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# A linear mixed-effect model analysis of the effect of schizotypal personality traits on confidence in reality monitoring

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A number of previous studies have reported overconfidence in reality monitoring in patients with schizophrenia. Reality monitoring is defined as the ability to discriminate between internal and external sources of information. We consider that the research on reality monitoring confidence should be extended to healthy participants who have a predisposition toward schizophrenia (schizotypy) in order to elaborate the biological markers of risk for schizophrenia. In the present study, we precisely examined the effect of schizotypy on reality monitoring confidence using a linear mixed-effect model analysis, which can consider random variation across participants and stimuli (random participant and stimulus effects). The results showed that random participant and stimulus effects had significant effects on confidence ratings for reality monitoring, while the fixed effect of schizotypy had a marginally significant effect on the ratings. Our findings demonstrate the importance of considering random effects associated with stimuli and participants for evaluating the effects of schizotypy in reality monitoring confidence.

**Key words:** reality monitoring, linear mixed-effect model, confidence rating, schizotypal personality, schizotypy

## Introduction

Reality monitoring refers to the ability to discriminate the information generated by one's own thoughts and actions from that generated by external events (Johnson & Raye, 1981). It is critical for adaptive behavior toward moment-to-moment changes in the surroundings. Patients with schizophrenia who have positive symptoms including hallucinations and delusions may show a lack of reality monitoring. They may not be able to recognize their own voice and perceive their own voice as other voices that are not actually present (Dunlosky & Metcalfe, 2010; Simons, Garrison, & Johnson, 2017).

However, a reality-monitoring deficit is not specific to schizophrenia and can be observed in patients with other psychiatric disorders (Moritz & Woodward, 2006). Therefore, recent research has focused on confidence in reality monitoring rather than on reality monitoring deficits (Moritz, Woodward, & Ruff, 2003) to discriminate schizophrenia from other psychiatric disorders. Importantly, overconfidence in erroneous reality monitoring has been specifically reported in patients with positive symptoms of schizophrenia (Moritz & Woodward, 2006; Moritz et al., 2003; Woodward, Menon, & Whitman, 2007).

Research on reality monitoring confidence in schizophrenia should be extended to healthy participants who have a predisposition toward schizophrenia, which is referred to

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as schizotypy (Claridge, 1997). Examining persons who exhibit schizotypy is a promising strategy for providing insights into the origins of schizophrenia (Raine, 2006), assessing behaviors without the confounding effects of studying chronically ill and medicated patients (Minas & Park, 2007), and elaborating the biological markers of risk for schizophrenia.

When examining reality monitoring confidence in healthy individuals with schizotypy, as in the present study, it is important to consider that the effect of random variation across experimental participants and stimuli (random participant and stimulus effects) could make it difficult to identify, among random effects, the effect of schizotypy on reality monitoring confidence as well as to interpret the present findings. Murayama (2018) raised an alarm over conventional statistical analyses using analysis of variance (ANOVA) in memory research. In general, to-be-remembered stimuli are considered as ideally randomly sampled from an infinite population of stimuli. Further, most studies assume that various properties of randomly sampled stimuli do not have a possible effect on dependent variables such as the confidence rating score. However, this possible effect is not completely zero, called as a random stimulus effect. Because conventional statistical analyses do not consider random stimulus effects, significant results may account for such effects and not fixed effects. In other words, these analyses could subsequently increase the Type-1 error rate. Therefore, we should interpret the significant fixed effects observed in these conventional analyses with caution. Thus, to address this issue, we newly examined reality monitoring confidence in a healthy population with high/low schizotypy using a linear mixed-effect model.

## Method

### *Participants*

Forty-one healthy graduate and undergraduate students (4 males and 37 females, with a mean age of 21.0 years and SD ±2.19 years) participated in this study. The experiment was approved by the Ethical Committee of Tohoku Fukushi University and conducted according to the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.

### *Materials and Procedure*

*Schizotypy:* We used the Japanese version of the Schizotypal Personality Questionnaire Brief (SPQ-B) (Ito, Obu, Ota, Takao, & Sakamoto, 2008) to measure participants' schizotypy. The SPQ-B consists of 22 items, each answered as "Yes" or "No." Higher SPQ-B scores indicate high schizotypy. Participants were asked to answer the SPQ-B after completing the reality monitoring task. For the subsequent analysis of variance (ANOVA), the participants were divided into two groups based on the SPQ-B mean score: 22 participants into the high score group (mean score of 11.55, SD ±2.52) and 19 participants into the low score group (mean score of 6.00, SD ±1.83). A mean split allowed for classification of all participants, while a median split leads to the exclusion of the data for some participants with a SPQ-B score corresponding to a median.

