RESPONSE INHIBITION AND STRATEGY REDUCED THE AUDITORY SIMON EFFECT IN FUTSAL ATHLETES

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Abstract

Response is usually slower and less accurate when task stimulus and required response are incompatible, but this might not be the case in open-skill sport athletes. The study aims to investigate the auditory Simon effect on the reaction time and the response correctness in male futsal athletes. Participants were 17 experienced right-leg-dominant male futsal players of Chulalongkorn University (21± 0.6 years) who refined not only automatic response but also enhanced response inhibition. In this experiment, participants performed the Simon task by stepping on either the left or right target in response to the provided auditory stimulus which was equally presented in compatible and incompatible trials. Participants were instructed to respond to the auditory stimuli as fast and accurately as possible. Participants completed 4 experimental sets, with 10 commands for each set, and 3 minutes rest between each set. Our t-test results revealed there was no statistically significance difference between the reaction time (RT) of two task conditions (p = .122). Likewise, there was no significance difference between movement time (MT) of S-R Com and S-R Incom conditions (p = .063) which demonstrated that futsal athletes could similarly maintain RT, MT, and response correctness in incompatible condition as they did in compatible condition. To sum up, our result confirmed two notions. First, athletes in open-skill sports could utilize their long-term response inhibition experience to minimalize the Simon effect that usually occurs in normal individuals. Second, response strategy could play an important role to define whether the Simon effect should occur at RT or MT duration. Decrease of the Simon effect might be due to enhanced response inhibition ability and response strategy in athletes.

Keywords: Simon effect, Response inhibition, Futsal, Cognitive control

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Introduction

It is clear that when person responds to a specific stimulus, such as in choice reaction time task, both speed and accuracy of response would be superior when stimulus and response are compatible than when they are not compatible. For example, after seeing an arrow pointing left, it would take less time with less error to response by turning to the left direction than to the right direction. The difference between response speed and accuracy when stimulus and response are spatially compatible (S-R compatible) and when they are not (S-R incompatible) is known as the Simon effect (Simon & Rudell, 1967). To date, there are two major assumptions suggested to explain mechanism of the Simon effect. First, it was proposed that when response location is irrelevant with spatial characteristic of provided stimulus, a special code would be generated to link the not-so-connected stimulus and response together, which would result in prolonged processing time and delayed response initiation, resulting in longer reaction time (RT) (Nortebaert, Soetens, & Melis, 2001; Rubichi, Iani, Nicoletti, & Umiltà, 1997).

Alternatively, the Simon effect might be a result of interferences between conditional and unconditional processing channels both activated during response selection processes. In unconditional processing channel, response that has high compatibility (or similarity, especially in spatially dimension) to stimulus would be automatically selected, while in the other conditional route response would be selected according to specific instruction regardless of the compatibility between stimulus and response. In the situation of S-R incompatibility, each processing channel acquires different sets of response causing conflict in response selection, resulting in additional reaction time (RT) used to select the appropriate response to task context (De Jong, Liang, & Lauber, 1994). It was further suggested that Simon effect can also delay movement time (MT) in case that interference between response selection occur after movement initiation (Rubichi, Nicoletti, Umiltà, & Zorzi, 2000).

However, multiple studies also found that, even robust, the Simon effects could be compromised especially in visual Simon task (Marble & Proctor, 2000; Proctor, Marble, & Vu, 2000; Tagliabue, Zorzi, & Umiltà, 2002; Tagliabue, Zorzi, Umiltà, & Bassignani, 2000; Vu, 2007). It has been suggested that with practice as least as 72 trials of S-R incompatible visual Simon task, the effect would reduce particularly in horizontal dimension (Tagliabue et al., 2002; Tagliabue et al., 2000; Vu 2007). It was further suggested that extensive practice of S-R incompatible visual Simon task for 600 trials might be able to eliminate conflict of processing and response selection in both horizontal and vertical dimension (Vu, 2007). Additionally, Iani, Rubichi, Ferraro, Nicoletti, & Gallese (2013) stated that the Simon effect could be reduced by merely observational learning such as watching the appropriate responses in S-R incompatible situation. In short, participants in their study were assigned to observe responses of S-R incompatible task made by computer. After the observation of 300 trials, the Simon effect shown in visual Simon task during the post-test were diminished. Correspondingly, a subsequent study by Theeuwes, Liefooghe, and Houwer (2014) further proposed that the Simon

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effect could also be reversed with substantial amount of instruction in S-R incompatible task, even without any actual practice. Decrease or even withdrawal of the Simon effect might be due to the ability to form task relevant S-R association mapping in short term memory after substantial amount of learning, which would be used to suppress effects of previously stored long-term S-R association (Iani et al., 2013; Liefooghe, De Houwer, & Wenke, 2013; Wenke, Gaschler, Nattkemper, & Frensch, 2009).

