THE EFFECTS OF GAMING ON WORKING MEMORY, INATTENTION, READING AND MATH – A LONGITUDINAL STUDY

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Previous research has shown both positive and negative effects of gaming on academic and cognitive performance. The purpose of this study was to assess the effect of gaming on development of working memory (WM), inattention, reading and math ability using a longitudinal design. A randomly chosen sample of 335 (168 girls) 6–25 year olds performed tests of visuo-spatial and verbal WM, reading and math ability twice, with a two year interval. Gaming and inattention were assessed with questionnaires. Time spent gaming did not affect development of any of the variables. However, game category did correlate with development of visuo-spatial WM, with action-gamers having a more favourable development. There was, however, no positive interaction with more time spent gaming for action-gamers. These results suggest that gaming should not be regarded as a damaging leisure activity. There could instead be some positive effects of gaming, but future research should try to identify the aspects of gaming contributing to this effect.

Gaming (video/computer/online) has become one of the most common leisure activities that children and adolescents engage in. The intense and engaging environment that games produce has been hypothesised to be a beneficial learning situation as well the opposite in the ongoing debate. Since the emergence of studies looking at the effects of gaming, both potentially enhancing and negative effects have been shown. The negative effects have mainly been in relation to obesity, addiction, aggression, and symptoms related to ADHD (Bioulac, Arfi, & Bouvard, 2008; Chan & Rabinowitz, 2006; Schmidt & Vandewater, 2008) but negative effects have also been seen in relation to academic performance (Anand, 2007). Enhancing effects have been seen in tests measuring eye-hand coordination, manual dexterity, reaction time (Green & Bavelier, 2006), spatial abilities, strategies for the allocation of attention (Dye, Green & Bavelier, 2009; Green & Bavelier, 2003; Ferguson, 2007), mental rotation (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Feng, Spence, & Pratt, 2007; Quaiser-Pohl, Geiser & Lehmann, 2005), faster information processing skills (Yuji, 1996), learning abilities and long-term memory (Meijs, Hurks, Feron, Wassenberg, & Jolles, 2007). Furthermore, improvements in visual abilities have been seen in experimental settings after just 10 hours of gaming and thus indicating a causal relationship (Green & Bavelier, 2003; 2006). However, in an attempt by Boot et al (2008) to replicate and extend the studies by Green and Bavelier (2003; 2006), no effects were seen in the experiment groups after intense gaming.

Considered together, these studies provide no simple interpretation for the effects of gaming. Possible limiting factors when trying to get an overview may be several, but three important factors so far have been that studies have different research designs,

varying measurements of gaming, and lacking combinations of psychological measurement with real life behaviour. First, effects seen in non-experimental studies are always target to the risk of being due to selection – individuals are more likely to play games that correspond to their pre-existing skills/limitations. For example, the association between time spent gaming and academic performance (Anand, 2007) was based on one single measurement. From that, it is hard to distinguish between inherited skills/limitations and effects from gaming. Studies showing a negative effect are to a large extent limited to inferences made from one measurement. Secondly, different games develop and recruit different cognitive processes and the content of the game may determine whether and what skills are learned (Boot et al 2008; Green & Bavelier, 2008, Dye et al, 2009; Schmidt & Vandewater, 2008). Whereas some studies distinguish between game categories, others do not. Studies that do not distinguish between game categories (Anand, 2007; Chan & Rabinowitz, 2006) are limited in their explanatory value as previous research has shown that effects could be specific for a certain game category (Green & Bavelier, 2003; 2006). It is possible that effects disappear when too crude measurements for gaming are used. Third, very few studies combine the fine tuned psychological measurements with more ecologically valid measurements reflecting real life behaviour. Not relating training effects seen in psychological measurements (Green & Bavelier, 2003; 2006) to real life behaviour limits our knowledge of how specific these effects are. It would for example be interesting to see if the training effects seen in Green and Baveliers experiments (2003; 2006) had any effect stretching further than the psychological measurements included in their study. Altogether, not taking these three aspects into account when designing or interpreting a study might limit the understanding of the effects of gaming.

With the limiting factors described above in mind, the present study wanted to be able to evaluate previous research. First, this study allowed for comparison of analyses based on one measurement with a longitudinal design. The purpose of this was to be able to distinguish between selection effects and development. This comparison was also motivated by that similar studies looking at the effects of watching television, have generated mixed results regarding the relation between time watching television and inattentional symptoms comparing measurements at one time point with longitudinal analyses (Landhuis, Poulton, Welch, & Hancox, 2008). Moreover, studies based on one measurement are limited in their assessment of whether effects are short-term or long-term. Second, by including both analyses for gaming in general and for gaming specified according to what category participants played, this study aimed to make it possible to evaluate if content of the game was a factor. Third, by combining fine tuned measurements with everyday life behaviour, this study hoped to show how specific or general these effects were.

