Using a smartphone game to promote transfer of skills in a real world environment

Inge Doesburg (doesburg.inge@gmail.com)
Department of Artificial Intelligence, University of Groningen, The Netherlands

Niels Taatgen (n.a.taatgen@rug.nl)
Department of Artificial Intelligence, University of Groningen, The Netherlands

Abstract

This article presents an experiment in which participant's working memory, tasks-switching and focusing skills are trained in a game called Wollie on a smartphone. Before and after the training period they performed three task (a recall, Stroop and task-switching). The goal of this research was to see how the participants, from the test group, learn within the game and how this affects the three tasks. Only in the Stroop results a clear difference between the two groups was found. However, we found that participants who had the most trouble in playing Wollie, improved the most on Stroop and task-switching, indicating that these participants still lacked the relevant skills for all these tasks.

Keywords: transfer; smartphone; working memory; task-switching; games

Introduction

The goal of this paper is to test if transfer can be found between a game on a smartphone and multiple cognitive tasks. The phenomenon of using certain skills learned in one task, while performing a different task is called transfer of skills. Taatgen (2013) describes transfer as an overlap between tasks. The author explains that skills needed to perform a task are broken down into small elements, called primitive information processing elements (PRIMs). While learning a specific skill, more general skills can be learned as well, which consist of a combination of PRIMs. When two tasks both need one or more of the same combination of PRIMs (units), training on one task can also improve the performance on the other task. When there is improvement in the second task, this means that there was transfer of the combination of PRIMs.

An important point to make is that in this study we focus on the assumption, as stated by Taatgen (2013), that the main motor of transfer is growth of skills and strategies. Many studies on transfer see brain-training as if training a muscle, but this would not explain how transfer occurs. While the primitive elements (PRIMS) theory shows how skills and strategies can be more easily understood to transfer between tasks.

Research on transfer often points to the field of education as the field that can gain the most from knowledge of transfer. Transfer can help to learn new skills quickly and most learning opportunities occur in educational facilities. Transfer is not only important within educational facilities, but also between a student's education and future workplace (Eraut, 2009; McKeough et al., 2013).

By making people train cognitive skills by using a game on their phone it will feel less like training and more like playing a fun game. This will help with keeping them excited and motivated (Prins et al., 2011). There have already been successful transfer studies using games to train certain skills (Anguera et al., 2013), but these were still played on a computer in an experimental setting. Dufau et al. (2011) have shown how cognitive research that would normally take years, can by using smartphones, be done in a couple of months.

We propose an experiment to see if transfer can occur between a game on a smartphone and three tasks played on a computer. Two groups of participants will be participating, a test and a control group. Both groups perform three tasks (recall, Stroop and task-switching) on a computer before and after training on their smartphone game. The control group receives the game Tetris, which trains no cognitive skills. The test group receives the game Wollie, which trains working memory, task-switching and focusing skills. We expect the test group to show more improvement on the task, due to transfer of skills. However, we expect improvement only to occur in those participants who do not yet posses the skills and strategies needed in the particular tasks.

Methods

Participants

54 participants (31 women, 23 men; mean age 23.4 years, range 19-39 years) participated in this study. Participants were compensated for their time.

Procedure

Participants came to the university to perform session 1 of the experiment. They needed an Android phone, with a screen size between 3.7 and 5.5 inch and have an Android version of 3.0 or higher. The first 9 digits of the IMEI number was used as a subject number, to make sure that it was easy to match the pre and post data to the data send to the server by the smartphone application. Participants performed three task, taking about 15 minutes each. The first task was a recall task, the second a Stroop task and the third a task-switching task.

After performing these three tasks, the participants were assigned to one of two groups. This was done semi-randomly to ensure that the two groups would, on average, not differ too much on their scores in the first session. For each new participant we would take the average of the three pretest scores, and compare this to the running averages of the participants that were already tested. On the basis of that comparison the participant would be assigned to the precondition that would reduce the difference between the running averages most.