*Reality monitoring task:* We used 80 easy words including verbs or adjectives and had four different stimuli types: (1) which consisted of 20 words selected from Umemoto (1969) and Mizukami (2013; 2014), (2) which consisted of 10 words used as a synonym and 10 words used as an antonym of each word from (1), (3) which consisted of 20 words related to both (1) and (2) on the basis of a synonym and related word dictionary on the web (http://renso-ruigo.com/), and (4) which consisted of 20 words not related to both (1) and (2). All words from (1) and the first letter of the words from (2) in Japanese were recorded by an experimenter using a microphone (ATR1100 Unidirectional Dynamic Handheld Microphone, Audio-Technica U.S., Inc., Stow, Ohio, USA).

The experimental stimuli were created using E-prime 2.0 (Psychology Software Tools, Inc., Sharpsburg, PA, USA). These stimuli were generated and controlled on a PC (Endeavor MT7900, Epson, Nagano, Japan) and were presented on the monitor (ProLite E1902S PLE1902S-W1; resolution 1280×1024 pixels; refresh rate 60 Hz, iiyama, Tokyo, Japan). The experiment consisted of learning and test trials. In a learning trial (Figure 1), first, a fixation cross was presented on the center of the monitor for 1000 ms. Subsequently, the Chinese character cue "類" (synonymous) or "対" (antonymous) was presented for 2000 ms on the center of the monitor. A randomly selected word from (1) was presented through the speakers (ECLIPSE TD508II, Fujitsu Ten, Hyogo, Japan). The first letter of a synonymous (or antonymous) word selected from (2) was presented 1500 ms after the presentation. Participants were asked to speak a word that was synonymous (or antonymous) with the selected word from (1) when the "類" (or "対") cue was presented and that also includes the first letter. An experimenter checked whether the participant's answer matched a word from (2) for each trial. If the participant's answer did not match the word from (2) that was selected by the experimenters but was synonymous (or antonymous) and in the same word class, we used the participant's answer as a stimulus in a test trial.

In test trials, a word each from (1), (2), (3), and (4) were presented in random order. Simultaneously, the alternatives for "1: New" and "2: Old" were presented at the bottom of the monitor. Participants were asked to select "2: Old" if they listened to or spoke the presented word in the learning trials and to select "1: New" if not. Next, participants were asked to rate on a 6-point scale how confident their old-new judgement was. If they selected "2: Old," new alternatives for "1: Experimenter" and "2: Self" were presented at the bottom of the monitor. Subsequently, participants were asked to judge whether a presented word was heard or spoken in a learning trial: "1: Experimenter" was to be selected if participants had listened to the presented word and "2: Self" if they had spoken it in the learning trials. Participants were also asked to rate on a 6-point scale how confident the experimenter-self judgment was. All judgments in the experiment were self-paced.