No study has so far to our knowledge included psychological measurements (visuo-spatial and verbal WM) in combination with real life behaviour (ratings of inattentional symptoms and tests of academic performance). This particular combination was motivated by that visuo-spatial and verbal WM measurements are some of the best single predictors for categorizing ADHD membership (Holmes et al, 2010) and because several studies have shown that WM skills are closely associated to performance in literacy and math (Gathercole, Brown & Pickering, 2003; Bull & Scerif, 2001).

Looking at WM in relation to inattentional symptoms or academic performance, this study could perhaps arrive at a more complete and comprehensive picture than what has previously been achieved.

Moreover, it was important to distinguish between the WM tests and academic performance for another reason. Whereas test of academic performance measure prior experience, WM tests tap fluid cognitive abilities (Gathercole et al, 2003). These are two different memory systems. Experience based effects could be for example when gaming results in too few hours spent on homework and thus decline in academic performance. Fluid effects on cognition could be for example when gaming affects development of WM. The present study design made it possible to distinguishing between these types of effects.

Hence, the purpose of this study was to investigate if there was any relation between gaming and development of WM, inattention, reading and math ability. The first aim of this study was to look at if gaming, no matter which category played, was associated to development of WM, inattention, reading and math ability. The second aim was to look at if game categories differed in their development of WM, symptoms of inattention, reading and math ability. Overall, this study hoped to avoid some of the shortcomings of previous studies and extend the understanding of their results by including a combination of real life and psychological measurements and looking at development over time.

Method

The present study was based on data gathered in a longitudinal study with two completed measurement points. WM-tests, tests of reading and math ability, and questionnaires were distributed to ages 6–25 at measure point 1 (T1) in 2007, and then two years later, 2009 (T2). One questionnaire covered leisure activities, the literacy environment and socio-economic background such as parental education, and another questionnaire was used to assess inattention. However, several more tests and questionnaires were included in the longitudinal study but as they were not used in this particular study, they are left out.

Participants

Participants were randomly chosen from the population registry in Nynäshamn, in Sweden. A letter with information was sent out to the parents together with a form of consent that was returned to the project administration if participants agreed to take part in the study. Parents were then contacted by telephone for an additional mutual consent and an opportunity to ask questions. This was done both at T1 and T2. Participants who were 18 years or older were contacted directly. About 33 % (335) of the contacted participated at T1, and of those (335) about 82 % (274) stayed in the study at T2. For details about how gender and age was distributed over game categories and time spent gaming, see table 1 and 2. Exclusion criteria were any diagnosis of psychiatric or

neurological disorder (with exception for ADHD or dyslexia), any vision or hearing impairment judged to affect the test-performance. The study was approved by the local ethics committee in Stockholm. Participants will be anonymous through out the longitudinal study.

Apparatus and material

WM

The Automated Working Memory Assessment (AWMA) test, Dot matrix, is a computer based visuo-spatial grid task and was used for measurement of visuo-spatial WM (Alloway, 2007). Total amount of points (raw results) was used as visuo-spatial WM measurement. The Dot matrix test was performed on a HP Compaq nc6320 laptop with a 15-Inch screen. Backwards digit recall was used for measurement of verbal WM (Alloway, 2007). The total amount of points (raw results) was used as a verbal WM measurement.

Reading and math ability

To measure reading comprehension, narrative and expository texts from The Progress in International Reading Literacy Trend Study (PIRLS 2003 T) were used (Martin, Mullis, Gonzalez & Chrostowski, 2004). The test items were piloted in second and sixth grade with 400 pupils in three schools in the Stockholm area. Some of texts and items were slightly modified as a consequence of the results in the pilot study. Math ability was based on the TIMSS (Trends in Mathematics and Science Study) (Martin et al, 2004) and BNST¹ (Basic Number Screening Test) (Gillham & Hesse, 2001). Test items were piloted together with the reading ability test. Item response theory (IRT) was used to generate age comparable outcome scores for both reading and math. The IRT calculations are described below under the *Analyses* section.

Inattention and gaming

Inattention was measured with raw scores from the Child Behavioural Check List (CBCL) (Achenbach, 2001). CBCL includes DSM-oriented scales that are used in many countries as a diagnostic and statistical manual for mental disorders. Leisure activities (including questions about gaming habits) were measured with a questionnaire developed by Klingberg (2007).

