky et al., 2000). Therefore, paranoid thoughts, suspicious thoughts or other related constructs like idea of reference in non-clinical populations are phenomena of interest in their own right and may provide a unique opportunity for us to further examine the formation of paranoia ideation and delusions in clinical populations.

This study aimed to adopt a phenomenological approach (for a review, see Colwell et al., 2000) to explore the suspicious thoughts, namely "feeling of being seen through", in a non-clinical sample. In particular, we used event-related potential (ERP) paradigm to examine such a phenomenon. Such information can be useful to understand the underlying neural processing of "feeling of being seen through" in the clinical cases as one subtype of suspicious thought. Preliminary clinical studies using ERP paradigms to investigate the neural activity underlying delusion have suggested that N400 was associated with severity of delusion (Debruille et al., 2007), whereas N200 and N300 were associated with reality distortion (Williams et al., 2000; Guillem et al., 2003) in schizophrenia. However, as far as we know, there is no comparable study examining this type of subjective anomaly of being seen through in non-clinical sample has been published. Given the preliminary findings on the crucial role of anterior cingulate and temporal cortex as the potential sources of paranoid ideation and delusional thoughts in schizophrenia (e.g., Blackwood et al., 2001, 2004), we predicted that the generation of this odd feeling of being seen through might be based on prefrontal and temporal processes. Moreover, as a validity check on the subjective rating of suspicious thoughts and paranoid ideation among non-clinical cases, we also predicted that participants endorsing higher level of suspicious thoughts and paranoid ideation would exhibit a higher amplitude of a specific ERP component to be found in prefrontal and temporal regions as compared to those who endorsed lower level of these ideations.

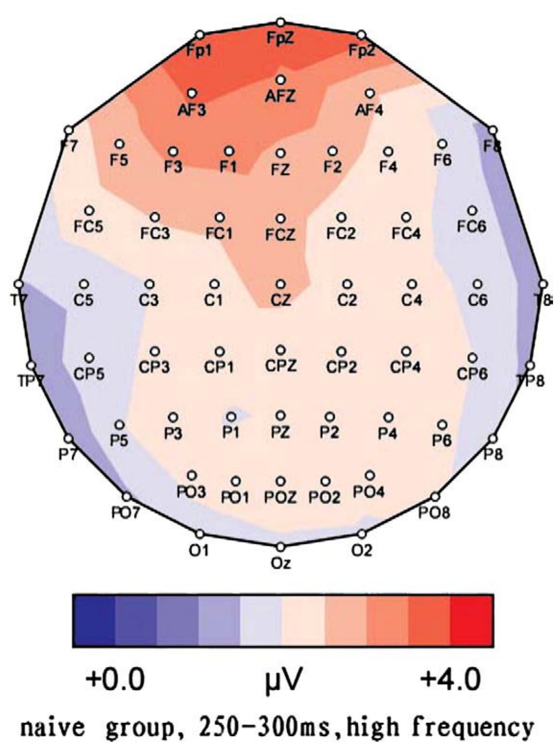


**Fig. 2 – The scalp topography of naive group in 250 ms–300 ms.**

## 2. Results

### 2.1. ERP component exploration

After a brief whole view of the waveforms in each scalp site first in naive group (for details, please see Fig. 1, in section 4 experimental procedures), visual inspection of the waveforms revealed a prominent positive deflection of the difference wave (the 'correct guess wave' subtracted 'incorrect guess wave') around the time window 200 ms–400 ms after the stimuli presentation (0 ms) in the naive group (Fig. 2). From the scalp topography, the positive wave during 200 ms–400 ms occurs at the frontal scalp. As a result, the frontal sites (Fp1, Fpz, Fp2), frontal central sites (FCz, Cz, FC5, FC6) and occipital site (Oz) were selected to illustrate the occurrence of this positive wave in naive group. (Fig. 3, left panel). The mean of the time to peak (±SD), which is the delay of the peak amplitude, was 321± 13 ms across all the recorded scalp sites. We would like to call this component as P3 for the simplicity of the following analysis. A negative deflection at about 500 ms in terms of the difference wave of high frequency in the naive group was also found. The mean time to peak (±SD) was 476± 12 ms. We would like to name this component as N5. In contrast, there was no such an obvious positive or negative deflection in the informed group by visual inspection in the same regions of interest (Fig. 3, right panel). Fig. 3 illustrates the preliminary impression of the potential difference between the naive group and the informed group, which warrants further ANOVA analysis.

### 2.2. LORETA analysis

The major generators associated with the topographically defined P3 and N5 were located approximately in the both sides of temporal lobes. LORETA method was used for the source analysis (Table 1). Within the time window from 250 ms to 350 ms, the right premotor cortex ($x=61$; $y=0$; $z=39$) was activated in the informed group in all conditions of high, middle, and low frequency. There was also activation in the left temporal medial gyrus in the middle frequency condition. For the naive group, within the same time window, In the high frequency condition, the right premotor cortex ($x=59$; $y=0$; $z=39$), the left medial temporal gyrus ($x=-39$; $y=0$; $z=-20$) and the right cerebellum ($x=0$; $y=-53$; $z=-20$) were activated. In the low frequency, right premotor cortex and the right inferior parietal lobe ($x=45$; $y=-40$; $z=39$) would be the major generator. However, in the middle frequency condition; the premotor cortex was the only generator.