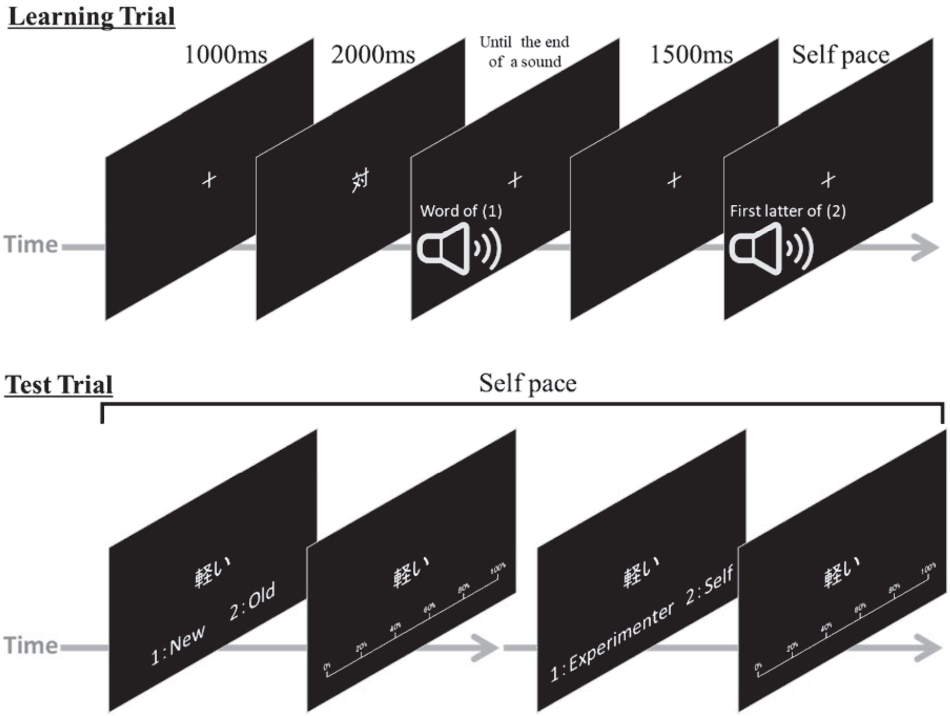


*Figure 1.* The stimulus sequence used in the reality monitoring task. (1) refers to the 20 words selected from Umemoto (1969) and Mizukami (2013; 2014). (2) refers to the 10 words used as a synonym and the 10 words used as an antonym of each word from (1). In this learning trial, participants were asked to speak a word that is antonymous with the word selected from (1) when the " 対 " cue was presented and that also includes the first letter of the antonymous word selected from (2). In this test trial, in which an alternative of "2: Old" was selected, the participants were also asked to select "1: Experimenter" or "2: Self." If an alternative of "1: New" was selected, the next test trial began.

## Results

### *Analysis of Variance (ANOVA)*

We first performed ANOVA with the factors of the SPQ-B total score, which have been used in previous studies on reality monitoring (Moritz & Woodward, 2006; Moritz, Woodward, Whitman, & Cuttler, 2005). Table 1 shows the mean reality monitoring accuracy for SPQ-B score group (high and low), and the mean reality monitoring confidence rating score for each reality monitoring response (correct and incorrect) and SPQ-B score group (high and low). We conducted a two-way mixed ANOVA for the confidence rating scores with reality monitoring response (correct or incorrect) as the within-participant variable and group (SPQ-B score high or low) as the between-participants variable. The main effects of both response and group were significant [response: $F(1, 39) = 60.16$, $p<.001$; group: $F(1, 39) = 9.32$, $p<.01$]. The interaction between response and group was not significant [$F(1, 39) = 1.47$, *n.s.*]. These results indicated that confidence rating scores were higher in correct than in incorrect reality monitoring responses and participants with high schizotypy scores tended to rate their confidence higher than did those with low schizotypy scores.

*Table 1*. Mean reality monitoring accuracy and confidence rating scores.
*Note*. N: Number of participants, M: Mean, SD: Standard Deviation.

| | | Reality monitoring accuracy (%) | | | Confidence rating (%) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Reality monitoring response | | Total |
| | | *N* | M | SD | Correct | Incorrect | |
| SPQ-B score | High | 22 | 67.78 | 3.74 | 88.71 | 78.39 | 83.55 |
| | Low | 19 | 66.45 | 3.89 | 75.71 | 68.18 | 71.94 |
| Total | | 41 | 67.16 | 3.82 | 82.21 | 73.28 | 79.75 |

*Linear Mixed-Effect Model*

We used a linear mixed model to analyze the effects of reality monitoring response and the SPQ-B score on confidence ratings considering random variation across participants, stimulus items, and other factors that may have an effect on confidence ratings. The analysis was performed using the *R* package *lme4* (Bates, Mächler, Bolker, & Walker, 2015) and *lmerTest* (Kuznetsova, Brockhoff, & Christensen, 2017). We included reality monitoring response (correct or incorrect), the SPQ-B score groups (high or low), and the interaction between the two as fixed-effect factors. We included as random-effect factors of participants, gender, stimulus, trial number, answer type (New, Experimenter, or Self), stimuli type ((1), (2), (3), or (4)), and observed participants' responses (New, Experimenter, or Self) on the slope for confidence ratings and the fixed effect factors as well as the intercept. Table 2 shows the marginally significant fixed effects of the SPQ-B score groups on confidence ratings [$\beta$ = .65, SE = .32, $t$ = 2.06, $p$<.10]. Figure 2 shows the significant random effects of participants [$p$<.001], stimulus [$p$<.001], answer type [$p$<.001], and stimuli type [$p$<.01] on the intercept. The random participant effect [$p$<.001] was significant for the slope for confidence ratings and reality monitoring response (correct or incorrect). The random gender, trial number and observed participants' responses effects (New, Experimenter, or Self) were not significant for the intercept and slope for confidence ratings and the fixed effect factors. The results showed that the SPQ-B score groups had an effect on confidence ratings, as did random-effect factors such as participants and stimulus.

