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Article

Response Patterns and Emotional Reactions after Self-Made Errors in the Simon Task

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Response patterns and emotional reactions in the Simon task after making errors were investigated to explore the processes of making continuous errors. Feedback for right, or wrong responses was given to participants for each trial under two conditions: normal feedback that reflected participants' responses, and false-feedback in 5% of trials. Results indicated that response times after making errors increased, such that response times after self-made errors, was significantly longer than response times in the false-feedback condition. Moreover, participants that made continuous errors had relatively more regrets. These results suggested that delayed response times and regret are characteristics of responses after self-made errors.

key words: chain of errors, intrapersonal chain of errors, post-error slowing, Simon task

Introduction

In daily life and at workplaces, errors and problems can trigger emotions, such as impatience and panic. These emotions can also trigger further errors as a chain reaction. We have named this phenomenon in which emotions mediate the continuation of errors, a chain of errors (Wada, 2009). This study was designed to clarify mechanisms of a chain of errors. The chain of errors discussed in the present study was divided into two processes, intrapersonal, and interpersonal. An intrapersonal chain of errors is the process in which the emotions of the person making errors provoke further errors, whereas an interpersonal chain of errors is the process in which emotions triggered by errors and problems that are caused by others result in continuous errors. Intrapersonal chains of errors were examined in the present study; furthermore, we examined the basic psychological paradigm of responses made after a person makes errors.

The change of response time after making an error is known as Post-Error Slowing (PES). Rabbitt (1996) gave consecutive multiple-choice tasks to participants and analyzed their responses after they made errors. The result indicated that the error responses themselves were made more quickly than other responses, and responses after the errors were delayed. The error rate decreased along with PES after the error. Rabbitt suggested that, when faced with errors, participants became more cautious, so as not to repeat the same mistake. The study conducted by Rabbitt indicates that committing errors leads a person to try and control his or her behaviors and cognitions (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Gehring, Goss, Coles, Meyer, & Donchin, 1993).

Conventional PES studies are conducted based on errors made by the participants. However, following the definition of a chain of errors in the present study, two cases of errors were considered. One was conventional errors that are made by participants (self-made errors), and the other were errors and problems caused by others. The present study explored whether the PES is characteristic of self-made errors or not.

In order to investigate our research question, a continuous simple task conducted over several hundred times, and feedback of correct, or wrong responses was given for every trial, by using the Simon task (Simon, 1990). The Simon task is known to be a response competition task, in which participants respond to given stimuli by pressing a certain key. For example, two types of stimuli such as red and green circles can be used. Participants are instructed to press a button on the left hand side when they see

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the green circle and to press the button on the right hand when the red circle is presented. Though there are only two stimuli, they are presented on the left or right side from a fixation point located in the center. When the stimuli are presented on a side congruent with the responding hand (relevant condition), the participants can respond without a problem, however, when the stimuli and responding hand are incongruent (irrelevant condition), the response time become longer, or the correct response rate decreases. The Simon effect refers to the response difference in these relevant and irrelevant conditions.

The Simon task was used, because in this task, participants can readily recognize the errors they make. The errors in the Simon task occur due the response competition for spatial information between stimuli and responses. Furthermore, a certain amount of errors on average can be expected based on the results of previous studies. The Simon task guarantees spontaneous errors and the recognition of self-made errors, making it an appropriate task to explore our research question.

In the present study, two conditions were developed, a normal condition in which the response feedback in the Simon task was given for each trial, and the false-feedback condition in which wrong feedback was given from time to time. In the normal condition, the feedback corresponded to responses made by participants, and participants were expected to better recognize their errors. On the other hand, in the false-feedback condition, wrong feedback was given at a certain rate regardless of the participants' responses. Participants were instructed that this feedback occurred because of a programming bug, such that in the false feedback condition, participants could perceive errors and problems caused by others including the experimenter. Different to typical interpersonal error situations, the instructions about a "programming bug" was expected to reduce emotions such as surprise, or feeling flustered that would be evoked by unexpected situations, whereas emotions, such as unpleasant feelings, and dissatisfaction might be induced, as a result of producing errors despite making the correct response. These conditions were expected to facilitate clear attribution of errors to either the self, or to others, because obviously errors in the false error condition would have been caused by others. The present study compared responses after self-made errors and responses after false-feedback.