Within the time window from 450 ms to 550 ms, for the informed group, left medial temporal gyrus ($x=-44$; $y=0$; $z=-25$) was the major generator in the high and low frequency condition. In the middle frequency condition, besides the left medial temporal gyrus, left middle frontal gyrus ($x=-42$; $y=42$; $z=-4$) was also activated.

For the naive group, in the high frequency condition, the left medial temporal lobe ($x=-39$; $y=0$; $z=-20$) and the cerebellum ($x=1$; $y=-54$; $z=-20$) were the major generators in the high frequency condition, whereas the premotor cortex and the inferior parietal lobe were the major generators in the low frequency condition. In the middle frequency condition, the middle prefrontal gyrus ($x=-36$; $y=55$; $z=0$) was the major generator.

### 2.3. ANOVA

Peak amplitudes within the time window from 200 ms to 400 ms were retrieved to examine the potential effects of channel, frequency and group on the P3. Main effects of channel and group were found on the P3 (Channel: $F(3,66)=9.531$, $p<0.01$; Group: $F(1,22)=7.625$, $p<0.02$). Since there was no prominent peak within 400 ms–600 ms, the mean amplitude was analyzed. A 4(Cz, Fpz, FCz, Oz)×2(group)×3 frequency (high, middle, low) repeated measure ANOVA (at the time window of 410 ms–550 ms) with group as the between-subject variable, and channel and frequency as the within-subject variable. There were significant main effects of channel and frequency, and interactions found within this time window (Frequency: $F(2,44)=5.374$, $p<0.01$; Channel: $F(3,66)=7.522$, $p<0.01$; Interaction: $F(6,132)=7.011$, $p<0.01$). No significant main effect of group was found within this time window (Group: $F(1,22)=1.159$, $p>0.05$). The waveforms from the frontal electrode sites to the occipital electrode sites were illustrated in Fig. 2. Compared to the wave forms time locked to the 'correct guesses', the 'incorrect guess' time locked wave always indicated a negative wave from 200 ms to 400 ms and the difference between 'correct guess' and 'incorrect guess' reduced from anterior area to posterior area. We used Levene's Test for the equality of variance between two groups in all the electrical sites in order to avoid the influence of latency jitter. As a result, it seemed that the variance of latency was equal statistically around 300 ms in the naive group and informed group.

**Table 1 – Summary statistics for the LORETA analysis for the informed- and naive groups**

| Time window | Group type | High frequency | Middle frequency | Low frequency |
|---|---|---|---|---|
| 250 ms–350 ms | Informed group | Right premotor cortex | | |
| | Naive group | Right premotor cortex, left medial temporal gyrus right cerebellum | The premotor cortex | Right premotor cortex the right inferior parietal lobe |
| 450 ms–550 ms | Informed group | Left medial temporal gyrus | The left medial temporal gyrus, left middle frontal gyrus | Left medial temporal gyrus |
| | Naive group | Left medial temporal lobe cerebellum | The middle prefrontal gyrus | Premotor cortex, inferior parietal lobe |

### 2.4. *Relationship with paranoid ideation*

The distributions of the paranoid ideation in the informed and naive groups were severely skewed. In view of these distributions, we used the upper and lower quartile scores as the cut-off score to divide paranoid ideation into high paranoid ideators (paranoid ideation score≥81, $n=4$ in naive group, $n=1$ in informed group) and low paranoid ideators (paranoid ideation score≤36, $n=3$ in naive group, $n=6$ in informed group) in the informed and naive groups independently. *U*-test comparisons indicated that, while in the informed group, there is no significant ERP peak amplitude difference between the high and low paranoid ideators in any condition, between the time window around 500 ms of the low frequency condition, significant EPR peak amplitudes ($U<0.001$, $p<0.05$) were found between the high paranoid ideators and low paranoid ideators in naive groups in the scalp site of FP2.

Moreover, in the middle frequency condition, between the time window 250 ms–350 ms, significant differences were also found in peak amplitudes between the high and low paranoid ideators in the scalp sites Cz, FC5, FC6, FCz, Fpz (all above $U<0.001$ $p=0.034$) in the naive group.

In high frequency condition, while there were no scalp sites indicating this significant difference in the informed group, there seemed to be much significant differences found between high and low paranoid ideators in the analyzed scalp sites of the naive group by using *U*-test. In the time window of 250 ms to 350 ms, there were significant difference in scalp sites of Cz, FC5, FC6, FCz, Fp2, and Fpz (all above: $U<0.001$, $p=0.034$). When it came to the low frequency condition, the significant difference between the high ideation and low ideation subgroup only lay in the Fp1 ($U<0.001$, $p=0.034$) in the time window of 250 ms to 350 ms and also Fp2 ($U<0.001$, $p=0.034$) in the time window of 450 ms to 550 ms (Table 2).

