TRANSFER LEARNING OF COGNITIVE CONTROL USING MOBILE APPLICATIONS

Vincent Setiawan, Tricia Jing Yi Chor, Yee Qi Lai, Gan Wang, Wei Lok Yap and W. Quin Yow
Singapore University of Technology and Design, 8 Somapah Road, Singapore 487372, Singapore

ABSTRACT

This research aims to explore the transfer learning of cognitive control skills using mobile applications. We explored whether mobile application can serve as a viable platform in training interference control, specifically the color Stroop task. Mobile phone's advantage lies in its portability and its ability to reach many people. Forty undergraduates from the authors' university were involved in the experiment. We introduced the use of a mobile application to present training exercises as well as to record answers and reaction times. Half of the participants were given standard logical thinking questions whereas the other half was given different types of Stroop task as a form of training, followed by the color Stroop test as a test of transference. The results showed that mobile app training using different types of Stroop task significantly improved the performance on the color Stroop Task in reaction time. Future studies can explore transfer learning of other types of cognitive control as well as explore our findings for other age groups.

KEYWORDS

Cognitive Control, Mobile Applications, Transfer of Learning

1. INTRODUCTION

Executive control, also known as cognitive control, is a group of mental processes where you must go against your intuition to achieve a wanted outcome. Exerting cognitive control is difficult as it is easier to go with the flow rather than oppose it. To exert control, an individual need to recalibrate his or her intuition and train it for the correct action (Diamond, 2013). In general, there are several types of cognitive control, e.g., prepotent response inhibition, mental-set shifting, updating and monitoring, and cognitive flexibility (Friedman & Miyake, 2004; Miyake & Friedman, 2012). Stroop task is one instance where suppressing of automatic or dominant responses is required, namely, the prepotent response inhibition aspect of cognitive control.

In a typical Stroop experiment, a reaction-timed task is used to illustrate the nature of automatic processing versus conscious visual control (Stroop, 1935). Participants were shown colored words filled with a different ink color and asked to name the ink color as fast as possible instead of the word. Participants tended to be slower in naming when the ink color was different from the text than when they were the same. (also known as the Stroop effect) Research on the Stroop effect has been extended to other tasks such as picture-word (Rosinski et al., 1975) and directional tasks (Shor et al., 1972)

Our experiment aims to explore the transferability of cognitive control, in particular, inhibitory control, using mobile application. Transfer learning has been observed from a spatial compatibility task to a color Stroop Task where manual response using keyboard is required for both tasks (Marini et al., 2011). Besides near transfer, far transfer learning from a mental-set shifting task into an inhibitory control task, e.g., from task-switching training to Stroop task, has also been observed (Karbach & Kray, 2009). However, none of these experiments have been done in the context of mobile devices.

Limited research has explored training of cognitive control in the context of mobile devices. It was shown that auditory attention, visual search, and resistance to distractor interference could be improved through mobile-application based cognitive training or mobile-based games (Bless et al., 2014; Oei & Patterson, 2013). Neither of these literatures explored training of inhibitory control with mobile devices. Cognitive control and Stroop tasks are typically conducted in a closed-door setting where participants are shown prompts on the computer and answer verbally or press on keyboard to indicate their answer. Use of mobile devices for cognitive control tests are rare and have not been done before for Stroop tasks. Mobile devices

ISBN: 978-989-8533-81-4

have huge potential in the training of cognitive control because it provides avenue for individuals to improve their cognitive control whenever and wherever they are. Moreover, mobile devices are more affordable compared to personal computers while allowing for accurate record of responses and ease of data processing.

In our experiment, we focused on Stroop task as the main indicator of transfer learning between inhibitory control tasks, that is, whether training using one type of Stroop task would improve the performance on another. We introduced the use of a mobile application where training exercises were presented to the participants and response time (RT) and accuracy to the color Stroop test was recorded. We hope our experiments can pave the way for future researchers to consider the use of mobile devices for similar experiments to reach out to more participants as well as to improve the ecological validity of the experiments.

2. EXPERIMENT METHOD

2.1 Participants

Forty undergraduate students from the authors' university participated in this study (*M* = 22 years, *SD* = 1.42; 31 males; 20 in control condition). Half of the participants were randomly assigned to a control condition, where they were given standard logical thinking questions (control group), and the other half was given different types of Stroop task as a form of training (experimental group).