It was expected that errors would affect not only the participants' subsequent performance, but also their emotions, depending on whether errors were attributed to themselves or not. Thus, we could also assess the emotional responses of participants when they made errors. Few studies have focused on the increase in emotional responses after a person makes errors. Wada & Ueda (2012) conducted a study using a train-driving simulator and assessed emotional reactions of participants when they made different types of errors or caused problems. The results indicated that relatively large problems, such as collision between railway cars and automobiles at railway-crossings, or the extreme overrun of platforms, triggered strong emotions, such as surprises, hurrying, and irritation, when compared to other problems. However, slight overruns triggered strong regrets compared to other problems. Since slight overruns often occur in daily lives due to the handling of brakes, it was assumed that emotions similar to self-made errors would be experienced among the participants. The nature of errors, whether errors could be attributed to the self, or others, triggers different types of emotions. Thus, emotions of participants were assessed and compared under two conditions: self-made error condition and when errors are attributed to others.

Method

Participants

Participants were 25 men (Mean age 27.8 years, Age range 22 to 34 years).

Simon task

The Simon task was used in the present study. Participants were instructed to respond as quickly as possible with a certain hand, based on the shapes presented on a screen. Participants were also required to use buttons provided for both their hands and feet, so as to induce a higher level of difficulty than responding simple by using the hands. Responses in which both hands and feet were pushed appropriately were considered correct responses. The response time was defined by the slower response of the two responses, i.e. correct hand response and correct foot response. Half the participants were told to respond with the right hand and foot when a red circle was presented on the screen

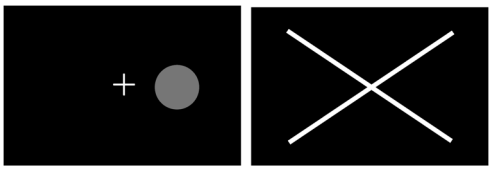

Figure 1 Example of the screens shown to the participants during the Simon task
The left screen shows the stimulus presentation, and the right screen shows the feedback. The feedback sign stretched across whole screen.

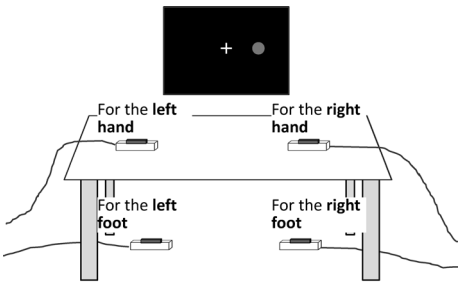

Figure 2 The assembly of devices used in the experiment
The computer was placed in a different room and it regulated the presentation of stimuli and recorded the responses.

and with the left hand and food when a green circle was presented on the screen. The other half of participants was told to do the opposite. The stimuli were limited to red, or green circles, and, in each trial, either circle was randomly presented on the left or right side of the screen (Figure 1). The feedback for the responses made by the participants was given in every trial. When the participants made correct responses the shape "○" appeared on the screen, and when the participants made wrong responses the shape "×" appeared on the screen and a beep was sounded. Participants had two seconds to respond in each trial. When the participants did not make a response within two seconds of the stimulus presentation, "×" also appeared on the screen and the beep sounded.

One block contained 160 trials. Of these trials, the red circle was shown on half the time and the green circle on the other half. Moreover, on half the trials, the stimulus was presented on the right side of the screen, whereas it was shown on left on the rest of the trials.

Devices

A personal computer FUJITSU LIFEBOOK AH550/5B (Windows 7, 32 bit) and a screen MITSUBISHI LDT551 V, as well as speakers, ONKYO GX-77M were used for stimulus presentation. A programmable keyboard KB-IOPAD4 for the hand responses, and a foot switch OFL-SG5-H-MCA-1-1.6M were used as responses input devices. A personal computer AH550/5B was used for stimuli presentation and recording responses. A program was developed using Microsoft VisualBasics 6.0 for stimuli presentation and response measurements. The devices were arranged on a table as shown in the Figure 2.

Measurement criteria

Response times and error responses were recorded as behavioral indices. Subjective feelings were assessed by using a questionnaire developed for assessing emotions, as well as the short, Japanese version of POMS (Yokoyama, 2005a, 2005b).

The questionnaire that was used for assessing emotions was originally developed in a previous study (Wada, 2010; Wada & Ueda, 2011, 2012). In this questionnaire, participants estimate the level of their feelings regarding each of 25 emotional words, such as surprise, arousal, and fear, using a 9-points scale. In previous studies (Wada, 2010; Wada & Ueda, 2011, 2012), we have presented different errors using train-driving simulators and assessed the emotions of participants by using this questionnaire. Factor analysis of the responses that were obtained enabled the identification of three emotions, surprise/hurry (e.g., flustered, surprised, hurried), irritation (e.g., displeased, troubled, irritated), and regret (e.g., regret, shame, sadness). In the present study, we assessed participants' emotions based on scores for these three emotions under each experimental condition.