We then examined the potential relationship between the paranoid ideation and the brain activities. Fig. 4a shows the correlation between paranoid ideation score, P3 peak amplitude and N5 peak amplitude was conducted by using nonparametric Spearman correlation ($n=12$). Eight scalp sites of interest in the frontal and central midline (Fpz, Fp1, Fp2, FCz, FC5, FC6, Cz, Oz) were examined. For the naive group, significant correlations were found in the high frequency conditions between P3 peak amplitude and paranoid ideation score in sites such as FC5 ($r=-0.713$, $p<0.01$), FC6 ($r=-0.860$, $p<0.001$), FCz ($r=-0.65$, $p<0.05$), Fp2 ($r=-0.797$, $p<0.01$), Fpz ($r=-0.58$, $p<0.05$). In the middle frequency conditions, there were significant correlations found between paranoid ideation and P3 peak amplitude in Cz ($r=-0.692$, $p<0.05$) and FC6 ($r=-0.084$, $p<0.01$). For the N5, there was also a significant correlation found in Fp2 of low frequency condition ($r=-0.657$, $p<0.05$). For the informed group, significant correlations were only found in FC5 ($r=-0.58$, $p<0.05$) and FC6 ($r=-0.727$, $p<0.01$) in high frequency condition but not the other frequency conditions.

However, a look on the figure shows that there are outliers in both the informed and naive groups. We then re-analyzed the data by eliminating the outliers in these two groups. Fig. 4b shows that the significant relationship between the P3 peak amplitude and ideation score remained in the naive group after the removal of the outlier. Another correlation graph of FCz before and after deleting the same point has also been listed in Appendix B. Similarly, the insignificant relationship between brain waves and ideation scores persisted in the informed group. These findings suggested that the correlation between paranoid ideation score and the P3 amplitude might not be only due to the outlier. Taken together, prefrontal lobe might be critical for the observed ‘P3’ in this study. Therefore, one of the prefrontal scalp sites was selected for the subsequent illustration of the relationship between paranoid ideation and neural activity.

**Table 2 – Scalp site on which amplitude is significantly different between high total score and low total score groups in both informed and naive conditions**

| Group | Window around | Low frequency | Middle frequency | High frequency |
|---|---|---|---|---|
| Informed | 300 ms | None | None | None |
| | 500 ms | None | None | None |
| Naive | 300 ms | None | Cz, FC5, FC6, FCz, Fpz | Cz, FC5, FC6, FCz, Fp2, Fpz |
| | 500 ms | Fp2 | None | FCz |

## 3. Discussion

The first major finding was that a prominent positive deflection of the ERP wave difference (the ‘correct guess wave’ subtracted ‘incorrect guess wave’) appeared around the time window 250 ms–350 ms after the stimuli presentation (0 ms) in the naive group which was named P3 throughout the current study. It was especially obvious in the high frequency condition. Previous studies have intensively explored P3 in schizophrenia (e.g. Higashima et al., 1998; Mucci et al., in press). In these studies, P3 was evoked in oddball paradigm, that is, the probability difference between target stimuli and nontarget stimuli could result in P3 component. However, P3 in the present study might carry a different psychological meaning because it was evoked in a different way. The discrepancy of the target stimuli could not be the ‘event’ of ‘P3’ in current study for the ‘P3’ also existed in most of the scalp sites in the middle frequency conditions where the frequency of the ‘correct guess’ and ‘incorrect guess’ were about the same. Moreover, in the low frequency conditions where the ‘correct guess’ appeared much less than ‘incorrect guess’, this ‘P3’ had not been demonstrated in most of the scalp sites, which might mean that this P3 could be an indication of a certain neural activity that was evoked when seeing the unbelievable ‘correct’ feedback. On the other hand, a discussion about the functional significance of the P3 wave of human event-related potentials (ERP) has also been largely put upon the notion of expectancy (see a review of Kotchoubey et al., 1997). Researches have found that P3 reflects a mechanism of actualization of experience in working memory related to receiving unexpected information (Donchin and Coles, 1988). This theory could explain the P3 component in our current study. ‘Being seen through’ might be an unexpected

