Using Action Video Games to Train Working Memory in Students with Working Memory Deficits

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INTRODUCTION

Working memory is a cognitive executive function that enables people to retain and manipulate information during short periods of time (Olesen et al., 2003). This brain system provides temporary storage and manipulation of the information necessary for complex cognitive tasks. In contrast to short-term memory tasks such as "digit span," working memory tasks involve trying to maintain information in active memory while simultaneously performing distracting or interfering activities (Dye et al., 2009). A recent meta-analysis of published work concluded that memory training programs such as CogMed, Jungle Memory, and CogniFit appear to produce short-term, specific training effects that do not generalize (Melby-Lervåg and Hulme, 2013). Although humans are able to develop significant levels of working memory skill, it is not a fundamental characteristic of the learner. Rather, working memory functions tend to be dependent on previous experience and thus large amounts of information are chunked together as more becomes available. Additionally, working memory capabilities are limited by the ability to engage in controlled attention and thus determine performance on working memory training tasks (Brooks et al., 2006). According to Miyake and Shah (1999), “There is a limit to how many unrelated items can be in the focus of attention or awareness at any given time. It may be that people can focus on, at most, one general scheme or perhaps several at a particular moment, but not on many related items or schemes” (1999). Play associated with video and computer games has been shown to foster academic, cognitive and social abilities in children, especially in those that lack motivation or confidence in other areas of learning. Moreover, they can provide instant feedback and can deal with substantial amounts of information with adaptive levels of challenge that can easily be modified for individual purposes (Goldin et al., 2013).

Working memory training can have significant effects among preschool children (Thorell et al., 2009). Research studies have indicated that between 0.4 and 4% of youths meet the criteria necessary for coexisting learning disability (LD) and attention deficit hyperactivity disorder (ADHD). Working memory is affected significantly by problems associated with LD and ADHD (Perwien et al., 2004). While working memory has been thought to be an innate trait, research has suggested that it can be improved through adaptive computerized training. Children trained on working memory improved significantly on trained tasks; they also showed training effects on non-trained tasks of spatial and verbal working memory, as well as transfer effects to attention (Thorell et al., 2009).

Olesen (2003) did an experiment in which adults performed working memory tasks for five weeks. An fMRI tracked brain activity, in which particular areas of the brain showed more activation after training of working memory. These brain areas included middle frontal gyrus and superior and inferior parietal cortices. Another study (Holmes et al., 2009) looked at children with low memory skills in a variety of areas (e.g., math, reading) to figure out whether their problems in working memory and related learning problems could be improved with adaptive training. The findings suggested that impairments in working memory and related difficulties in learning have a chance to improve with behavioral treatment.
Several computer programs can be used to assess working memory function and capabilities. Cogmed is one example of a computer-based program that trains both verbal and visuospatial working memory. The program consists of 25 sessions over five weeks, each of which are 30-45 minutes long and include eight exercises each session. The sessions include eight different tasks, and each systematically works on different parts of working memory. A ‘Cogmed Qualified Coach’ leads the training and works with the individual throughout the Cogmed program to provide support, structure, and feedback. Throughout the program, the training is closely monitored and discussed. After the program is completed, there is a 6-month follow-up interview, which assesses the effects of Cogmed training over an elapsed period of time (Cogmed.com).

Cogmed’s design is very focused on working memory improvement, and the user is always challenged (Cogmed.com). The program can quickly adjust its difficulty depending on the user’s performance so that the user is being trained at his/her cognitive ability. According to Cogmed.com, “Working memory capacity determines your cognitive performance. Cogmed training improves your working memory. Your strengthened working memory allows you to perform better. The training creates the cognitive foundation you need to prepare for success.” A study which focused on the training of working memory (in youths with learning disability/ADHD) used Cogmed found that the “Results suggest that WM training may enhance some aspects of WM in youths with LD/ADHD, but further development of the training program is required to promote transfer effects to other domains of function” (Gray et al., 2012).