Stroop task

In the second part of the experiment, the participant performed a Stroop task. This task was created in PsychoPy2 (Peirce, 2007) and is based on the similar Stroop task used by Juvina & Taatgen (2009). In each trial the participant would see three words. The word in the middle had a particular color: red, blue or green. The participant was asked to press Z if the left word described the color of the word in the middle, or M if the right word described the color of the word in the middle. The critical measure in the Stroop task is the Stroop interference: the difference between reaction times on congruent trials (color and word are the same) and incongruent trials (color and word are different).

There was a practice block containing 12 trials, followed by 4 blocks of 2x36 trials. The entire task used a list with 36 possible trials of which each was randomly chosen once in each part of each block. Between each block participants were allowed to take a short break.

Task-switching task

The final task was created in MATLAB (MATLAB 8.5, The MathWorks Inc., Natick, MA, 2015). The type of task was based on the similar task used by Karbach & Kray (2009), while the design is based on the similar task by Rogers & Monsell (1995). In this task, the participant is shown 4 squares. Every trial, a picture will appear in one of these squares. The first picture will always appear in the upper left square. In later trials, the picture will appear in the next square in a clockwise direction. Whenever a picture appeared in the upper two squares, the task was to judge whether the object in the picture was small or large. Whenever a picture appeared in the lower two squares, the task was to judge whether the object in the picture was a fruit or a vegetable. This means that in half of the trials the task is the same as in the previous trial, and in the other half the task switches.

The measure in task switching is the difference in reaction times between repetition trials (task remains the same), and switch trials (task switches).

Recall task

The recall task was created in PsychoPy2 (Peirce, 2007) and is based on the similar recall task used by Chein & Morrison (2010). In this task the participant was presented with a number of words and letters. Their goal was to recall only the letters. When presented with a letter, they did not need to do anything, but when presented with a word they needed to perform a decision task. They were asked to press yes, the right ctrl key, if they thought the word referred to themselves. If they did not think the word referred to themselves they were asked to press no, the left ctrl key. Examples of words presented in this tasks are: lazy, caring, arrogant and tidy.

The task consisted of seven blocks of which the first was a practice block. Each block contained three types of trials, one with 4 letters, one with 5 and one with 6 (span 4, 5 and 6). Each trials consisted of the presentation of the first letter, followed by 4 seconds of the decision task. After this the next letter was presented, again followed by 4 seconds of the decision task. This continued until the length of the span was fulfilled. Each letter was presented for one second. When all letters where presented followed by the decision task, the participant had to recall the letters in the correct order.

Wollie

The game Wollie was created for the test group to train the subjects working memory, task switching and focussing skills. It is based on a smartphone game called Rules, which can be found in the App Store. See figure 1 for multiple screen shots of the game Wollie.

The game consists of 9 levels, which can be played in two difficulty modes, beginner and expert. The goal of this game is to complete each level, by remembering and applying rules. Each new level is a bit harder than the previous one, because the higher the level the more complex the rules. In each level you will eventually have to remember 10 rules. See table 1 for the rules in level 1. Each level starts with a presentation of the first rule, for instance: Tap in descending order. After being presented with this rule, a new screen appears with a 4 by 4 grid of blocks, each block containing a picture and a number.

The first rule, needs to be applied to these blocks. Applying this particular first rule, means tapping the blocks in order of high to low numbers. When the correct block is tapped, it disappears. When an incorrect block is tapped it will expand for half a second after which it returns to its former size. When all blocks are removed from the field within the given time frame the player has successfully completed the first rule. In the second part of the level, the player is presented with the second rule, for instance: Tap all green things. After the presentation of the second rule, a new 4 by 4 grid appears. Now that we have more than one rule, the newest rule is always applied first. In this case this means, that all blocks containing an image which is green will be tapped first, when there are no more green images, the first rule must be applied, until all blocks are removed from the field. Again, when the player empties the screen within his playing time, he has successfully completed the second part of this level. Whenever one rule is applied successfully, meaning that there are no more blocks for this rule and the player needs to switch to an older rule, the screen flashes yellow for a second. In case the smartphone is on vibrate, the phone will also vibrate on a switch moment. If the smartphone is on normal mode, it will not vibrate but it will play a short sound. All of this is to help the player realize that he needs to switch to a different rule. This process described above repeats itself until the player has learned and applied 10 rules or fails to tap all images before the time is up.