*Table 2.* Results of the linear mixed effect model analysis for fixed effects on reality monitoring confidence.

| | *β* | SE | *t* | *p* |
|---|---|---|---|---|
| **(Intercept)** | 4.11 | .65 | 6.29 | <.001 |
| **Reality monitoring response (Correct / Incorrect)** | .33 | .43 | .77 | *n.s.* |
| **SPQ-B score group (High / Low)** | .65 | .32 | 2.06 | <.10 |
| **Reality monitoring resoponse ×SPQ-B score group** | .06 | .12 | .50 | *n.s.* |

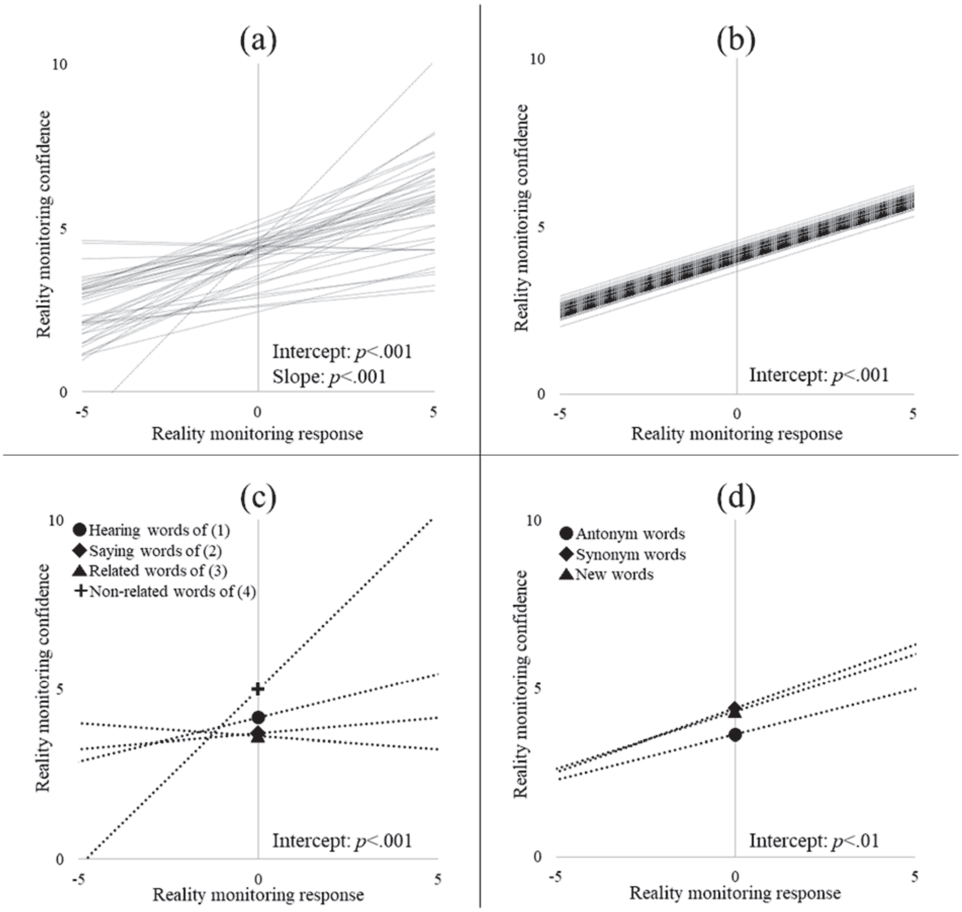


*Figure 2.* Results of the linear mixed effect model for reality monitoring confidence. (a) depicts random participant effects on the intercept and on the slope for confidence ratings and reality monitoring response (correct or incorrect). (b) depicts random stimulus effects on the intercept. (c) depicts random answer-type effects on the intercept. (d) depicts random stimuli-type effects on the intercept.

## Discussion

We examined the effect of schizotypy on reality monitoring confidence using a linear mixed-effect model analysis as well as ANOVA. The result of ANOVA indicated that high schizotypy led to higher confidence in the reality monitoring task compared to low schizotypy. This result seems to be similar to previous studies on reality monitoring confidence in patients with schizophrenia (Moritz et al., 2003; Moritz & Woodward, 2006). However, the linear mixed-effect model analysis showed that the effect of schizotypy on reality monitoring confidence was marginally significant, while the random participant and stimulus effects were significant. In other words, the results of the linear mixed model analysis demonstrated that random variation across participants and stimulus (random participant and stimulus effects) increased the Type-1 error rate in the results as indicated by the ANOVA, which account for random participant but not random stimulus effects. Reality monitoring confidence for the word stimuli used in the present study cannot be necessarily equal to that in an infinite population of words that can be observed across schizotypy conditions (e.g., Murayama, Sasaki, Yan, & Smith, 2014). Conventional statistical analysis can detect significance in possible (small) differences in reality monitoring confidence between the sample and population. In other words, random variation in the random sampling of words may increase Type-1 errors and lead to erroneous results. Therefore, we need to be cautious about this possibility in conventional analyses that do not consider random stimulus effects.

In future research, similar findings might also be obtained in patients with schizophrenia. Therefore, it would be meaningful to elucidate the random stimulus effects on reality monitoring overconfidence in patients with schizophrenia for the quantitative and objective classification of schizophrenia and other psychiatric disorders and for devising a biological marker to predict proneness to schizophrenia.

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