The Simon effect does not occur only for visual stimuli but researches also showed interference between incompatible auditory stimulus and response (Proctor & Shao, 2010; Xiong & Proctor, 2016). In fact, the Simon effect from incompatible auditory stimuli and response was found to be greater than that of visual stimuli (Wascher et al., 2001). Moreover, the auditory Simon effect does not seem to decrease as the visual counterpart even after prolonged practice (Proctor & Shao, 2010; Wascher et al., 2001). Such difference was suggested as a result of dissimilarity in basis of the Simon effect between auditory and visual stimulus (Dittrich, Kellen, & Stahl, 2014) with regard to the fact that human can perceive auditory stimuli only in particular frequency (Suzuki & Takeshima, 2004; Yost, 2009) and duration (Ratcliff & Smith, 2004; Yost, 2009) but can see almost, if not all, visual stimulus. Unfortunately, even the original Simon effect study was done using auditory stimuli (Simon & Rudell, 1967) study on the effect of S-R compatibility with auditory stimuli are very limited and required to further explore.

In open skill sports, athletes usually confront with situations requiring them to act in contradict with regular response strategies stored in long-term memory. To answer to such requirement, response inhibition ability of the executive function is very necessary as it can predict whether athletes will be able to appropriately respond to the situation (Vestberg et al., 2012). Response inhibition ability is used in selection process to find appropriate but usually uncommon response, while ignoring other automatic responses that do not match with context or task requirement. For example, football defender must refrain from responding to another player of the attacking team who quickly run behind his back but remain focus on the player who is actually controlling the ball. It has been repeatedly confirmed that open-skill sports athletes possess superior response inhibition ability than non-athletes and athletes of closed-skill sports due to their long-term experience with conditions that require response inhibition (Chan, Wong, Liu, Yu, & Yan, 2011; Wang et al., 2013; You et al., 2018). As the Simon effect is a result of difference in processing mechanism, it might be possible that athletes of the open-skill sports might be able to overrule processing conflict in S-R incompatible task and decrease degree of the Simon effect by using enhanced response inhibition capability. However, to our knowledge, there is not nearly enough evidence to support the hypothesis, especially in the auditory Simon task. Therefore, the present study was conducted to examine if athletes of open-skill sports such as futsal athletes would be able to avoid processing conflict in auditory S-R incompatible situation and decrease the Simon effect.

Methods

Participants

A total of 20 participants were initially recruited to participate in the present study. However, three of them were withdrawn from the experiment due to injuries from training and competition. Thus, a total of 17 participants (21± 0.6 years), who were right-leg-dominant male futsal players of Chulalongkorn University (Thailand), were included in the study. All participants gave informed consents to participate in the present study. All participants had at least one year of experience and were regularly trained for two hours per day, five days per week. During the experiment, all participants also competed in a tournament for one match per week on no-train day.

Materials

The experiment was set up at biomechanics laboratory, faculty of sports science, Chulalongkorn University. Eight 3-D motion capture cameras, Qualisys Oqus, Sweden, were set around the laboratory. A video camera was also place with the 3-D motion capture camera posited right in front of participants to record behavioral information. Each participant was attached with reflective marker at the head of 5^{th} metatarsal of the right foot and stood at the center of laboratory allowing the marker to be captured by the cameras. Two speakers were placed at three meters on left and right hand sides of the participants for providing auditory left-or-right word stimulus at 85 dB and 500-3000 Hz of frequency range created with Studio one 3 software. The researchers and computer were positioned behind the participant to prevent distraction. All participants were instructed to respond to the auditory stimulus by stepping one of two targets (1 x 1 ft. each) lying flat on the floor in front of the participants at 45 degrees. The targets were placed at 100% arm length in both directions. The index of item-objective congruence (IOC) of the test results were rated by 5 luminaries. The IOC result was acceptable at the level of 0.95.