Many contemporary studies have researched the effects of video games on cognitive learning and function. Dr. C. Shawn Green, an assistant professor at the University of Wisconsin-Madison, has focused his research on “factors that affect the generality, rate, and depth of perceptual and cognitive learning.” (Green, n.d.). In addition, he looks at the way action video games evoke different types of visual processing, such as low-level vision, mid-level vision, to high-level vision. His research focuses on specificity and generalization in learning. Green and his research partners design video games in order to find out more about perceptual learning, cognitive abilities, and decision-making. Some of their recent work includes findings that playing first person point-of-view video games are able to affect perception, attention, and cognition (Green, n.d.). Moreover, playing action-packed, first-person video games, distinguished from other games (e.g., strategy or role-playing) by their speed and high perceptual, cognitive, and motor loads, have the potential to augment attentional control and executive functioning in young adults at the prime of their capacity (Green and Bavelier, 2012). Expert action video game players have been found to outperform non-gamer controls on tasks measuring a number of aspects of overall visual attention (Dye et al., 2009). This effect has been found to be causal in nature, with training studies that have demonstrated that playing action video game enhances attentional resources and allows players of such games to better allocate their attentional resources over a visual scene (Dye et al., 2009).

Although work from Dr. Green’s laboratory has primarily focused on attention, we wish to show that action video games might have an effect on improving working memory as well. In recent studies, researchers designed a custom three-dimensional video game called NeuroRacer to train multitasking abilities in older adults (60 to 85 years old) (Anguera et al, 2013). By playing an adaptive version of NeuroRacer in multitasking training mode, older adults reduced multitasking costs compared to both an active control group and a no-contact control group, attaining levels beyond those achieved by untrained 20-year-old participants, with gains persisting for 6 months. This resonates strongly to our proposed study because this training
resulted in performance benefits that extended to untrained cognitive control abilities (enhanced sustained attention and working memory). If the claim that attention and working memory are related holds true, then Dr. Green’s work, which shows how video games can affect attention, can further show how video games can have an affect on working memory.

For our central research question we seek to investigate if it is possible to improve working memory. More specifically, we want to evaluate whether training with action video games could improve working memory for special education students who have a working memory deficit. For children who fall in the bottom 10% in working memory, 80% also have significant problems with reading, math, or both (Gathercole & Alloway, 2008). Working memory deficits have a significant impact on learning and, therefore, if it can be shown that working memory can be improved for these children, their capacity to learn in domains such as reading and math can be positively impacted. The following study, therefore, is aimed at children who have difficulty learning in the hopes that improving their working memory will help them achieve success academically.

METHODS

Participants and Procedure

Six groups of 30 students will participate in this study. Three experimental groups will comprise of students in special education who have been identified with a working memory deficit. We chose special education students whose primary label is learning disabilities because we thought rather than test an entire school district we could find many subjects with a working memory deficit in this population. As mentioned previously, we also wanted to work with a population of students who could most benefit from this training. If there’s difficulty finding enough participants with a working memory deficit from special education, we may include students from general education who have a working memory deficit. A working memory deficit would be measured as any score below the 40 percentile as measured by the AWMA. These three groups will be randomly assigned to one of three groups: Group 1 - action video game training, Group 2- Cogmed training, and the control group who plays Tetris, Group 3. The other three groups will consist of students in general education and chosen at random from the school district. Group 4 will receive action video game training, Group 5 will get Cogmed, and Group 6 will play Tetris. All subjects will be middle schoolers from the same school district between the ages of 11 and 14. The mean age in each group could change the results of this study, therefore we will try and make the mean age of all the groups as similar as possible. Both male and female subjects will participate in this study. According to Szafarski et al., (2012), right handed people process language left laterally, compared to left handers who process language with both hemispheres. Therefore, we will screen out students who are left handers so as not to throw off our results. We will also obtain a self report of subjects experience with video gaming.

How often in the last year have you played video games?

