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An examination of the sequential trial effect on experiences of agency in the Simon task

Yuru Wang, Tom G.E. Damen, Henk Aarts*

Department of Psychology, Utrecht University, the Netherlands

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ABSTRACT

Previous research shows that agency experiences are reduced when response selection is dysfluent. Expanding on this work, we report two experiments addressing the influence of Simon response conflict on agency. Participants responded to congruent and incongruent Simon task trials and indicated their experienced agency after each response. Results show that incongruent trials were related to reduced agency experiences, thus replicating earlier work on the response-selection agency-link. Furthermore, the data further showed an interesting sequence effect: The congruency effect on experienced agency mainly emerged when a trial was preceded by a congruent trial. There was however no congruency effect on experienced agency when a trial was preceded by an incongruent trial. These findings are briefly discussed in the context of research on response selection and experiences of agency.

1. Introduction

The sense of agency is the pervasive experience of performing a voluntary action or causing an effect (Aarts, Custers, & Wegner, 2005; Gallagher, 2000; Haggard & Tsakiris, 2009). The experience of agency has attracted considerable scientific interest over the past decade, as numerous studies have shown that this experience can be influenced both by internal and external cues (e.g., David, Newen, & Vogeley, 2008; Moore & Fletcher, 2012; Moore, Wegner, & Haggard, 2009; Synofzik, Vosgerau, & Voss, 2013). One factor that has been argued to alter the sense of agency concerns a person's ability to fluently select one response out of many response-possibilities (Haggard & Chambon, 2012; Sidarus & Haggard, 2016; Wenke, Fleming, & Haggard, 2010). In the present study we expand on the response fluency-agency link by investigating response selection and agency in a response-conflict task.

1.1. Agency: Prediction and inferences

Two processes have dominated the literature on the sense of agency over the past years. First, agency can emerge through a process of forward prediction. That is, prior to action performance, the sensory consequences of the actions are simulated. A subsequent match between the simulated and actual effects will lead to an increased sense of agency, and a mismatch will reduce it (Blakemore, Wolpert, & Frith, 2000, 2002). Whereas this primary assessment of agency originates from the workings of the sensorimotor system, experiences of agency may also occur on a cognitive level following inferential processes (Wegner & Wheatley, 1999; Wegner, 2002). Agency can be inferred when it is easy to relate one's actions or the action effects one produces to any thoughts preceding it (Aarts et al., 2005; David, Stenzel, Schneider, & Engel, 2011). Besides, agency beliefs (Desantis, Weiss, Schütz-Bosbach, &

* Corresponding author at: Utrecht University, Department of Psychology, Heidelberglaan 1, 3584 CS Utrecht, the Netherlands.
E-mail address: h.aarts@uu.nl (H. Aarts).

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Waszak, 2012; Dogge, Schaap, Custers, Wegner, & Aarts, 2012) or contextual information (Damen, Van Baaren & Dijksterhuis, 2014; Dijksterhuis, Preston, Wegner, & Aarts, 2008) have been shown to modulate the experience of agency.

1.2. Response conflict as a source of agency

Recent empirical attention on the emergence of experienced agency has been directed at the relation between fluency in response selection and agency. The importance of fluency was first shown in a study by Wenke et al. (2010), who subliminally primed their participants with potential future actions that were either compatible or incompatible with actual future responses (e.g., presenting left arrow primes just before participants performed left or right responses). Participants reported increased agency when the primes matched the performed responses compared to when primes and responses mismatched (see also Damen et al., 2014). According to Wenke et al. (2010), congruent response primes 'smoothen' response selection. Specifically, they facilitate the response-selection processes by differentiating between response alternatives and supporting the correct response.

Recent studies on the role of response selection fluency in agency employed Stimulus-Response (S-R) compatibility tasks such the Flanker or Stroop tasks (respectively, Morsella et al., 2009; Sidarus & Haggard, 2016). In these studies, participants are typically presented with stimuli whose features provide compatible or conflicting information, thereby facilitating or interfering with response selection. The experience of agency is then usually assessed by subjective report of perceived control over performed responses and subsequent effects (e.g., pushing a button to produce a tone). For example, Sidarus and Haggard (2016) used a Flanker task showing that the conflict induced by incongruent trials impaired both action performance as well as the experience of agency, compared to the congruent trials. Similarly, in a study on response interference, Morsella et al. (2009) showed reduced perceptions of control after incongruent trials on a Stroop task (Stroop, 1935). These, and other recent findings (Sidarus, Vuorre, & Haggard, 2017; Sidarus, Vuorre, Metcalfe, & Haggard, 2017; Vastano, Pozzo, & Brass, 2017) have provided important groundwork to establish the relation between response selection (conflict) and agency.