Procedure

Before the experiment, the experimenter explained the study to the participants. Then the participants responded to the POMS and emotional questionnaire. Then, participants were explained about the task, following which they conducted a trial. After the practice trial, participants were given an opportunity to ask questions about the task. Once we confirmed that the participants had no more questions, the trial started.

A trial was conducted as follows: first, the fixation

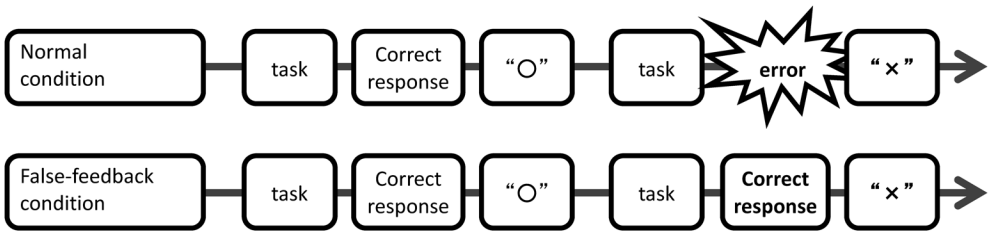

Figure 3 The flow of the experiment in each condition

point was presented on the screen, and then the red or green circle appeared after one second, either on the left or the right side of the fixation point. Once the stimulus was presented, the participants were told to respond as quickly as possible using their corresponding hand and foot by pressing the buttons. If the response was correct, the shape "○" quickly appeared on the screen, whereas the shape "×" quickly appeared if the response was wrong. After the feedback, the fixation point reappeared for one second and then the next trial was presented (Figure 3).

Each participant went through four blocks of 160 trials. Of these, two blocks were in the normal condition and two blocks were in the false-feedback condition. Each condition was consecutive. Half of the participants experienced the normal condition first, and the rest of the participants first experienced the false-feedback condition. Before going into the false-feedback condition, participants were told that they may experience a program bug so they may see "×" on the screen regardless of their responses. In the case that participants experienced the normal condition after the false-feedback condition, they were told that no such thing would happen. After finishing every block, the participants responded to the POMS and emotional questionnaire.

Upon completing all the trials, participants were asked how they had felt during the trial and how much they had believed in the program bug. At last, they answered the questionnaires again during rest and completed the experiment. The experiment took two hours for each person to conduct.

Results

Response judgment

The response times and error rate after making errors were examined. For the error rate, the correct and wrong responses were categorized based on the following criteria. Wrong responses were considered as original error trials, and defined as responses that actually lead to the error feedback when both hand and foot pressed a wrong button and when the participants could not correctly respond with both hand and foot within the limit. In addition to the previous two cases, two other types of errors were defined; when the hand and foot responded differently and when participants re-pressed the same button (which was inadequate to be considered a correct response). Although the latter two errors did not lead to wrong feedback, they were different from correct responses, and they were categorized as error responses only after original error trials.

Post-error responses

We analyzed responses after error feedback (post-error responses) in the normal and false-feedback conditions, excluding participants that made no original error from analyses. First, we analyzed response times of the first to the fifth responses after the original error trial for each condition (Figure 4, $n=15$). In the false-feedback condition, the trial resulting in false-feedback was used as the original point instead of the error trial in which the participant made the actual error. A two-way analysis of variance ANOVA, for the two conditions (the normal and the false-feedback conditions)×5 post-error responses (first to the fifth), was conducted for response times that had been logarithmically transformed. The result indicated a significant main effect of times of trials from the error response, $F(4, 56)=7.46$, $p<.001$, $\eta_p^2=.35$. Moreover, there was a significant interaction between the condition and trial times from the responses, $F(4, 56)=4.42$, $p<.005$, $\eta_p^2=.24$. A post hoc analysis revealed a simple main effect of condition at the first trial, $F(1, 14)=12.97$, $p<.005$, $\eta_p^2=.48$, indicating that the response time the after error was longer in the normal condition than in the false-feedback condition.