What kind of video games do you play?  Circle amount of Time and indicate game(s)

First Person Shooters (Halo, Call of Duty, Gears of War, GTA, Half-life, Unreal etc)
Hours per week:  Never, 0-1, 1-3, 3-5, 5-10, 10+
Name of Game/Games
Action/Action Sports Games (God of War, Mario Kart, Burnout, Madden, FIFA, etc)
Hours per week:  Never, 0-1, 1-3, 3-5, 5-10, 10+
Name of Game/Games_______________________________

Other (Sims, Solitaire, Angry Birds etc.)
Hours per week:  Never, 0-1, 1-3, 3-5, 5-10, 10+
Name of Game/Games__________________________________________________________

This information will be used to assess the difference that video game experience may play on participants’ working memory skills. If participants engage in action video games we can look at a correlation between their working memory scores and amount of game playing.

Pre and Post Measure

Prior to the intervention all subjects will be screened for working memory using the Alloway and Gathercole Automated Working Memory Assessment Screener. Because the AWMA is automated and adaptive, this screener will also be used after intervention in order to measure any gain in training. This assessment will measure visuo-spatial working memory and verbal working memory. Subjects in Groups 4 through 6 will be screened out if they test below the 50th percentile.

In addition to working memory assessments, 20 subjects from each of the 6 groups will undergo a fMRI before and after the training period. During the scan, subjects will be given an N-back test. They will see a string of letters and have to determine if the current letter is the same as the letter 3 letters back in the string. We will be looking for activity in the parieto-frontal network which is associated with working memory. These two measurements would take place the day the training ends, after 1 month, and 6 months to see if there are any lasting effects of the training.

![Fig 1: Expected FMRI of activation in prefrontal cortex regions during working memory training (courtesy of: http://neurosciencenews.com/neuroimaging-children-working-memory-neuroscience-273/)](image-url)
INTERVENTION

The subjects in the video game training group will receive 25 training sessions of 30 minute intervals. These will take place 5 days a week for 5 weeks at the beginning of their school day. The Cogmed group will receive the same training schedule, and the control groups will play Tetris for the same amount of time.

Action Video Game - Burnout

According to Colzato et al., (2013), people who play action video games have better working memory skills than people who do not play action video games. UW Madison’s Shawn Green has shown that first person point of view action video games have a positive effect on attention and cognition (Green et al., 2012). Dye, M.W.G. et al., (2009) suggest that the key ingredient in action video games is the amount of actions per unit of time required to achieve the greatest reward. Achtman et al., (2008) point out that action video games place high demands on the player’s visual attention system, requiring the player to constantly monitor the periphery for unpredictable events that require a quick and accurate response. Players must track many fast moving objects while avoiding distractors in order to do well. Importantly, action video games commonly have a variety of difficulty levels, ensuring that different players can have an equally challenging yet successful experience. It is this kind of research that has influenced our desire to test these games as a way of improving working memory for students who have working memory deficits.

We chose the car racing game Burnout to train working memory. Burnout is an action video game falling under the “racing” genre. The game is known for its especially high sense of speed and emphasis on aggressive driving. The game rewards risky behavior that requires fast reflexes and tight control, including driving through oncoming traffic and causing opponents to crash (without crashing yourself). In order to be successful, the player must not only win the race, but also engage in a sufficient amount of the risky behavior just described. Burnout is a game that creates a high cognitive load for the player, requiring them to keep in mind multiple goals simultaneously. These goals include: (1) keeping speed up to win the race, (2) avoiding obstacles, (3) causing opponent cars to crash in order to gain points and position, and (4) finding shortcuts in the periphery. Burnout is a prime example of an action video game that we wish to show can be a useful tool in training working memory, especially for students with working memory deficits.