However, S-R paradigms such as the Flanker and Stroop task actually provide two sources for conflict: There can be conflict due to observing incompatible stimulus features (the word 'blue' printed in a red font on the Stroop task, or, contrasting arrows on the Flanker task), and there is conflict between two responses (the alternative response possibilities). Systematic manipulations of these underlying processes have in fact revealed separable contributions of stimulus and response conflict (Carter & Van Veen, 2007; Dignath & Eder, 2015; Van Veen, Cohen, Botvinick, Stenger, & Carter, 2001; Zmigrod, Zmigrod, & Hommel, 2016). The question therefore remains whether fluency-agency effects are caused by the incompatibility in stimulus features, response conflict, or both. Accordingly, the Simon Task may provide important insights on the source of the fluency-agency effects given that the reduced performance on this task is inherently caused by response conflict (Hommel, 2011; Wühr & Heuer, 2017).

In the Simon task (Simon, 1969; Simon & Rudell, 1967), participants are instructed to respond to a non-spatial stimulus dimension according to an arbitrary rule while ignoring the spatial dimension of the stimulus. Specifically, in a typical *auditory* Simon task (Simon & Rudell, 1967), stimuli consist of high-pitched and low-pitched sounds that require the selection of two alternative actions. There are two dimensions of the stimuli, the identity (the pitch relevant for the specific selection of an action, e.g., low-pitch: push left, high-pitch: push right) and the position of the sound (left or right ear). When the low-pitched voice is presented in the right ear (incongruent condition), the irrelevant spatial dimension of the voice automatically activates a right-hand response and conflicts with the actually required (i.e., left-hand) response. This leads to increased reaction times and error rates compared to a spatially congruent condition. This Simon congruency effect, as mentioned above, is often attributed to the conflict at the response-selection stage. Therefore, if an incongruent condition on the Simon Task could be shown to be related to reduced experiences of agency this would provide strong evidence for the importance of response selection for the sense of agency.

1.3. Sequence effects in performance and agency

Our ability to fluently select and performs action is not only influenced by the parameters of the present but also by those of the past. For example, many studies that featured S-R compatibility paradigms have revealed that performance on present trials is modulated by the nature of earlier trials. Specifically, performance on an incongruent conflict trial typically impairs when that trial was preceded by a congruent conflict trial. However, and importantly, performance on an incongruent conflict trial considerably improves when that trial was preceded by another incongruent conflict trial. This congruency sequence effect (CSE; aka as the Gratton effect) has been commonly referred to as conflict adaptation Botvinick, Braver, Barch, Carter, & Cohen, 2001; Gratton, Coles, & Donchin, 1992; but see Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014a, 2014b; Egner, 2007 for a discussion of several accounts for the CSE).

Although the processes underlying sequence effects are a matter of much debate and thus remain tentative, they reliably occur to influence response selection and performance. Because most of the research on the sense of agency addresses single actions and events (but see Sidarus et al., 2017 using a game context), the degree to which the subjective experience of agency is also sensitive to sequential effects has not been empirically examined so far. Given the close relation between response fluency and performance on the one hand, and agency on the other hand it would therefore be interesting to explore the influence of sequence effects in performance on the experience of agency.

1.4. The present research

In the present research we investigated the relation between action selection fluency and the experience of agency in the context

of sequential actions. In two studies participants performed an auditory Simon task in which they had to respond to targets to cause a tone to occur (see Wang, Damen, & Aarts, 2017; for a demonstration for experienced agency of operant actions assessed by implicit measures – intentional binding – in the Simon task). The targets were presented in locations that were either congruent or incongruent with the physical response locations. After responding to a target participants were presented with a tone, and were then asked to indicate the degree to which they felt to cause the tone to occur. Apart from the typical congruency effects on performance, we expected higher levels of experienced agency on the congruent rather than incongruent trials. Furthermore, we explored sequence effects on action performance (reaction times and errors) and subjective experience of agency.

2. Experiment 1

2.1. Method

2.1.1. Participants

Based on previous findings in a series of experiments reported by Sidarus et al. (2016), we aimed to gather at least a test-sample of 25 subjects. Thirty-one university students (M_{age} = 23.29 years, SD = 2.60, 17 females) were recruited. Participants gave written informed consent and were paid 8 Euros for participation in this experiment. All participants were right-handed, and reported having normal audition. Five participants were excluded from the analysis due to a programming error.