Procedures

After the marker was attached, participant was instructed to respond to the auditory stimuli as fast and as accurately as possible by stepping on the left or the right target posited in front of them according to the command from a speaker, and then quickly returning to the starting position. In each trial, the word “left” or “right” was provided at one of the two speakers. When the auditory stimulus was presented from the speaker at the same side as the assignment (for example, word “left” from the left speaker), it was considered as a compatible trial (S-R Com). On the other hand, when the auditory stimulus was presented from speaker at the opposite side (for example, word “left” from the right speaker), it was considered as incompatible trial (S-R Incom). With randomly assigned order, half of S-R Com and S-R Incom trials came from the left speaker and the other half came from the right speaker. Interval between auditory stimuli were random between three to six seconds. Participants were allowed one practice block of six trials to ensure their comprehension of the task. Proceeding the practice trial, participants completed the 4 actual experiment sets with 10 commands for each set. The participants could rest for 3 minutes between each set. To prevent

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acute reverse Simon effect from learning that might occur after sufficient repeat of S-R Incom condition, participants were assigned to complete four blocks of ten trials each with three-minute break after each block, summing up to a total of 40 trials. Participants' response including reaction time (RT), movement time (MT), and response correctness were collected and analyzed as mean and standard error. Statistical analysis was performed using paired t-test with alpha level at $p < .05$.

Results

Of 20 participants, three were withdrawn from the experiment due to injuries from training and competition. Therefore, data from 17 participants were further analyzed, yielding power of test at .80 and effect size at 1.0. Performance from the practice block trials were not included from the analysis. RT was defined from the onset of auditory stimulus to the first time point that right foot movement velocity exceeded 7% of the its maximum, considered as movement initiation. MT was specified from movement initiation to movement termination, which was the time point when right foot movement velocity decreased to lower than 7% of the maximum velocity (McIsaac & Benjapalakorn, 2015).

For reaction time, participants averagely spent 0.461 ± 0.016 seconds before initiate motion response in compatible condition, and 0.475 ± 0.018 seconds in incompatible condition (Figure 1.). There was no statistical difference found between RT of two task conditions ($p = .122$). Likewise, there was no difference between MT of S-R Com and S-R Incom conditions ($p = .063$) as participants' movement times were at 0.701 ± .021 seconds and 0.720 ± 0.021 seconds in S-R Com and S-R Incom, respectively (Figure 2.)

For response correctness, only four participants responded in wrong direction with the total numbers of six error responses, and only one participant showed three response error. There were three incorrect responses happened in S-R Com condition and the other
three happened in S-R Incom condition, resulting in 99.56% of correctness in both conditions with no statistical difference of $p = 1.000$.

Table 1. Results of *t*-test Analysis between Reaction Time and Movement Time (n=17)

Variable	Compatible $\bar{x} \pm$ SE	Incompatible $\bar{x} \pm$ SE	*t*	*Sig.*
Reaction time (sec)	0.461±0.016	0.475±0.018	2.674	0.122
Movement time (sec)	0.701±0.021	0.720±0.021	4.005	0.063

Figure 1. The bar graph demonstrated reaction times spent during compatible (S-R Com) and incompatible (S-R Incom) Simon task conditions. No statistical difference was found between reaction time of S-R Com and S-R Incom conditions (p = .122). Error bar represented standard error of participants' performances.

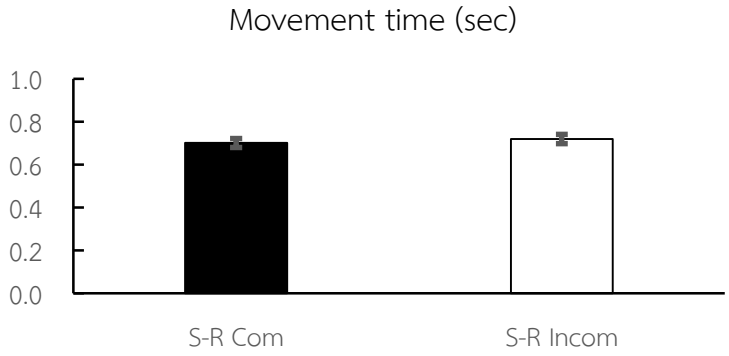

Figure 2. The bar graph demonstrated movement times spent during compatible (S-R Com) and incompatible (S-R Incom) Simon task conditions. No significant difference was found between movement time in S-R Com and S-R Incom conditions (p = .063). Error bar represented standard error of participants' performances.