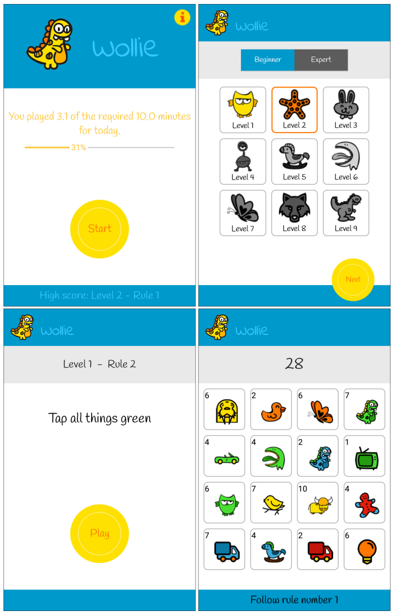

Figure 1: Four screen shots of the smartphone game Wollie. Top left: the home screen. Top right: screen to chose which level to play. Bottom left: screen showing the newest rule to apply. Bottom right: game play screen with 4x4 grid.

Table 1: Wollie rules level 1.

Rules level 1 Wollie	
1	Tap numbers in descending order.
2	Tap all things green.
3	Tap odd numbers.
4	Tap nines.
5	Tap animals.
6	Tap walruses.
7	Tap monsters.
8	Tap green monsters.
9	Tap birds.
10	Tap tens.

The rules that need to be applied to the 4x4 grid have to be recalled from memory. Learning to store and recall these rules will help the participants train their working memory. Every time they have tapped all the images for one rule, they need to switch to the previous rule and tap the images for this rule. These switching moments will help train the participant's task-switching skills. Learning to focus on the rule to come and therefore thinking about which attributes of the images to focus on will train their focusing skills. To help the participant in remembering to play the game everyday a notification will appear on their phone everyday at 7 o'clock at night.

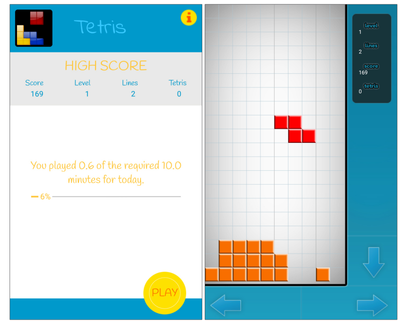

Figure 2: Screen shots of the smartphone game Tetris. Left: the home screen, right: the game play screen.

Tetris

The game Tetris was created for the control group. The game Wollie requires subjects to switch between tasks and recall rules, while Tetris only requires subjects to focus on one object at a time. Making it a good control task. Because Tetris is a well known game, which is reproduced for all kinds of platform we used some basic Java code found on the open-source website Github (www.github.com/tdan94/Tetris, at the moment of publishing this Github repository was no longer available) and added what we needed to use it in our experiment. See figure 2 for some screen shots of our version of Tetris.

Both applications show the participants how much they had to play on that day, to make sure they reached their total playing time of 140 minutes within two weeks. The applications also presented a reminder at seven o'clock at night, which told them if they had already played enough and if not, how much time they still needed to play that day. Data about their training behavior was stored on the participant's smartphone and send to a server. After two weeks of training the participants came back for the second session. They performed the same three tasks as performed in the first session, namely recall, Stroop and task-switching.

Results

For each task we will present an array of results. First, we test the difference in improvement between the control and test group with an ANOVA. After which we dig a little deeper into the influence of each group's smartphone application on the scores of the task. The influence of the condition (Wollie/Tetris) on the pre/post scores will be given.

For each task a table will be presented showing the correlation between the following variables and the accuracy score of the task: Time, Level20, Level120, DiffLevel and HighScore. *Time* is the total amount of time a subject has trained with the application. This tests whether more training leads to better transfer. *Level20* is the highest level reached after 20 minutes. This tests whether initial progress on the tasks can predict the amount of transfer. *Level120* is the highest level reached after 120 minutes. This tests whether progress made in the minimum amount of time subjects had to train predicts transfer. *DiffLevel* is the difference between *Level20* and *Level120*. This tests more or less the same as just *Level120*, but focusses on the learning gain. *HighScore* is the highest level reached. Because Tetris has no levels we use the highest score at the specific time points instead of the level when looking at the influence of Tetris on the accuracy score of the task.