2.1.2. Materials and procedure

The procedure and materials of the adapted Simon task were based on Wang et al. (2017). In this task, participants learn to respond to targets to cause a single tone to occur, and to indicate their feelings of control over triggering the tone. Participants first learned the associations between the auditory targets and the subsequently required actions. At the start of each trial, participants heard the spoken Dutch target word “ja” (which means “yes”), which was played binaurally through a headset. Either a high pitch or a low pitch male voice expressed the target. Participants were instructed to press the left button with the index finger of the left hand when they heard a high pitch voice, and to press the right button with the index finger of the right hand when they heard a low pitch voice (or vice versa). Participants were told to respond as fast and accurately as possible. On the first 10 trials participants received feedback on the correctness of their responses. In total, participants were given 50 trials to learn the target-response associations. A Cedrus R530 response pad was used in the present study.

After participants completed the association-learning block, they practiced the target-response associations in another block consisting of 20 trials. In this block participants also learned that their correct response caused a tone to occur 250 ms later (frequency = 600 Hz, duration = 100 ms). If they committed errors, i.e., pressed the wrong button, no tone would occur. Participants subsequently got acquainted with the agency rating procedure and completed 12 trials in which they responded to the auditory targets, heard tones, and were required to report agency judgements (“How much control do you feel over triggering the tone by your action”, from 1 = *“least control”* to 9 = *“total control”*), using the measure employed by Sidarus and Haggard (2016).

The procedure in the test phase was similar to the last block of the practice phase. A crucial difference compared to the practice phase was that the high pitch and low pitch target voices were not presented in both ears, but were randomly presented in either the left ear or the right ear (i.e., an auditory Simon manipulation). Participants were again required to respond to the voice targets with their left of right hands, thus creating spatial compatibility (e.g., presentation in left ear, left response) and spatial incompatibility (e.g., presentation in left ear, right response). As in the practice phase participants were instructed to press the corresponding button as fast and accurately as possible to cause the tone to occur. 250 ms after the key-press, a tone (frequency = 600 Hz, duration = 100 ms) occurred following the correct response. The test phase consisted of four blocks of 40 trials each. Inter-Trial Intervals (ITIs) varied randomly, between 3000 and 5000 ms. If participants selected the wrong button, or they did not respond in time (1000 ms), then the trial would be repeated at the end of the corresponding block. The trials with wrong button presses, the trials following the error trials (Clayson & Larson, 2011; Verguts, Notebaert, Kunde, & Wühr, 2011; Nieuwenhuis et al., 2006), and trials where participants did not react within 1000 ms were excluded from the analyses on RTs and agency.

To explore the sequence effects in performance and agency, we followed previous procedures (Clayson & Larson, 2011) by classifying each trial according to its congruency and the congruency with the preceding trial, which resulted into four types of trials: congruent trials preceded by congruent trials (CC); congruent trials preceded by incongruent trials (IC); incongruent trials preceded by congruent trials (CI); incongruent trials preceded by incongruent trials (II). The CC and II trials were considered as cognitively similar sequences; The CI and IC trials were considered as a cognitively dissimilar sequence.

2.2. Results

2.2.1. Simon reaction times

The Reaction Times (RTs) results are presented in Fig. 1.1A. The mean RTs of correct trials were subjected to a repeated measure ANOVA with previous-trial congruency and current-trial congruency as two within-subjects factors (previous-trial congruency: congruent vs. incongruent; current-trial congruency: congruent vs. incongruent), and mapping as a between-subjects factor (mapping: low-right/high-left vs. low-left/ high-right). These analyses revealed a main effect of current-trial congruency, indicating a Strong Simon effect, $F(1, 24) = 70.92$, $p < .001$, $\eta_p^2 = 0.75$. Mean RTs on the incongruent trials were longer than the mean RTs on the congruent trials ($M_{incongruent}$ = 638.28, SD = 68.04; $M_{congruent}$ = 595.45, SD = 74.88). The main effect of previous-trial congruency was not significant, $F(1, 24) = 1.48$, $p = .236$, $\eta_p^2 = 0.06$. More importantly, there was a significant interaction effect