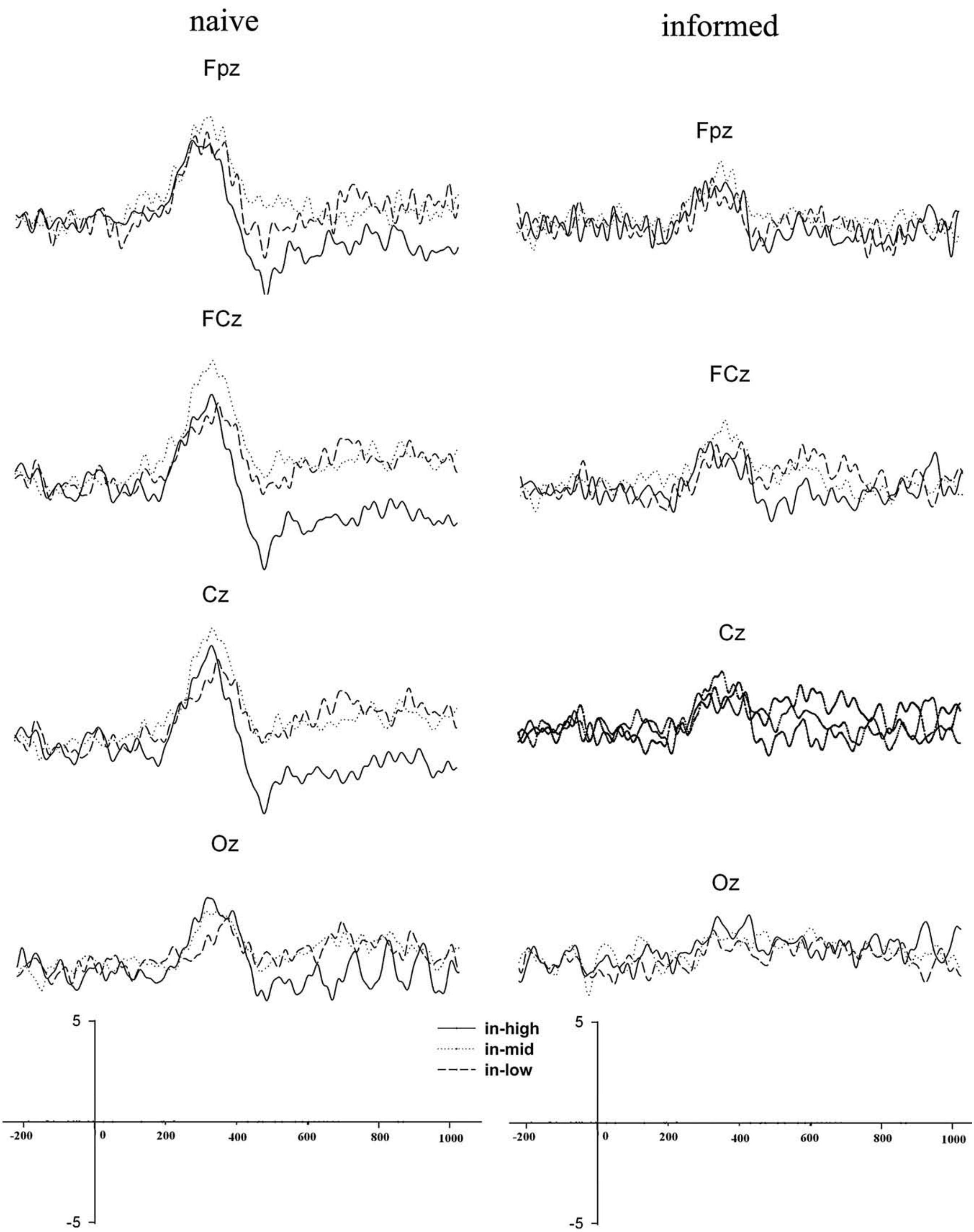


**Fig. 3 – Waveforms of eight electrode sites (Fpz, FCz, Cz, Oz) in three frequency conditions of naive group (left panel) and informed group (right panel). Note: where y meets x is 0 in the x axis. The interval of points in x axis is 200 ms.**

information for the naive subjects so that P3 component was evoked thereafter.

The ERP wave difference between 'correct' and 'incorrect' reduced progressively from anterior area to posterior area, which may shed light on the development of paranoid-like ideation in non-clinical population. At least some specific neural activities might occur when people noted that their input digits had been 'guessed' correctly by others. As shown in Fig. 1, the progressive reduction of the differences of P3 amplitudes between the 'correct guess' and the 'incorrect guess' from frontal sites to occipital sites suggested that such differences would not be an artifact caused noise but a specific neural activity generated from frontal lobes.

Furthermore, LORETA analysis showed that there were more brain regions activation found in the naive group as compared to the informed group, including the left medial temporal gyrus and inferior parietal lobe in the time window of 250 ms to 350 ms ('correct guess' feedback). The differences of brain activations found between the naive and informed groups were most obvious when the high frequency of 'correct guessing' was concerned. In the high frequency conditions, there were activations found in the left medial temporal gyrus, the right cerebellum, and the right premotor cortex in the naive group. These findings were consistent with the previous studies on the neural substrates of delusion in schizophrenia (Liddle et al., 1992). These authors found that reality distortion was associated with increased rCBF in left medial temporal lobe, left ventral striatum, and left infero-lateral frontal cortex and with decreased rCBF in right posterior cingulate and left lateral temporo-parietal cortex.

A statistical and clinical meaningful relationship was demonstrated between ERP amplitudes and paranoid ideation in the present non-clinical sample. Previous studies have suggested a negative correlation between N400 amplitude and delusion severity (Debruille et al., 2007). However, contrary to our previous prediction for the present study, there was an inverse relationship found between 'P3' and paranoid ideation score. That means, people endorsing a higher level of suspicious thoughts and paranoid ideation would exhibit lower amplitude of a specific ERP component in prefrontal and temporal regions as compared to those who endorsed lower level of these ideations in the naive group. This negative correlation was consistent across all the electrical sites where significant correlations were found. One of the possible explanations could be that for the non-clinical participants, there could be a 'usual' response of neural activity when they recognized their digits inputs were guessed correctly by others. For those with higher level of paranoid ideation, this 'usual' reaction to the 'correct guess' might be inhibited resulting in a lower amplitude of the ERP. The preliminary association found between the ERP amplitudes and paranoid ideation suggest that this type of paradigm may be useful to the understanding of the subjective anomalous experiences in non-clinical sample as well as a potential tool to investigate suspicious thoughts or delusions in clinical groups. This finding in non-clinical sample might also contribute to the mechanism of the delusion formation in clinical population from another aspect in addition to the deficits of semantic information integration in schizophrenia as indicated by previous studies by using N400 amplitude as an index. N400 could only be elicited by processing semantic meanings. In the current study, digits stimuli in our paradigm which elicited P3 has developed another method of investigating subjective anomalous experiences associated with delusion formation, at least initially in non-clinical sample.