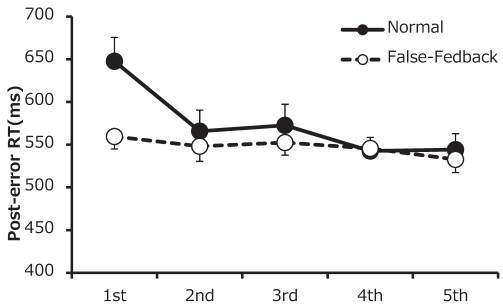

Figure 4 Response time after the feedback in each condition

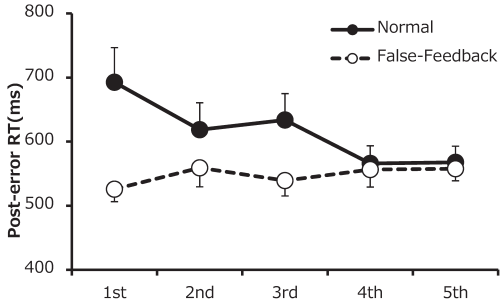

Figure 5 Response time after error feedback in each condition (data of continuous errors only)

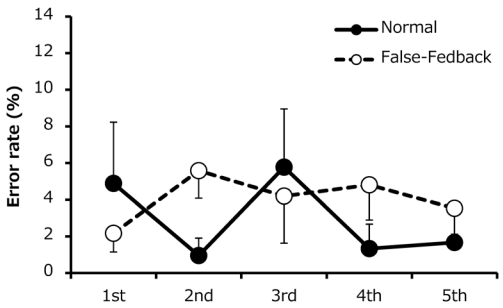

Figure 6 Error rate after the error feedback in each condition

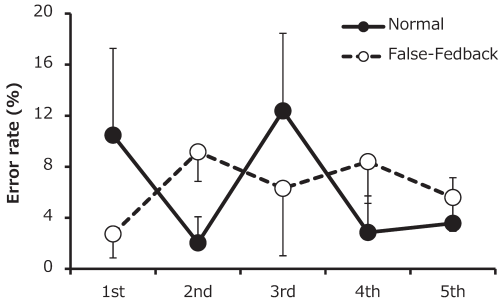

Figure 7 Error rate after error feedback in each condition (data of continuous errors only)

The purpose of the present study was to investigate an intrapersonal chain of reactions. Therefore, we analyzed continuous errors by identifying participants that made at least one continuous error within 5 trials of making the original error (Figure 5, $n=7$). The result indicated a marginally significant main effect of condition, $F(1, 6)=5.60$, $p=.06$, $\eta_p^2=.48$. Furthermore, the interaction between condition and trial times after the error responses were significant, $F(4, 24)=5.12$, $p<.005$, $\eta_p^2=.46$. A post hoc analyses revealed that the first and third trials after the error responses significantly differed as a function of the condition, the first trial, $F(1, 6)=8.40$, $p<.05$, $\eta_p^2=.58$; and the third trial, $F(1, 6)=12.20$, $p<.05$, $\eta_p^2=.67$.

A two-way ANOVA, 2 conditions×5 post error responses, was also conducted on error rates of post-error responses (Figure 6), which indicated no significant effects. Moreover, there was no significant effect for participants that made continuous errors (Figure 7). Therefore, the error rate was considered not to differ as a function of the conditions.

Since the present study utilized the Simon task, we analyzed differences in post-error responses between relevant and the irrelevant trials. Of those participants that made continuous errors, five participants who experienced both post-error responses in relevant and irrelevant trials were chosen, and their response times for each type of trial were averaged. Then, we performed condition×relevance, two-way ANOVA (Figure 8). The number of the trials after the error response was limited to the third trial, because the pervious analyses revealed that a simple main effect was observed up to the third trial.

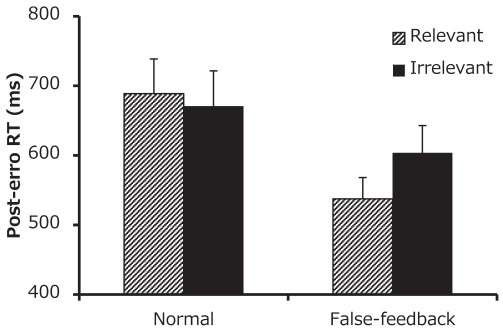

Figure 8 Response times for three relevant and irrelevant trials after making error (data of continuous errors only)

The results indicated that an interaction between condition and relevancy, $F(1, 4)=18.61$, $p<.05$, $\eta_p^2=.82$. Post hoc analysis revealed no simple main effect of relevancy in the normal condition, and a marginally significant simple main effect of congruency was only observed in the false-feedback condition, $F(1, 4)=6.55$, $p=.06$, $\eta_p^2=.62$. Moreover, although there was no simple main effect of condition in irrelevant trials, there was a marginally significant simple main effect of condition in relevant trials, $F(1, 4)=7.22$, $p=.06$, $\eta_p^2=.64$.