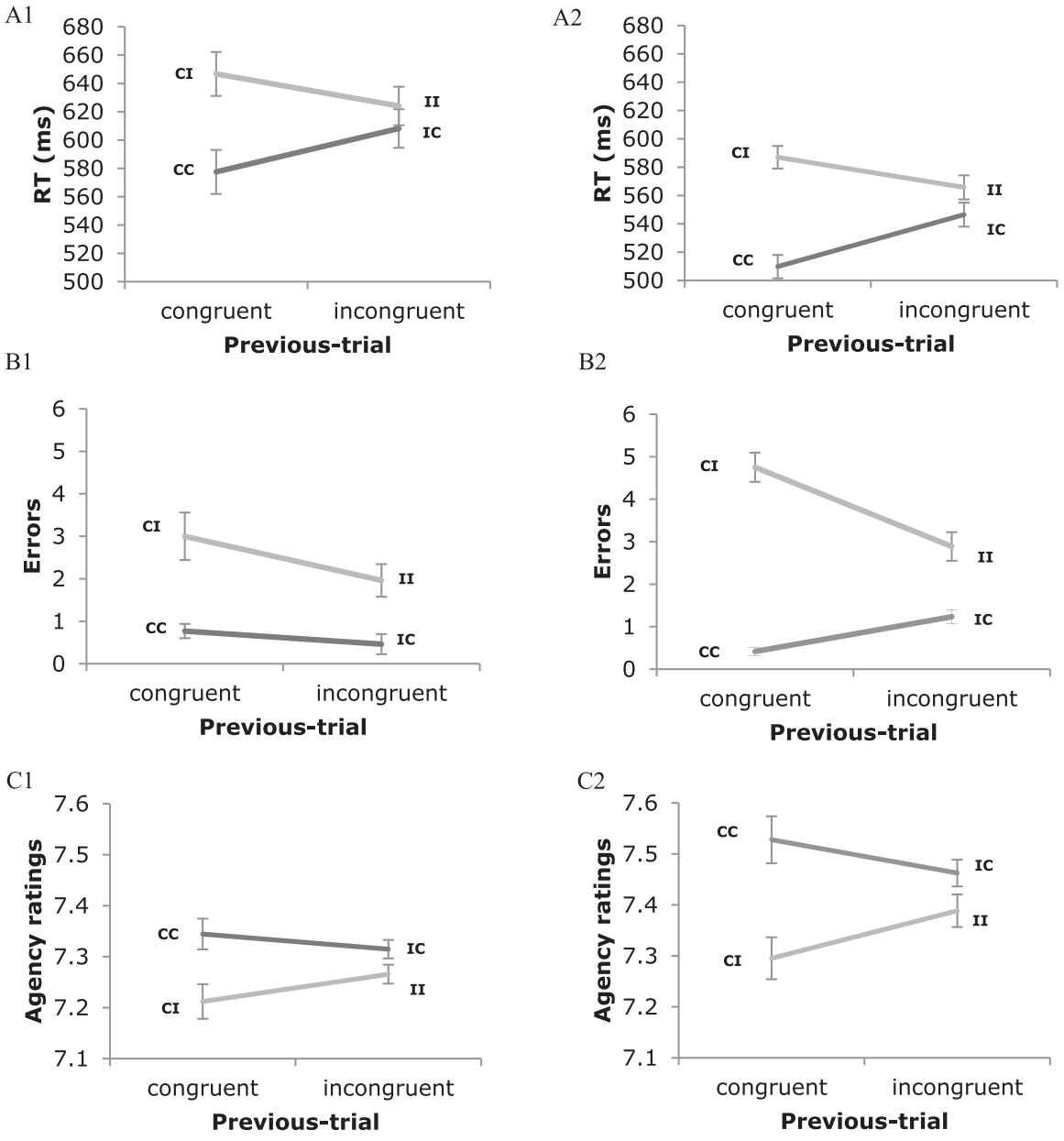

Fig. 1. (1.1) (Left) Results for Experiment 1. (1.2) (Right) Results for Experiment 2. Panel A shows Mean RTs as a function of current-trial congruency and previous-trial congruency; Panel B shows the mean error number; Panel C shows mean agency ratings. RTs, errors, and agency ratings revealed a congruency effect and this congruency effect was reduced after incongruent trials compared to congruent ones. Error bars show standard errors of the means. CC: congruent trials preceded by congruent trials; IC: congruent trials preceded by incongruent trials, CI: incongruent trials preceded by congruent trials; II: incongruent trials preceded by incongruent trials.

between previous-trial congruency and current-trial congruency $F(1,24) = 38.22$, $p < .001$, $\eta_p^2 = 0.61$, demonstrating a smaller Simon effect (incongruent RTs – congruent RTs) after incongruent trials ($M_{difference} = 15.81$, $SD = 31.52$), $p = .017$, dz = 0.50, than after congruent trials ($M_{difference} = 69.19$, $SD = 35.57$), $p < .001$, dz = 1.95.