However, the current study was limited by a number of methodological designs. First, the classification of the groups into naive and informed cases was crude and arbitrary. Inclusion into each of the two groups was based on the manipulation of the instruction. Some individuals form the naive group might be more suspicious than some individuals from the informed group and vice versa. Further studies should do the baseline checking of suspicious thought and psychological profile examination first. The results might be confounded by something more than the results of suspiciousness such as social desirability. However, a check on the status of the subjects in naive group with a structured funnel interview has revealed that all of the subjects in the naive group who took part in the ERP recording had not doubted or realized the generation of stimuli was manipulated by the computer instead of their friends. This validity check, though not very rigorous in nature, might prevent any social desirability being induced by the assigned group status. Moreover, in future work, it may be helpful to ask the participants, before they start with the experiment, the odds with which they expect their friends to be able to guess a randomly chosen number in their mind. In so doing, one could empirically gauge how "surprising" the experimental stimuli and events are to the participants. Although not too likely, it is theoretically possible that the participants with high paranoia ideation in the current study may happen to be the participants who for whatever reason thought it much more likely that their friends would be able to guess the number correctly. It may be that participants with high paranoia ideation in general do also believe that people can see through them and often can guess the number correctly, but we do not know.

Second, in the low frequency condition, chance for the 'correct guess' feedback was 1/3, that is a probability which was much higher than the actual 'correct guess' chance level (1/9). This 1/3 proportion was set to meet the technical requirement of the ERP data analysis so that there would be enough 'correct guess' trials to merge and average in low frequency condition. However, this limitation did not increase the systematic bias much in result because it was the contrast between different frequency conditions that the current study focused on.

Third, personality traits are important if relation should be investigated between brain function (explored by EEG) and extent of suspiciousness (measured by questionnaires). We did not recruit any clinical cases or individuals with proneness to psychosis such as schizotypal personality features. However, a pilot test of the paradigm recruiting cases with higher and lower schizotypal personality features has suggested a difference between individuals with higher and lower schizotypal personality features, and hence, a preliminary face validity of the current paradigm.

Further study should be done to validate and confirm the applicability of this paradigm to clinical cases with different subtypes of psychotic symptoms in the near future.

In conclusion, this study provides preliminary evidence on the use of an ERP paradigm to detect paranoid ideation or suspicious thoughts in non-clinical sample. This paradigm may also serve as a potential tool to examine psychopathology of paranoid ideation in schizophrenia and related psychiatric disorders in the near future.

## 4. Experimental procedures

### 4.1. Participants

Twenty-four pairs of healthy college students, ranging in age from 19 to 23 years (mean=19.78 years old, SD=1.24) from Zhuhai Campus of Sun Yat-Sen University, participated in this study. All of them came in pairs (all of the pairs were either good friends or classmates who knew each other well) and they were explained that the main aim of this study was to explore the impact of friendship on guessing digits from friends without detailing the specific aim of "being seen through" by others.

### 4.2. The paradigm

The paradigm was run in pair with the subjects sitting in two independent cubicles. Subject A who involved in the EEG recording was required to input the digits from 1 to 9 at random under the invitation of the computer, whereas subject B was required to 'guess' the digit subject A input. Both subject A and B were told that the two computers they used were connected and the digits they input would be transmitted between these two computers, while actually the 'guess outcome' presented to the subject A who input the digits at random was controlled by the computer program instead of the real guess from the other participant. Subject A was required to pay attention to the screen's feedback, that is, the 'guess' outcome of subject B after he or she input the digit randomly. Fig. 1 illustrates the flow of the experimental procedure.

Each trial procedure of the 'random input' subject A was as following: first an input box would appear at the center of the screen to require participant to input a digit from 1 to 9 at random. If the subject input the digit out of this range or accidentally press the enter key without any inputting, the program would ask the subject to input a proper digit again. If he or she input a proper digit, a text would appear to inform this subject to wait for the other to 'guess' their inputs. This text would appear for 1000 ms to 2000 ms at random. Then a 'feedback' would be given to the participants for 1000 ms and at the same time a trigger code would be sent to the EEG recording computer. Different trigger code would be sent when the feedback was right or wrong. After that, a blank screen would appear for 1000 ms in order to provide enough time for participants to think about the feedback.