Emotional reactions

In order to examine emotions associated with a chain of errors, the participants were divided into two groups, the group in which participants did not show continuous errors (non continuous error group) and participants showing continuous errors (continuous error group). We compared pre-measured indices in these two groups in each condition (Figure 9). A two-way ANOVA with continuous errors (present or not present)×measurement point (pre-trials, normal, false-feedback) was conducted. The result indicated that of the three dimensions of the questionnaire assessing emotions, the regret factor showed a significant interaction between continuous errors and measurement point, $F(2, 42)=2.57$, $p=.09$, $\eta_p^2=.11$. A post hoc analysis revealed a significant simple main effect of continuous errors in the normal condition, $F(1, 21)=3.28$, $p=.08$, $\eta_p^2=.14$, and that the participants had more regrets when they made continuous errors in the normal condition, or intrapersonal chain of errors, than when they did not make the continuous errors, whereas the other indices were not significant.

Each index of POMS was also analyzed using a continuous errors×measurement time, two-way ANOVA, which indicated no significant effects.

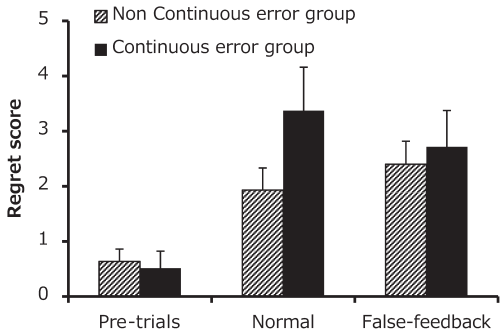

Figure 9 Score of regret index at pre-trials, normal condition, and false-feedback conditions

Discussion

The present study was conducted to examine the process of intrapersonal chains of errors by consecutive presentation of the Simon task. The result of the study indicated that error rates after the error feedback did not significantly differ as a function of error type; self-made errors, or errors attributed to others. On the other hand, the response time was delayed at the first trial after a self-made error, which clearly identified characteristic reactions after a self-made error, which was objective of the present study. Moreover, we identified that participants making continuous errors and analyzed their response time, which indicated that the delay was extended to the third trial. These results suggest that the delay in response times was longer when there was a relatively strong error tendency after the original error.

Moreover, results indicated that regret was affected by differences between conditions and the presence of continuous errors. Particularly, participants that made continuous errors scored had higher regret scores in the normal condition, thus regret could have been an emotional characteristic of these participants.

PES was a clear observation of changes in performance after making errors. This is in line with previous studies, such as Rabbitt (1966). The PES, or the delay of responses, observed in the present study has two possible causes; participants became more cautious after making errors, or they were confused and could not make the right decisions. One reason could be because participants that made continuous errors showed a stronger tendency to have longer response times after making errors. It suggests that the participants' solutions for taking a long time to respond did not necessarily lead to the right response. Therefore, participants could have been in a state confusion and could not make normal decisions. On the other hand, the result of the Simon task indicated that there was no difference between relevant and irrelevant trials after making self-made errors. If the participant was simply confused, the response time should have been longer, regardless of the relevance; however, the response time was longer only in relevant trials. This indicates that even in easy trials, such as relevant trials, participants spent a similar

time as in irrelevant trials, and were cautious about responding. That is, as a behavioral tendency, participants tried to control their behavior in order to decrease the possibility of making the wrong responses. From the above discussion, it can be assumed that after making errors participants were cautious and tried to decrease reoccurrence of errors, however, their cognitive processing ability had decreased, which resulted in making continuous errors.

It was expected that one factor promoting continuous errors was emotional characteristic regarding self-made errors. The present study indicated that participants who made continuous errors experienced emotional regret. Previous studies about intrapersonal chains of errors (Wada, 2010; Wada & Ueda, 2011, 2012) have indicated that surprises and hurry were central emotions associated with errors. However, the results of the present study were different, suggesting emotions experienced in self- made errors could be different from emotions experienced as a result of errors attributed to other factors. In the present study, we measured participants' emotion at the end of each block, thus we cannot draw causal inferences between continuous errors and the experience of emotions. In the future, we need to clarify this relationship and investigate details, such as errors when the "regret" factor was experienced, and their effect on cognitive processes.

The present study indicated that responses after self-made errors led to a delay in responding. Moreover, it was suggested that the underlying cause of the delay was pertaining to behavioral control, which aimed to decrease making continuous errors, but nonetheless, such behavior was inadequately processed by cognition, which resulted in participants making continuous errors. In the present study, however, the overall error rate was low, suggesting the need to accumulate more experimental data, in order to confirm our findings.

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