2.2.2. Accuracy

The results for accuracy are presented in Fig. 1.1B. The overall accuracy rate of Experiment 1 was 96.63%. The number of button-press errors were submitted to a repeated measure ANOVA. The results showed a main effect of current-trial congruency, $F(1, 24) = 19.76$, $p < .001$, $\eta_p^2 = 0.45$. Participants committed more errors on the incongruent trials than on the congruent trials ($M_{incongruent} = 4.96$, $SD = 4.40$; $M_{congruent} = 1.23$, $SD = 1.80$). The main effect of previous-trial congruency was also significant, $F(1, 24) = 9.49$, $p = .005$, $\eta_p^2 = 0.28$. There were fewer errors when the previous trial was incongruent ($M_{incongruent\_previous} = 2.42$,

SD = 2.50) compared to when the previous trials was congruent ($M_{congruent\_previous}$ = 3.77, SD = 3.14). Though the interaction between previous-trial congruency and current-trial congruency was not significant, $F(1, 24) = 2.27$, $p = .145$, $\eta_p^2 = 0.09$, there was a clear trend: The Simon effect (incongruent errors – congruent errors) appeared to be stronger after congruent trials ($M_{difference}$ = 2.23, SD = 2.82), dz = 0.79, than after incongruent trials ($M_{difference}$ = 1.50, SD = 2.06), dz = 0.73.

2.2.3. Agency ratings

The agency ratings results are presented in Fig. 1.1C. The mean agency ratings were submitted to a repeated measures ANOVA. These analyses revealed a main effect of current-trial congruency, $F(1, 24) = 5.99$, $p = .022$, $\eta_p^2 = 0.20$. The mean agency ratings on the incongruent trials were lower than the mean agency ratings on the congruent trials ($M_{incongruent}$ = 7.22, SD = 1.70; $M_{congruent}$ = 7.32, SD = 1.67). The main effect of previous-trial congruency was not significant, $F(1, 24) = 0.38$, $p = .541$, $\eta_p^2 = 0.02$. Also, the interaction effect between previous-trial congruency and current-trial congruency was not significant, $F(1, 24) = 1.19$, $p = .286$, $\eta_p^2 = 0.05$. For exploratory purposes, we analyzed the agency-congruency effect as a function of previous trial-type. These analyses showed that the congruency effect (congruent ratings – incongruent ratings) was absent when the previous trial was incongruent ($M_{difference}$ = 0.03, SD = 0.16), $F(1, 25) = 2.40$, $p = .134$, dz = 0.19, but present when the previous trial was congruent ($M_{difference}$ = 0.13, SD = 0.31), $F(1, 25) = 4.64$, $p = .041$, dz = 0.42.

2.3. Discussion

Experiment 1 showed that incongruence between the location of a presented stimulus and a physical response location hampered response selection, and led to reduced experiences of agency (or alternatively, congruency facilitated response selection and agency). We therefore replicate previous work employing other S-R compatibility tasks, such as response priming task, Flanker task, and Stroop task (e.g., Morsella et al., 2009; Sidarus & Haggard, 2016; Wenke et al., 2010). Moreover, we found a sequence effect: The Simon effect in the present experimental setup was much smaller following incongruent trials than following congruent ones. The experiment thus successfully replicates previous studies showing sequence effects in S-R tasks (Egner & Hirsch, 2005; Kerns, 2006). Importantly, a similar trend was visible for the agency ratings: The differences in agency ratings between compatible and incompatible trials were smaller when trials followed earlier incongruent rather than congruent trials – though the overall difference was not statistically significant.

It should be noted that the Simon task in the present study was different from previous typical Simon task (Egner & Hirsch, 2005; Kerns, 2006) as the agency self-report was inserted between trials. Previous literature found an attenuated sequential effect with longer inter-trial intervals in reaction time tasks (Vallesi, Lozano, & Correa, 2013) thus the self-report procedure and a relatively longer inter-trial interval of present study should be taken into account when addressing the sequential effect.

Although suggestive, the data do not allow us to draw firm conclusions about the relation between the CSE and the experienced agency. Therefore, Experiment 2 was developed to provide a replication of Experiment 1 with a larger sample size in order to achieve more statistical power. Based on previous recommendations, we aimed to include at least 2.5 times more subjects than in the first study (Simonsohn, 2015).