Three conditions were set to investigate idea reference in this experiment—high frequency of right 'guess' (about 70%), moderate frequency of right 'guess' (about 50%), and low frequency of right 'guess' (about 30%). The experiment contains 12 blocks with 4 blocks in each condition. There were 40 trials in each block. 12-Block order was counter-balanced among subjects. In order to prevent subjects suspicious about the feedback, the right 'guess' number in each block would be randomly set 1–3 difference. For example, in '30%' condition, there should be 12 trials 'guessing' right and 28 trials 'guessing' wrong. Now, there might be 9–15 trials 'guessing' right and 25–31 trials 'guessing' wrong at random in different blocks.

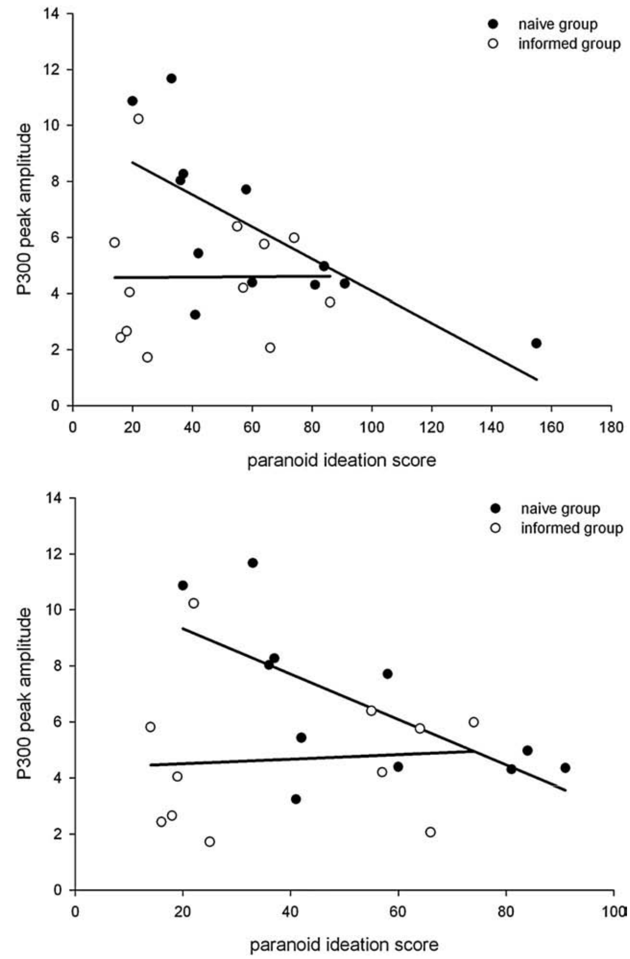


**Fig. 4 – Correlation between the paranoid ideation score and P3 peak amplitude at the right prefrontal site (Fp2) of the naive group (the slanted line) ($n$=12, $r$=−0.797, $p$=0.002) whereas no significant correlation was found in the informed group (horizontal line) ($n$=12, $r$=0.035, $p$>0.9). Greater P3s correspond to more positive voltages. The regression line did not extend to axes and just fit to the data range in each group.**

The preliminary face validity of this paradigm was replicated in one of our ongoing study using the same paradigm on 3 college students, two with high proneness to schizotypal personality features and one with no such proneness according to the Schizotypal Personality Questionnaire (Raine, 1991; Chinese version, Chen et al., 1997). The ongoing replicated experiment averaging from these three cases showed again that there was significant difference wave between 'correct-guess' and 'incorrect-guess' at the P3. These preliminary results replicated the face validity of this paradigm (Appendix A).

### 4.3. Procedure

The subjects came in pairs were randomly assigned to two groups, the naive group and informed group, according to the manipulation of the instruction given. That is, for the naive group, when the subjects came, we would just tell them the general aim of the study was an investigation on the impact of friendship on 'guess' outcome and they were instructed that the feedback they would receive from the computer was generated by their friends. For the informed group, we told them the true aim of the study directly and explained to them the feedback they received during the experiment was just generated by the computer program. As a validity check on whether the subjects were still being "naive" to the study after the completion of the experiment, we used a structured funnel interview to examine the subjects in the naive group whether they had had any doubt on the source of the feedback given by their friends during the experiment. If the structured interview indicated that participants doubted or realized that the feedback was generated by the computer program, the data of this case would not be included into the naive group. The results of the structure funnel interview ensured that none of the subjects in the naive group had doubted or realized the feedback was manipulated by a computer.

Moreover, after finishing the EEG recording procedure, subject A (who involved in the EEG recording) in each pair was asked to complete a self-reported paranoid checklist (Chan et al., submitted for publication). This was a 15-item checklist to screen for paranoid ideation in both healthy and clinical cases, mainly derived from previous similar checklists (e.g., Fenigstein and Vanable, 1992; Freeman et al., 2005). Acceptable reliability and validity of this checklist has been reported in Chan et al. (submitted for publication) among a group of 952 college students (803 subjects with no schizotypal personality features and 149 subjects with schizotypal personality features). Chan et al. demonstrated that the internal consistency (in terms of alpha coefficient) and correlation of the scale to the item of idea of reference in the Schizotypal Personality Questionnaire (Raine, 1991; Chinese version, Chen et al., 1997) was 0.94 and 0.6 ($p<0.01$), respectively.