Procedure

Each participant went through two separate testing sessions on different occasions at both T1 and T2 (except for the 6 year olds at T1 who did not perform reading or math tasks). The psychological testing, including the WM-tests took about 2 hours including a 10-minute break. Reading and math tests took about 30–35 minutes each and were separated with a ten minute pause. Both test sessions were carried out in the school of the participant or at the Karolinska hospital in Stockholm.

¹ BNST was used with permission of Hodder and Stoughton International.

Visuo-spatial WM-test

Participants were asked to remember the exact position of a red dot in a 4x4 grid on a white background. The dots were presented for 1 000 ms and the intra stimulus interval (ISI) was 500 ms. The test started with a training trial with one, two and then three dots, after which the actual test started with one dot. Difficulty increased (number of dots) until the participant failed to pass a level. Each level consisted of six trials and four correct answers was the minimum for moving to the next level. A correct answer equalled one point. If the participant answered correctly on the first four trials, they were given six points without having to do the last two trials. The test was done individually.

Verbal WM-test.

Participants were asked to repeat digits backwards that were read out loud to them. The test started with a training trial of two and then three digits after which the actual test started with two digits. Difficulty level increased until the participant failed to pass a level. Each level consisted of six trials, and four correct answers was the minimum for moving to the next level. A correct answer equalled one point. If participants answered correctly on the first four trials, they were given six points without having to do the last two trials. The test was done individually.

Reading Comprehension

There were 4 versions of the reading test depending on what age participants were. These versions were based on the results of the pilot study. All age groups (8, 10, 12 and 14+) had 30 minuets to complete the test. Each participant completed their test individually. Tests were distributed either one at a time or in groups.

Math ability

There were 4 versions of the math test depending on what age participants were. All age groups (8, 10, 12 and 14+) had 35 minuets to complete the test. These versions were based on the results of the pilot study. Each participant completed their test individually. Tests were distributed either one at a time or in groups.

Inattention

Parents rated their child (under 18) for how true each characteristic was during the last 6 months, using the following scale: 0 = not true; 1 = somewhat or sometimes true; 2 = very true or often true. One example of an item measuring inattention is: *Often does not seem to listen when spoken to directly*. The present study used the raw results from these assessments. Other characteristics measured by CBCL were not included in this particular study.

Gaming

Parents (together with their children) where asked to answer questions about media habits in a questionnaire. The following two questions were used in this study for the assessment of gaming: "How much time does the child spend on computer games/video games/on-line games per week?", "Which category is played the most action/adventure, first person shooter, puzzle, racing, role play, simulators, sports, strategy?". Each category had an example (role play – World of Warcraft, action/adventure –

Battlefield). The first question was used for assessment of gaming hours per week. The second question was used when the effects of game category was examined. Although several more categories were included, the present study distinguished between three categories: “action-gamers” (action/adventure and first person shooter), “strategy-gamers” (role play and strategy), and “non-gamers” (playing zero hours per week). This categorization was made based on the hypothesis in an earlier gaming study where action-games and strategy-games were hypothesised to recruit different cognitive abilities. Whereas the fast paced action-games were believed to be dominated by usage of attentional abilities, the slower paced strategy-games were thought to be directed towards more strategic behaviour (Boot et al, 2008).

Analyses

Analyses of WM and gaming behaviour were based on ages 6–25 at T1 and 8–27 at T2. Reading and math ability analyses were based on ages 8–25 at T1 and 8–27 at T2. Analyses of inattentional symptoms were based on ages 6–16 at T1 and 8–18 at T2. No assessment of inattentional symptoms were made for participants who were 18 years or older as the present study did not want to use assessments of inattention that were made by the participants themselves. In order to be able to compare the different age versions of the reading and math ability tests, item response theory (IRT) analyses were made. The assumptions behind these analyses were that passing a particular item is determined by difficulty of that item and the ability of a specific participant. This resulted in ability scores for each participant that were comparable even though they did not perform exactly the same test items.

Results

The purpose of the present study was to investigate if gaming affected cognitive development, reading and math abilities. The first aim was to look at if gaming in general affected WM, inattentional symptoms, reading and math abilities. The second aim was to see if gaming categories differed in their development of WM, symptoms of inattention, reading and math ability. Table 1 shows the number of hours participants spent gaming per week, independent of which games they played. Table 2 shows how age and sex are distributed over the game categories. Gender was unevenly distributed over what category of game participants played and for how many hours they spent gaming every week. Furthermore, age was unevenly distributed over the game categories and thus, analyses below controlled for the effect of age and gender.

Table 1. Gaming hours per week for T1 and T2.