3. Experiment 2

3.1. Method

3.1.1. Participants

We recruited 90 university students between 18 and 30 years (M_{age} = 20.81 years, SD = 2.22, 74 females). All were right-handed native Dutch speakers, and reported having normal audition. Participants gave written informed consent and were paid 8 Euros for participation in this experiment. One participant made too many errors (> 50%) and was therefore excluded from analyses.

3.1.2. Materials and procedure

Experiment 2 was a replication of the first experiment, with one small alteration. Debriefings from Experiment 1 indicated that participants found the time between the rating and the next response trial sometimes too long, and therefore felt they had to regularly wait before the task proceeded. Therefore, shorter inter-trial intervals were used, varying randomly between 1500 and 3000 ms. Furthermore, to establish the effectiveness of the Simon task as a way to manipulate action selection fluency, at the end of the task we asked participants to indicate how difficult it was to respond in the congruent condition and in the incongruent condition. They answered on a 9-point scale (1 = "*very easy*" to 9 = "*very difficult*").[1]

[1] In Study 2 we explored the effects of different type of instructions as to the representation of the task: One group of participants was told the task would demonstrate how external cues can automatically influence behavior; another group was told the task would demonstrate how the mobilization of willpower can overcome automatic influence of external cues on behavior; external influence; another group was given no additional instructions (identical to Study 1). However, the manipulation-checks showed complete failure to influence participants' perception of the task. Also, the manipulations did not yield meaningful effects on the dependent variables. We report this manipulation as a footnote for reasons of both transparency and readability.

3.2. Results

3.2.1. Difficulty ratings

A paired *t*-test on the ratings of task difficulty showed that participants experienced more difficulty in the incongruent condition than in the congruent condition ($M_{incongruent}$ = 5.04, SD = 2.04, $M_{congruent}$ = 4.16, SD = 2.42), $t(88) = -3.68$, $p < .001$, dz = 0.39, suggesting that response selection was felt as more difficult when the auditory location and the response location differed.

3.2.2. Reaction times

The mean RTs are presented in Fig. 1.2A. The mean RTs of correct trials were subjected to a repeated measure ANOVA with previous-trial congruency and current-trial congruency as within-subjects factors (previous-trial congruency: congruent vs. incongruent; current-trial congruency: congruent vs. incongruent), and mapping as a between-subjects factor (mapping: low-right/high-left vs. low-left/high-right). These analyses revealed a main effect of current-trial congruency, $F(1, 87) = 291.03$, $p < .001$, $\eta_p^2 = 0.77$. A strong Simon effect was shown: The mean RTs of the incongruent trials were longer than the mean RTs of congruent trials ($M_{incongruent}$ = 575.69, SD = 77.03; $M_{congruent}$ = 527.28, SD = 77.94). There was also a main effect of previous-trial congruency, $F(1, 87) = 10.75$, $p = .002$, $\eta_p^2 = 0.11$. Mean RTs were shorter when the previous trial was congruent than when the previous trial was incongruent ($M_{congruent\_previous}$ = 545.78, SD = 75.84; $M_{incongruent\_previous}$ = 556.74, SD = 78.44). In general, the reaction time in the present experiment was shorter than in Experiment 1, which may be caused by the adjustment of the ITI with a relatively shorter time.

Importantly, there was a significant interaction effect between previous-trial congruency and current-trial congruency, $F(1, 87) = 179.89$, $p < .001$, $\eta_p^2 = 0.67$, indicating a decreased Simon effect (incongruent RTs – congruent RTs) following the incongruent trials ($M_{difference}$ = 19.24, SD = 34.23), $p < .001$, dz = 0.56, than following the congruent trials ($M_{difference}$ = 77.19, SD = 32.57), $p < .001$, dz = 2.37.

3.2.3. Accuracy

Mean accuracy is presented in Fig. 1.2B. In experiment 2, the overall accuracy rate was 94.61%. The number of button press errors for all experimental trials (including the wrong button choices in the rerun trials) were submitted to a repeated measure ANOVA. The results showed a main effect of current-trial congruency, $F(1, 87) = 104.68$, $p < .001$, $\eta_p^2 = 0.55$. Participants committed more errors in the incongruent trials than in the congruent trials ($M_{incongruent}$ = 7.20, SD = 5.64; $M_{congruent}$ = 1.43, SD = 2.04). There was also a main effect of previous-trial congruency, $F(1, 87) = 12.43$, $p = .001$, $\eta_p^2 = 0.13$. There were fewer errors when the previous trial was incongruent ($M_{incongruent\_previous}$ = 4.12, SD = 3.92) compared to when the previous trial was congruent ($M_{congruent\_previous}$ = 5.17, SD = 3.48). Furthermore, there was a significant interaction effect between previous-trial congruency and current-trial congruency, $F(1,87) = 58.41$, $p < .001$, $\eta_p^2 = 0.40$. The Simon effect (incongruent errors – congruent errors) was smaller following incongruent trials ($M_{difference}$ = 1.65, SD = 3.12), $p < .001$, dz = 0.53, than following congruent trials ($M_{difference}$ = 4.34, SD = 3.30), $p < .001$, dz = 1.32.