Stroop

In figure 3 the average pre and post scores on the Stroop task are presented. The ANOVA showed a weak effect of group on improvement in accuracy F(1,52)=3.91, p=0.053. To see if the game variables had some impact on the improvement on the task, the correlations were calculated. Table 2 shows the influence of previously discussed variables on the improvement in the Stroop task. In the Wollie group both *DiffLevel* and *HighScore* have a negative significant influence on the improvement. This means that the lower the *DiffLevel* or *Highscore*, the higher the improvement on the task. For Tetris no significant correlations were found. In figure 4 the significant negative correlation between *DiffLevel* and the improvement in accuracy can be seen. The correlation of -0.42 (p=0.03) means that 17.6% of the improvement on the task can be assigned to the *DiffLevel* variable. This figure also shows us that subjects who improved greatly in Wollie, were also likely to score high on the first Stroop task session.

Task Switching

In the Task Switching data we excluded one person in the control group who had a switch-cost of 2182 ms. Figure 5 shows the average pre and post switch-costs for each group. The ANOVA showed no effect of group on improvement in accuracy F(1,51)=0.996, p=0.32. However, in table 3 it can be seen that there are a few variables in the Wollie group that had a significant correlation with the amount of improvement in switch-costs, namely *Level120*, *DiffLevel* and *HighScore*. Like in the Stroop data these correlations were negative, meaning that the faster subjects progressed through the game, the lower the improvement on task switching.

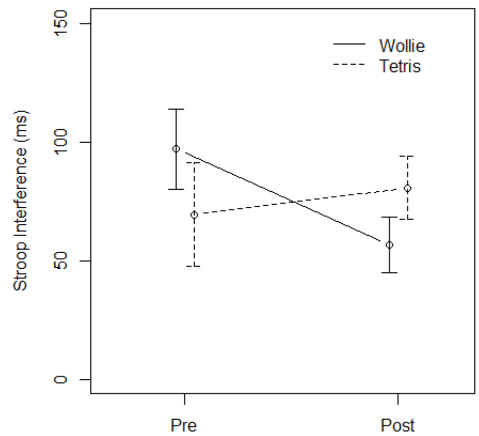

Figure 3: The influence of the two different smartphone applications on the Stroop Interference.

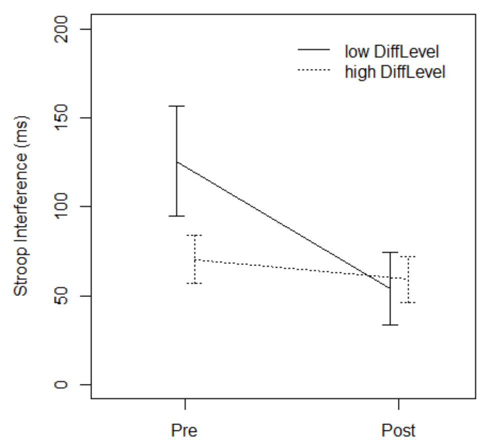

Figure 4: The improvement on the Stroop Interference for subjects with a low and subjects with a high DiffLevel in the test group.

Table 2: Correlations between performance measures in the training and improvement in Stroop interference. The p-values are presented within parenthesis. The * means that the result was significant (p<0.05).

Stroop correlation values					
Group	Time	Level20	Level120	DiffLevel	HighScore
Wollie	-0.07 (0.74)	-0.20 (0.92)	-0.37 (0.057)	-0.42 (0.03*)	-0.42 (0.03*)
Tetris	0.16 (0.44)	-0.20 (0.32)	0.05 (0.82)	0.29 (0.14)	0.004 (0.99)

Table 3: Correlations between performance measures in the training and improvement in switch costs in task switching. The p-values are presented within parenthesis. The * means that the result was significant (p<0.05).