2.2 Materials

We created an Android application to present the training exercises in a user-friendly and portable way. All our experiments were done on Mi Note 2 and Samsung Galaxy Note 5. In the training phase, participants in the control condition were given 10 general logical thinking questions, while participants in the experimental condition were given 10 Stroop-like questions instead (see Figure 1 and 2).

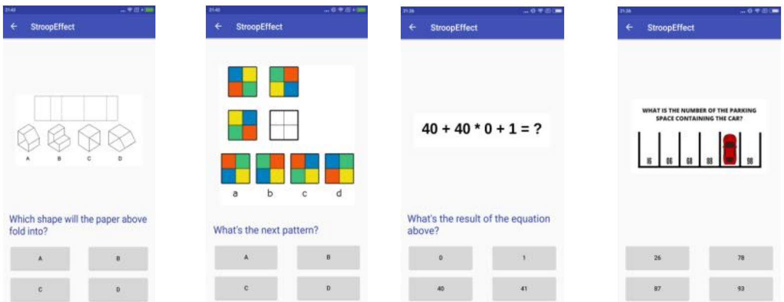

Figure 1. Examples of non-Stroop related control group question

Figure 2. Examples of Stroop task training question

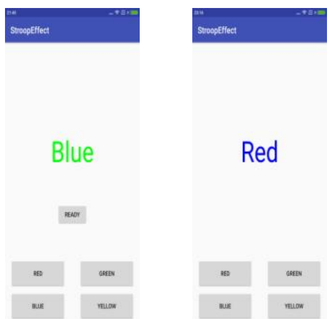

Figure 3. Examples of test question

In the test phase, all participants were given 10 color-word Stroop questions where the text was incongruent with the color it was printed in (see Figure 3). The button layout for the response key to color-word Stroop tasks were fixed to minimize the time taken for the participants to look for the correct button.

2.3 Procedure

Participants were recruited at different venues at the authors' university, such as cafeteria and library, and completed the study individually. Each participant was given a mobile device and told to answer a set of questions, untimed. After the first 10 questions were completed, the experimenter explained to the participants that the subsequent questions would be timed and instructed the participants to try to answer the questions correctly and as fast as they could. Participants were told to choose the option that corresponds to the color of the text, ignoring the text written. Participants were also asked to familiarize themselves with the buttons layout to minimize the contribution of the time taken to look for the correct options out of the total reaction time recorded. Participants' RT and the number of correct responses for the test questions were recorded and analyzed as the dependent variables of the study.

Upon completing all the questions, the mobile application presented a form to the participants that asked about gender, contact details, and color vision of the participant. All participants reported that they had normal color vision. The experimenter then explained the purpose of the experiment to the participants and concluded the experiment.

3. RESULTS

We hypothesized that the skills learned from a Stroop task presented on a mobile device is transferable to another. We first checked the normality of our RT data. Shapiro-Wilk test revealed that the *p*-value is 0.11, thus we concluded that the data comes from a normal distribution.

3.1 Response Times

We then computed the mean RT for each group. As shown in Figure 4, the average RT for the experimental group was approximately 120ms faster than that of the control group (*M* = 1225.53 vs. 1344.39 respectively).

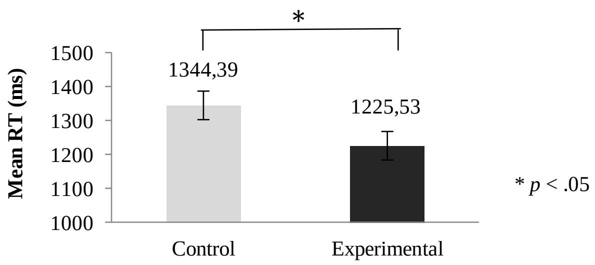

Figure 4. Mean RT of control vs. experimental group

One-way ANOVA test on RT showed a significant effect of transferability ($F(1,38) = 4.85$, $p = .034$). The experimental group was significantly faster in responding correctly to the Stroop task than the control group.