3.2.4. Agency ratings

The mean agency ratings results are presented in Fig. 1.2C. The analyses revealed a main effect of current-trial congruency, $F(1, 87) = 4.94$, $p = .029$, $\eta_p^2 = 0.054$. The mean agency ratings on the incongruent trials were lower than the mean agency ratings on the congruent trials ($M_{incongruent}$ = 7.35, SD = 1.35; $M_{congruent}$ = 7.50, SD = 1.32). The main effect of previous-trial congruency was not significant, $F(1, 87) = 0.81$, $p = .370$, $\eta_p^2 = 0.009$. Furthermore, the interaction effect between previous-trial congruency and current-trial congruency was significant, $F(1, 87) = 11.86$, $p = .001$, $\eta_p^2 = 0.12$. Simple effects analyses showed a difference between the current congruent trials and incongruent trials when preceded by congruent trials ($M_{difference}$ = 0.23, SD = 0.81), $F(1, 88) = 7.31$, $p = .008$, dz = 0.28, but that this difference was statistically absent following incongruent trials ($M_{difference}$ = 0.07, SD = 0.53), $F(1, 88) = 1.73$, $p = .192$, dz = 0.13.

4. The relationship between the performance and agency experiences

We explored whether performance itself explains our findings on agency effects. For both experiments, we examined the role of responses time and response accuracy as predictors of agency. Note that the sample size in Experiment 1 is small, and the initial sequence effect in this experiment was not significant. For the sake of completeness, however, we report the role of responses time and response accuracy for both experiments.

4.1. Response times

The response times can be considered as the output of an action selection process that is modulated by response conflict and the previous trial type. Thus RTs may serve as a cue for subjective experiences, such as the sense of agency. Therefore, linear mixed-effects models were used to model single-trial level data. The ratings were modeled by the factors current-trial congruency and previous-trial congruency. RTs were added as a covariate. Current-trial congruency, previous-trial congruency, and RTs were allowed to vary between participants (i.e., participant random intercepts and slopes). The results showed that RTs were negatively related to agency ratings and this effect was significant Exp. 2, $t(82.89) = -5.25$, $p < .001$, 95% CI = [−2.09e − 3, −9.41e − 4]; this effect was not significant in Exp. 1, $t(25.21) = -1.67$, $p = .107$, 95% CI = [−1.52e − 3, 1.56–4]. Importantly, the sequence effect

(interaction effect between current-trial congruency and previous-trial congruency) remained a significant predictor of agency ratings in Exp. 2: $t(13231.88) = 2.05$, $p = .040$, 95% CI = [0.003, 0.135]; as in the original analysis of Exp. 1, the covariance analysis produced a non-significant sequence effect, $t(3785.90) = 0.294$, $p = .769$, 95% CI = [−0.081, 0.110]. Taken together, the analyses suggest that slower responses are associated with weaker agency experiences. Importantly, the sequence effect remained significant, indicating that RTs alone cannot fully explain the sequence effect on agency experiences.

4.2. Response accuracy

We also explored the relationship between the general accuracy and agency ratings. Because the congruency sequence effect data only include accurate trials, we calculated the Pearson Product Moment correlation coefficient between general accuracy and agency experiences on the level of subjects. In neither experiment was there a significant correlation between the number of response errors and experienced agency: Experiment 1 $r(26) = 0.316$, $p = .116$; Experiment 2 $r(89) = -0.17$, $p = .103$. This suggests that variations in agency experiences cannot be easily attributed to accuracy.

5. Discussion

In the present research we employed an auditory Simon task to explore the relationship between response selection and experienced agency. In two experiments, we found a typical Simon effect: Participants were slower to respond, and committed more errors on trials on which a target locations and response locations were spatially incompatible rather than compatible (Simon & Rudell, 1967). Additionally, in the present experiments individuals reported reduced agency experiences after incongruent compared to congruent trials. We thereby replicate previous research showing that whereas fluent responding is associated with stronger experiences of agency, difficulties in responding are associated with reduced experiences of agency (Chambon, Sidarus, & Haggard, 2014; Haggard & Chambon, 2012; Sidarus et al., 2017; Wenke et al., 2010).