### 4.4. EEG recording

Electroencephalogram (EEG) was recorded using eemagine package (ANT Software BV, Enschede, the Netherlands) (512 Hz sampling rate) from 64 electrodes, which were placed on the head according to the modified expanded 10–20 system. Vertical electro-oculogram (VEOG) was recorded from electrodes placed above and below the left eye and horizontal electro-oculogram (HEOG) from electrodes placed at the outer cantus of each eye. EEG and EOG were acquired every 2 ms and bandpass filtered from 0.1 Hz to 40 Hz impedances in the above electrode sites were maintained below 5 kΩ. All electrodes were re-referenced offline to an average of the signals at the two ears with a right mastoid ground. The stimulus presentation program was Eprime1.1 (Psychological Software Tools, Inc.).

### 4.5. Data analysis

The EEG data was offline analyzed by the eeprobe package, using ASA software for source analysis (ANT Software BV, Enschede, the Netherlands). Single trials exceeding +100 μV were rejected. Remaining trials were corrected for the effects of eye blinks and eye movements on the basis of correlations of VEOG and HEOG with the EEG recorded at the each electrode site. We computed stimulus-synchronized averaged from −200 ms to 1000 ms separately for the correct and wrong feedback in all the trials of the three conditions the baselines from −200 ms to 0 ms in order to assess the mental responses that may happen when the participants found their friend 'guess' their minds correctly.

Since the paradigm had never been used before, first of all, the visual inspection of the wave forms in all electrode sites and the scalp topography. Scalp topography was used to guide the number and site of electrodes to be reported for this study (see results for details). The locations of the major generators for the ERP component that were observed in the waveform and scalp topography were modeled on grand average waveforms for each group using Advanced Source Analysis (ASA) software program. We used the Low Resolution Electromagnetic Tomography method (LORETA) to determine the brain electrical sources of the potential ERP component found in the first part of data analysis based on all the 64 scalp electrodes. LORETA version in the current study used a three-shell spherical head model registered to the Talairach space. We used LORETA to calculate the three-dimensional localization of the electrical sources contributing to the electrical scalp field for each group (informed and naive group) and frequency (high, middle and low) at the possible time window. Finally, peak amplitude and mean amplitude of the observed ERP components were retrieved using repeated measure ANOVAs, with informed and naive group as a between-subject variable. Separate ANOVAs were conducted for each time window based on the visual inspection analysis. Group (informed vs. naive) was a between-subject variable while channels, frequency (high, middle, low) were repeated factors. The scatter plot was also conducted to explore the possible relationship between idea reference and ERP results.

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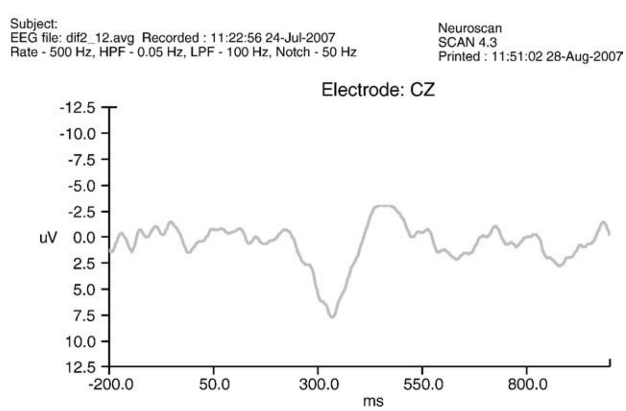
## Appendix A. Pilot study results

The demographic and descriptive information of the three cases recruited for the pilot study are summarized as follows:

| Sub | Sex | Age (year) | SPQ | Paranoia checklist | Frequency | 200 ms–400 ms time window peak amplitude (delay) |
|---|---|---|---|---|---|---|
| 1 | Female | 25 | 36 | 110 | Low | 5.0 μV (302 ms) |
| | | | | | Middle | 5.0 μV (282 ms) |
| | | | | | High | 7.9 μV (334 ms) |
| 2 | Male | 28 | 38 | 84 | Low | 5.0 μV (234 ms) |
| | | | | | High | 1.5 μV (212 ms) |
| | | | | | Middle | 3.1 μV (352 ms) |
| 3 | Male | 24 | 11 | 86 | Low | 4.8 μV (394 ms) |
| | | | | | Middle | 0.07 μV (296 ms) |
| | | | | | High | 2.0 μV (336 ms) |

All of the three cases were in naive group (uninformed of the actual source of feedback). SPQ is the schizotypal personality questionnaire and P3 amplitude is the peak amplitude within the time window of 200 ms to 400 ms. A higher score in the SPQ indicates a proneness to the schizotypal personality features.