3.2 Accuracy

The average percentage of correct responses was found to be the same for both groups at 97%. Since the accuracy data was not normally distributed (*p* -value for Shapiro-Wilk test < .001), we ran a nonparametric test on the comparison of accuracy between the two groups. Mann-Whitney U-test for independent samples showed that $p = .93$. The response accuracy for the two groups did not differ significantly from each other.

4. CONCLUSION

In conclusion, we obtained evidence that mobile application can be used as a platform to train cognitive control in young adults. Results showed that participants in the experimental group at test were significantly faster than participants in the control group, demonstrating that training did improve performance. However, no significant difference in accuracy was found. This is likely because, given the (low) level of difficulty of the task, most participants were able to identify the correct answer albeit taking a slightly longer time. This is in congruence with past research on Stroop and Stroop-related tasks (Chen & Johnson,1991).

Our results serve as a motivation for greater integration of mobile application in the training of cognitive control for young adults. Mobile devices are light, portable, and are usually more intuitive than desktop computers or laptops. Given that cognitive control skills predict many life successes (Diamond, 2013; Imbrosciano & Berlach, 2005), it is important that adults can regularly train their cognitive control on the go while children can play with such mobile applications to develop their emerging cognitive control skills.

It is noteworthy that the environment in which different participants complete the test was not standardized as they were in different venues in the university. Some venues might be noisier (cafeteria) while others quieter (library). On the other hand, conducting the study in varied environments would give ecological validity to the effectiveness of the study. This would allow the mobile application to be effectively deployed in different settings that are natural and practical, such as at home and in the classroom.

As our sample population was predominantly undergraduate male, future studies should replicate the same research with equal number of male and female participants, and sampling a larger population other than those in the authors' university, such as children or older adults. Lastly, future studies should consider extending it to other components of executive control, such as mental-set shifting, both within-component transfer as well as between-component transfer, to explore whether this finding is specific to the color-word Stroop task, or it could be extended to other control tasks.

ACKNOWLEDGEMENT

We are grateful to the students who participated in this study. This work was partially supported by the SUTD-MIT IDC grant (IDG31700102) awarded to the last author. Correspondence concerning this paper should be addressed to Vincent Setiawan, Singapore University of Technology and Design, 8 Somapah Road, Singapore 487372. E-mail: vincent@mymail.sutd.edu.sg.

REFERENCES

Bless, J. J., Westerhausen, R., Kompus, K., Gudmundsen, M., Hugdahl, K. Self-supervised, mobile-application based cognitive training of auditory attention: A behavioral and fMRI evaluation. *Internet Interventions, 1*(3), 102-110.

Chen, J. Y., & Johnson, M. K. (1991). The Stroop congruency effect is more observable under a speed strategy than an accuracy strategy. *Perceptual and Motor Skills,73(1), 67-76.*

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology, 64*, 135–168.

Friedman, N. P., Miyake, A. (2004). The relations among inhibition and interference control functions: a latent-variable analysis. *Journal of Experimental Psychology: General, 133*, 101–35.

Imbrosciano, A., & Berlach, R. G. (2005). The Stroop test and its relationship to academic performance and general behavior of young students. *Teacher Development, 9(1), 131-144.*

Karbach, J., & Kray, J. (2009). How useful is executive function training? Age differences in near and far transfer of task-switching training. *Developmental Science, 12*, 978-990.

Marini, M., Iani, C., Nicoletti, R., Rubichi, S. (2011). Between-task transfer of learning from Spatial Compatibility to a color Stroop task. *Experimental Psychology, 58, 473-479.*

Miyake, A., & Friedman, N. P. (2012). The Nature and Organization of Individual Differences in Executive Functions: Four General Conclusions. *Current Directions in Psychological Science, 21*(1), 8–14.

Oei, C. A., Patterson, D. M. (2013). Enhancing Cognition with Video Games: A Multiple Game Training Study. *PLoS ONE, 8* (3).

Rosinski, R. R., Golinkoff, R. M., & Kukish, K. S. (1975). Automatic semantic processing in a picture-word interference task. *Child Development, 46*, 247–253.

Shor, R. E., Hatch, R. E., Hudson, L. J., Landrigan, D. T., & Shaffer, H. J. (1972). Effect of practice on a Stroop-like spatial directions task. *Journal of Experimental Psychology, 94*, 168–172.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643–662.