The present replication was important given that fluency and congruency in the Simon task paradigm are relatively straightforward to explain: Whereas the (dis)fluency emerging from the response priming task (Wenke et al., 2010), the Stroop Task (Morsella et al., 2009), and the Flanker Task (Sidarus & Haggard, 2016) can all be explained through both response conflicts *as well as* the presentation of an incompatibility across stimuli, the source of congruency effect in the Simon task is inherently caused by a difficulty in response selection. Our findings with the Simon Task therefore allow for an increased degree of certainty of the importance of response selection conflicts in the relation between fluency and agency.

In our analyses we explored sequential trial effects. In line with previous studies we found that the Simon effect was reduced following incongruent trials relative to congruent trials (Egner & Hirsch, 2005; Kerns, 2006). More importantly, however, in Study 2 (with a relatively large sample size) we also found that specific trial sequences influenced participants' reported experiences of agency. While incongruent trials were typically associated with reduced experiences of agency relative to congruent trials, this difference in reported agency became much smaller when trials were preceded by incongruent (vs. congruent) trials. Specifically, our congruency sequence exploration of the data in terms of response selection fluency effects on agency suggests a sort of Gratton effect on agency experiences. The Gratton effect commonly pertains to performance, and has been initially explained in terms of conflict adaption (Blais, Stefanidi, & Brewer, 2014; Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Clayson & Larson, 2011; Gratton, et al., 1992) but also explored in terms of different accounts (associative priming, conflict costs; Duthoo et al., 2014a, 2014b; Egner, 2007, 2014; Mayr, Awh, & Laurey, 2003; Nieuwenhuis et al., 2006; Schmidt & De Houwer, 2011; Schmidt & Weissman, 2014). Whereas the exact mechanism underlying sequence effects on performance remains unclear, it is important to note that the present sequence effect on agency experiences could not be easily attributed to actual performance alone. This novel and intriguing finding shows that whether or not one feels agency for actions is influenced by the nature and experiences of previous events and actions.

Recent conceptual developments on agency suggest that the sense of agency consists of two levels of agency: The implicit "feeling of agency" and the explicit "judgment of agency". Implicit agency has been suggested to emerge from sensorimotor prediction (Berberian, Sarrazin, Le Blaye, & Haggard, 2012; Dewey & Knoblich, 2014; Lynn, Muhle-Karbe, Aarts, & Brass, 2014; Saito, Takahata, Murai, & Takahashi, 2015), whereas explicit agency is assumed to also emerge from higher-level cognitions (Synofzik, Vosgerau, & Newen, 2008). While the present study only investigated the explicit sense of agency, a recent study by Wang et al. (2017) using the same Simon task found no effects of action fluency on implicit agency with an intentional binding measure. The findings in present study therefore provide an intriguing contrast to Wang and colleagues' findings (2017) as these research lines suggest that response selection fluency affects agency through inferential processes related to the explicit sense of agency but not sensorimotor prediction underlying the implicit sense of agency. More research is however required to further validate this notion.

On a final note, it should be stressed that the present study did not include a baseline, which makes it difficult to be conclusive about the direction of effects. Whether effects are due to facilitation, or interference, or both, cannot be resolved with the present design. A previous study using the Flanker task (Sidarus & Haggard, 2016) showed that agency ratings were significantly lower in an incongruent condition than in a congruent condition and that the difference between a congruent and neutral condition was not significant. But it is hard to anticipate whether this can be generalized to the present Simon task. Previous studies using the Simon task to determine either facilitation or interference showed mixed results (Lu & Proctor, 1995; Simon & Acosta, 1982), and more Simon-task studies featuring a baseline are therefore required to determine the direction of both the effects on performance and agency. Another limitation is that whereas previous studies revealed that shorter inter-trial intervals increased interference sequence effects - and that longer inter-trial intervals reduced them (Egner, Ely, & Grinband, 2010) – the length of the inter-trial intervals in the present studies was not recorded and could therefore not be included in the analyses.

This research replicates and expands on previous research that examines the relationship between action selection fluency and agency. It shows that difficulty in response selection leads to reductions in agency, and that this dysfluent response selection effect on agency is sensitive to the sequential action context.

Conflict of interest

There are no conflicts of interest to report for any of the authors.

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