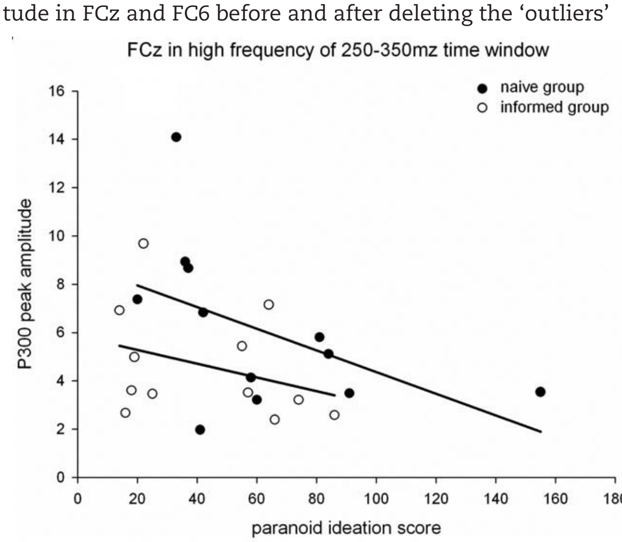
Moreover, this pilot experiment averaging from these three cases replicated the result we got in the current study: the subjects in naive group showed a P3-like and a N500-like difference wave form by subtracting 'guess-wrong' from 'guess-correct' condition (illustrated below).



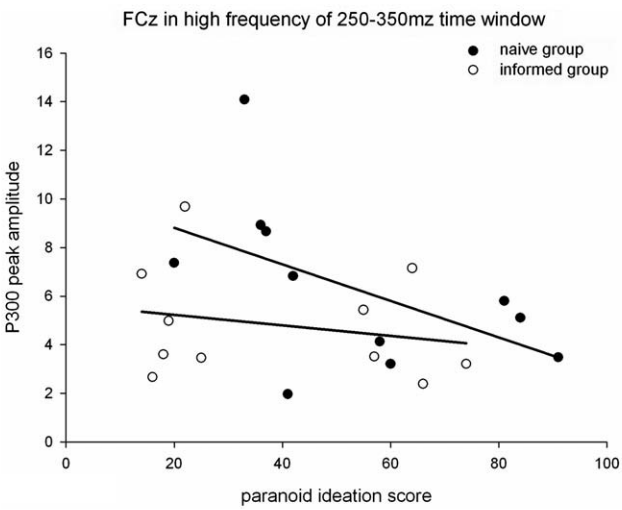

By visual inspection, the difference between the "guess-right" and "guess-wrong" again elicited a positive waveform around 300 ms, together with a negative waveform around 500 ms in the pilot study averaged from 3 cases' EEG data in uninformed group by using the paradigm reported in the manuscript.

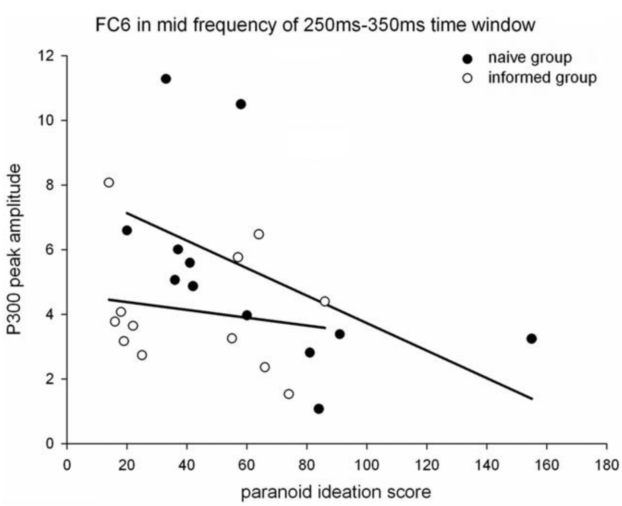
## Appendix B

Correlations between paranoid ideation scores and P3 amplitude in FCz and FC6 before and after deleting the 'outliers'

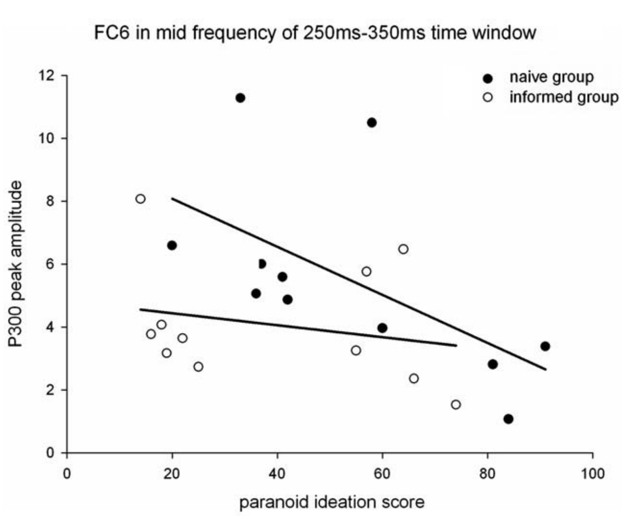



After deleting the highest paranoid score of 155, the correlation graph in FCz would be as follows (Spearman's correlation: $r = -0.655$, $p = 0.029$, $n = 11$ for naive group; $r = -0.264$, $p = 0.233$, $n = 11$ in informed group):




After deleting the highest paranoid score of 155, the correlation graph in FC6 would be as follows (Spearman's correlation: $r = -0.719$, $p = 0.004$, $n = 11$ for naive group; $r = -0.500$, $p = 0.117$, $n = 11$ for informed group):

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