Task Switching correlation values					
Group	Time	Level20	Level120	DiffLevel	HighScore
Wollie	0.05 (0.80)	-0.18 (0.37)	-0.42 (0.029*)	-0.43 (0.023*)	-0.42 (0.031*)
Tetris	0.0 (1.0)	0.08 (0.71)	0.18 (0.38)	0.20 (0.32)	0.03 (0.87)

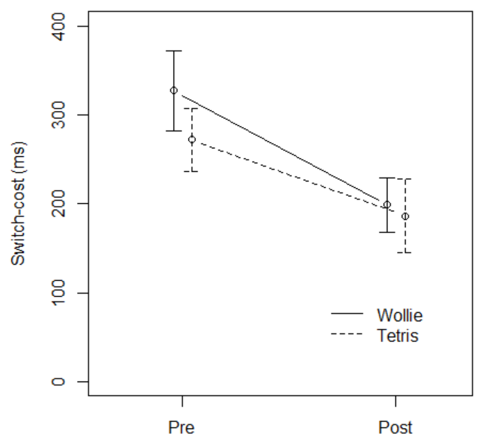

Figure 5: The influence of the two different smartphone applications on the switch-costs in the Task Switching task.

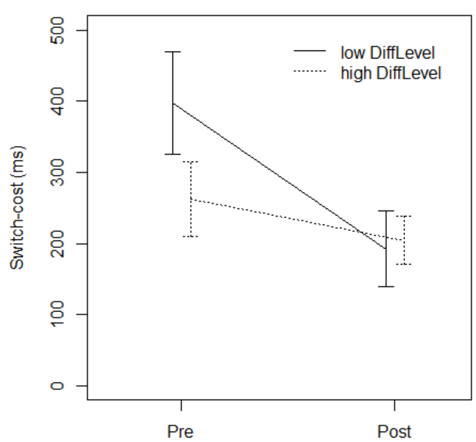

Figure 6: The improvement on the switch-costs between subjects with a low and subjects with a high DiffLevel in the test group. A low DiffLevel means that subjects only had a small improvement in reached levels between 20 and 120 minutes of training.

In figure 6 a graph with a visualization of the correlation between subjects' DiffLevel and the amount of improvement on the switch-costs is shown. The correlation of -0.43 (p=0.023) means that 18.5% of the improvement on this task can be assigned to the *DiffLevel* variable. The graph is very similar to figure 4, where the improvement for the low and high DiffLevel group was also presented, but then for the Stroop task. Just like figure 4, figure 6 indicates that subjects who managed to progress through the Wollie levels at a fast pace (a high *DiffLevel*) were also likely to score high on the first task-switching session.

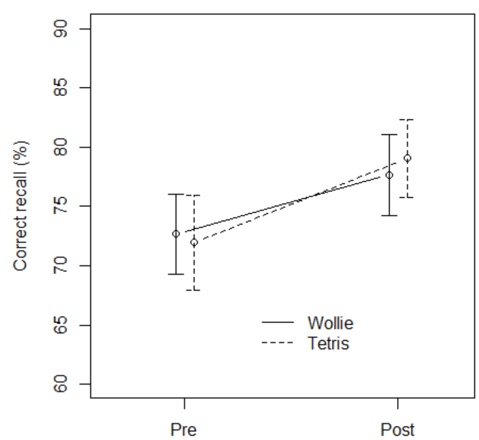

Figure 7: The influence of the two different smartphone applications on the correct amount of recalled letters in the Recall task.

Recall

Figure 7 shows the average pre and post recall scores of the two smartphone application groups. Looking at the graph it is not surprising that when performing an ANOVA it showed no effect of group on improvement in accuracy F(1,52)=0.412, p=0.524. Both group seem to improve an equal amount. In table 4 the correlations between the game variables (mentioned above) and the improvement on the recall task are presented. There is only one significant correlation, which is between *Level120* and the improvement on the task in the Tetris group.

Discussion

The goal of this experiment was to test whether a game in which skills can be identified that correspond to well-known

Table 4: Correlations between performance measures in the training and improvement in recall score. The p-values are presented within parenthesis. The * means that the result was significant (p<0.05).