Burnout has multiple difficulty settings, as well as a large number of levels and races.
available to play. We will have to choose an appropriate level of difficulty and set of races that are simultaneously not too easy (would not train working memory) and not too difficult (impossible to play) for both groups in the action video game condition. This is especially important for the group of students with working memory deficits, as they may have comorbidity of, e.g., dyspraxia, in addition to their working memory deficit. We will address this concern in two ways. First, we will screen all participants for their basic ability to hold a game controller and control the car in the game. Second, we will run a pre-test with a small sample of participants in order to determine an appropriate level of difficulty and set of races for the population of participants we are interested in. We will then hold this difficulty setting and set of races constant for the full study.

Cogmed

Cogmed is an adaptive training program that trains both visuospatial and verbal working memory. Subjects will be using the Cogmed RM version for ages 7 and up. The program keeps students at the edge of their cognitive limits, which keeps them challenged. Cogmed advertises that the training generalizes to other areas such as attention, resisting distractions, self-management, and learning (Cogmed.com). There is controversy about whether these claims can be substantiated or not (Morrison & Chein, 2012).

Tetris

For our active control group, participants will play the classic video game: Tetris. Past research on training attention with video games has shown that playing Tetris is not nearly as effective in training the brain as compared to playing action video games (Achtman et al., 2008). Tetris -- and games like it -- differ from action video games in a number of important ways. There are only a limited number of objects for participants to attend to at any one time, the spatial location of these objects is highly predictable, and spatial configurations and moves can be memorized rather than requiring the player to adapt to a constantly changing environment (Destefano et al., 2011). The combination of these elements make the playing of Tetris a suitable control condition for our proposed study.

DISCUSSION

We have several different hypotheses about this study. We expect that the students with a working memory deficit will show more improvement, compared to the students who did not show a working memory deficit, on the AWMA, and an increase in parieto-frontal network activity in the video game group. Flook et al., (2010) showed that training executive functioning did not have an effect on children who did not need it, but it showed the biggest gains for kids who needed it the most. Therefore, we anticipate that students who have a working memory deficit will show the biggest improvements compared to subjects who don’t have a working memory deficit.

We also expect to see an improvement in AWMA and parieto-frontal activity for Group 4. We would expect that most of this improvement will come from those students who have a lower rating on video gaming experience and therefore have more room for improvement. It will be interesting to note if there is a correlation between measures of working memory and experience with action video games.

We would hope that this study shows sustained improvement at the 6 month follow-up. There has been evidence that training working memory can have long term benefits. A study
looking at children training working memory with Cogmed shows evidence of long-term effects of WM training. According to Holmes (2009), “The majority of the children who completed the adaptive program, which involved intensive training of 35 minutes a day in school for at least 20 days, improved their WM scores substantially over this period and for a further 6 months after training had been completed”. This shows a 6 month period post-training in which working memory was still positively impacted by training.

Potential Limitations

We tried to control for subjects improvement being based purely on playing video games by comparing the experimental group to control groups who play Tetris. Having the control groups play Tetris will allow us to infer that more improvement in the action video game training group isn’t just from playing a video game.

Motivation may be lower for the Group who receives Cogmed which therefore could potentially weaken the case that the action video game group outperformed the Cogmed group. The fact that Tetris and our video game may be more enjoyable than Cogmed, we eliminate motivation as a factor in finding more improvement with action video games over Tetris.

“Video-game players have been reported to show improved hand/eye coordination, increased visual processing in the periphery, enhanced mental-rotation skills, greater divided attention, and enhanced visuospatial memory” (Dye et al., 2009). This may affect the results of our study by possibly showing action video game groups only improving visual working memory and not verbal working memory. We have not controlled for this possibility but will be curious to see if playing action video games also improves verbal memory or if Cogmed proves to be more helpful for this type of working memory.

If our hypotheses prove to be correct, this would have implications for how professionals consider remediating working memory issues with children. We would also hope that if we could show great results with something tangible like video games on such an important aspect of learning, that schools would start remediating executive functions and not just academic areas like math and reading. Lastly, instead of parents discouraging video game playing, they might start encouraging their children to exercise their cognitive skills through action video game playing.

References