Discussion

The aim of the present study is to examine the auditory Simon effect on the reaction time and the response correctness in male futsal athelents. In general, individuals would react faster and more accurate when auditory stimulus and required response share compatible spatial information than when they are not, especially in the horizontal plane of action. Differences in response duration and accuracy between compatible and incompatible conditions is called the Simon effect (Simon & Rudell, 1967). However, such effect can be minimized or even reverse when one is familiar with such incompatibility, whether it would be by actual physical practice or indirect practice such as observation and repeated instruction (e.g. Iani et al., 2013; Theeuwes et al., 2014; Vu, 2007).

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Reaction time

The result showed that there was no significant difference between the reaction time in the stimulus-response compatible condition and stimulus-response incompatible condition. It is generally known that athletes usually have superior automatic response than non-athlete counterparts, and the ability is being more advanced in very skilled athletes (Sanchez-Lopez, Fernandez, Silva-Pereyra, Martinez Mesa, & Di Russo, 2014). The ability allows athletes to have shorter reaction time in particular than the non-athlete. On the other hand, skilled athletes, especially those who practice open skill sports, also possess greater response inhibition ability than non-athletes and even closed skill sport athletes (You et al., 2018). As a result, open-skill sport athletes would be able to suppress automatic response mechanism that is inappropriate to task context with ease. It is suggested that long-term response inhibition experience resulted from practice might play a major role in enhancing the ability (Chan et al., 2011; Di Russo et al., 2006; Wang et al., 2013). Therefore, we hypothesized that if athlete's automatic response ability is dominant in response selection process, the Simon effect should persist. However, if response inhibition ability is stronger, the Simon effect should be diminished or reverse.

In this experiment, RT in S-R Com and S-R Incom conditions differed by only three percent. This might be able to explain with two possibilities. First, as mentioned earlier, our participants might possess strong response inhibition ability so that they could choose appropriate response even when dealing with conflict from the provided auditory stimulus. Since all participants in this study are experienced, it is possible that they are familiar with the situation requiring them to refrain from using automatic response process but to select response appropriate to task context. As mentioned earlier, athletes who have long-term experience in situations requiring response inhibition would be able to employ the ability quickly, especially when compared with the non-athlete (Chan et al., 2011; Di Russo, Taddei, Apnile, & Spinelli, 2006; Wang et al., 2013). It was further suggested that experienced athletes of the open-skill sports might be able to develop the speed of response inhibition without suffering from increase of response error, as it usually occurs due to trade-off between speed and accuracy (Chavan et al., 2017). This statement is yet again confirmed in the present study as response correctness was relatively high (99.56%) both in S-R Com and S-R Incom conditions.

Response correctness

Second, the result showed that there was no significant difference between the response correctness in the stimulus-response compatible condition and stimulus-response incompatible condition. It is possible that response selection processes of our participants did not occur during pre-movement initiation period but after. Rubichi and Pellicano (2004) proposed that the Simon effect should affect only the response selection processes. This might also imply that the pre- and post-selection processes should not be influenced by conflict of spatial preferences when stimulus

and response are incompatible. Furthermore, it was suggested that the Simon effect could be observed in three cases, RT only, MT only, and both RT and MT depended on when response selection processes occur (Rubichi & Pellicano, 2004), if participants in the present study initiated their movement without specifying the direction (spatial response selection), their reaction time would not be influenced by the Simon effect as a result.

We also found from video observation that participants, in a few trials, started their movements by stepping in the neutral direction between the two targets, and then quickly turn to the instructed direction. This response method might refer to response strategy to react to the auditory stimulus quickly as instructed. Therefore, instead of selecting direction prior starting movement, they decided to hasten the response by moving the right foot before specifying the direction. This assumption satisfies the statement by Rubichi et al. (2000) as well as Theeuwes et al. (2014) suggesting potential influences of instruction on the Simon effect.

In conclusion, male futsal athletes were not influenced by auditory Simon effect. Our result confirmed two notions. First, athletes in open-skill sports could utilize their long-term response inhibition experience to minimalize the Simon effect usually occurs in normal individuals. Second, response strategy could play an important role to define whether the Simon effect should occur at RT or MT duration. In situation that quick reaction is required, especially in sporting circumstances, initiation of response might be executed before response selection processes would happen so that athletes would be able to get advantages from quick response and compensating potential prolonged movement execution with greater physical capabilities. Nonetheless, the present study applied direct spatial auditory stimuli by using words “left” and “right” to mimic real sporting situations. Hence, it is very interesting for further research to investigate the Simon effect when provided auditory stimuli need to be decoded or interpreted, such as words or signals commonly used as secret instruction from coaches. Additionally, to expand knowledge about the Simon effect in sports and athletes, further research should compare if there are any differences between visual and auditory Simon effect.

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