Recall correlation values					
Group	Time	Level20	Level120	DiffLevel	HighScore
Wollie	-0.20 (0.32)	0.10 (0.61)	0.18 (0.36)	0.18 (0.36)	0.10 (0.64)
Tetris	-0.14 (0.48)	-0.27 (0.17)	-0.39 (0.046*)	-0.31 (0.12)	-0.38 (0.051)

experimental paradigms can improve performance on these paradigms. The evidence we found is mixed: a comparison to a Tetris control condition does not result in a consistent benefit of Wollie over Tetris, with only a weak effect on the Stroop task.

However, when we correlate the improvement on the game to the tests, we see that subjects that progress through the Wollie game at a fast pace are already good at both Stroop and task switching, and therefore show little improvement. On the other hand, subject that struggle to improve on the game show considerable improvement on both Stroop and task switching. A possible explanation is that some subjects has already mastered the appropriate control skills before they came into the experiment. These subjects had an easy time on the game, but therefore also had no benefit from playing it. Other subjects were not yet strong on the relevant control skills, and therefore still had something to learn.

A limitation of the research presented here is that the control condition (Tetris), despite its use in the past as a control condition in gaming studies, may have cognitive benefits after all. This may be the case for the improvement on recall, because there subjects that made slow progress with Tetris made more progress on Recall. However, any benefits from Tetris are more diffuse, but may still have affected the direct comparisons with Wollie.

Future research on this topic should focus on those people who do not yet posses the skills and strategies needed to succeed in particular areas of their lives. Those people are the ones who will eventually benefit most from knowledge on transfer. They could be children in an educational facility, but also adults needing to improve some skills to apply in their workspace. This research has shown that people can benefit from even a small amount of training with a smart phone application. Nowadays, most people own a smart phone and carry it with them all day. Making this an easier and fun way to practice new skills.

References

Anguera, J. A., Boccanfuso, J., Rintoul, J. L., Al-Hashimi, O., Faraji, F., Janowich, J., … others (2013). Video game training enhances cognitive control in older adults. *Nature*, *501*(7465), 97–101.

Chein, J. M., & Morrison, A. B. (2010). Expanding the minds workspace: Training and transfer effects with a complex working memory span task. *Psychonomic Bulletin & Review*, *17*(2), 193–199.

Dufau, S., Duñabeitia, J. A., Moret-Tatay, C., McGonigal, A., Peeters, D., Alario, F.-X., … others (2011). Smart phone, smart science: how the use of smartphones can revolutionize research in cognitive science. *PloS one*, *6*(9), e24974.

Eraut, M. (2009). 2.1 transfer of knowledge between education and workplace settings. *Knowledge, values and educational policy: A critical perspective*, 65.

Juvina, I., & Taatgen, N. A. (2009). A repetition-suppression account of between-trial effects in a modified stroop paradigm. *Acta psychologica*, *131*(1), 72–84.

Karbach, J., & Kray, J. (2009). How useful is executive control training? age differences in near and far transfer of task-switching training. *Developmental science*, *12*(6), 978–990.

McKeough, A., Lupart, J. L., & Marini, A. (2013). *Teaching for transfer: Fostering generalization in learning*. Routledge.

Peirce, J. W. (2007). Psychopypsychophysics software in python. *Journal of neuroscience methods*, *162*(1), 8–13.

Prins, P. J., Dovis, S., Ponsioen, A., Ten Brink, E., & Van der Oord, S. (2011). Does computerized working memory training with game elements enhance motivation and training efficacy in children with adhd? *Cyberpsychology, behavior, and social networking*, *14*(3), 115–122.

Rogers, R. D., & Monsell, S. (1995). Costs of a predictible switch between simple cognitive tasks. *Journal of experimental psychology: General*, *124*(2), 207.

Taatgen, N. A. (2013). The nature and transfer of cognitive skills. *Psychological Review*, *120*(3), 439.

Acknowledgments

This research was funded by ERC-StG grant 283597 awarded to Niels Taatgen.