	T1	T2
	Hours/week (SD)	Hours/week (SD)
Boys	8,8 (8,1)	11,0 (10,2)
Girls	3,9 (4,4)	4,3 (4,4)
Total	6,8 (7,3)	8,3 (9,0)

Table 2. Age and sex distribution over game categories for T1 and T2.

Game	T1			T2		
	N	Mean age in years and (SD)	Boys/Girls in %	N	Mean age in years and (SD)	Boys/Girls in %
Strategy	48	14,5 (3,8)	67/33	53	14,8 (3,4)	70/30
Action	44	12 (3,3)	86/14	49	13,1 (3,6)	73/17
Non	71	13,2 (5,6)	24/76	52	15,8 (4,3)	17/73
All games	229	11,9 (4,1)	60/40	217	13,0 (3,7)	60/40
Total	301	12,2 (4,5)	51/49	268	13,6 (3,9)	52/48

Gaming in general

This section is related to the first aim, gaming was measured by number of hours spent gaming per week. In order to be able to compare longitudinal effects with cross-sectional, the present study included a correlation table for T1. Age and gender was partialled out. Hours spent gaming and both WM measurements were positively associated at T1 – those who played more performed better on the WM measurements. There was a negative correlation between math ability and hours spent gaming at T1 – those who played more performed worse in the math ability test. See table 3.

Table 3. Partial correlations between all variables at T1.

	1	2	3	4	5
1. Gaming hours	1 (335)				
2. Visuo-spatial WM	0,201** (295)	1			
3. Verbal WM	0,147* (295)	0,436** (331)	1		
4. Reading	-0,047 (239)	0,239** (265)	0,286** (265)	1	
5. Math	-0,162* (239)	0,364** (265)	0,257** (265)	0,664** (265)	1
6. Inattention	0,085 (248)	-0,077 (256)	-0,196** (256)	-0,248** (207)	-0,279* (207)

(N), ** $p < 0,01$, * $p < 0,05$ (2-tailed)

As this study wanted to look at the development depending on how many hours that was played at T1, regression analyses were conducted with either WM, inattention, reading or math ability at T2, controlling for the same measurement at T1, gender and age. Method of regression was set to enter. Hours spent gaming at T1 did not predict development of any of the variables (Table 4; Fig. 1).

Table 4. Gaming hours at T1 as a predictor for inattention, visuo-spatial WM, verbal WM, reading and math at T2.

	β	P value
Inattention	0,051	0,423
Visuo-spatial WM	0,066	0,165
Verbal WM	0,010	0,836
Reading	0,075	0,173
Math	0,051	0,180

Figure 1. Partial regression plot for time spent gaming at T1 and inattentive symptoms at T2. X and Y axis contain the residuals of inattention at T2 and time spent gaming at T1 given the other independent variables effect on inattention T2.

Game categories

This section is related to the second aim and here, the effect of game category was evaluated. In order to see if game categories were a factor effecting development, a between-subjects ANCOVA was employed with either WM, inattention, reading or math ability at T2 as the dependent variable. The between subjects factor was game category at T1 and had 3 levels: non-gamers, action-gamers and strategy-gamers. In order to see if game category at T1 was a factor effecting development, performance at T1 was put in as a covariate along with gender and age. If there was significance or a trend towards significance, a 2*3 mixed ANOVA design was used with T1 and T2 measurements for either inattention, WM, reading or math ability as a within-subjects factor, and gaming category as a between subjects factor. The latter included only those who stayed within the same game category at both measurement points. The purpose of this analysis was to check how robust this effect was. Age and gender were put in as covariates.

Game category at T1 was not a predictor for development for inattentive symptoms, verbal WM, reading ability, or math ability (see table 5). The only measurement that showed a trend towards a significant effect of game category was visuo-spatial WM ($p = 0,102$).

Table 5. Gaming categories at T1 as a predictor for inattention, visuo-spatial WM, verbal WM, reading and math ability at T2.

	Partial eta squared	P value
Inattention	0,020	0,370
Visuo-spatial WM	0,037	0,102
Verbal WM	0,001	0,948
Reading	0,035	0,165
Math	0,017	0,412

As the ANCOVA showed a trend towards significance for the effect of gaming category on visuo-spatial WM, a post hoc analysis was done to compare groups. The LSD post hoc analysis showed that action-gamers increased visuo-spatial WM from T1 to T2 significantly more than strategy-gamers ($p = 0,033$). Next, analysis was done including only those who stayed within the same game category at both T1 and T2. The mixed ANOVA showed a visuo-spatial WM by gaming category interaction trend towards significance ($p = 0,070$). As there was a trend in the mixed ANOVA as well, post hoc analysis was done to compare the groups. Action-gamers did not increase more than non-gamers ($p = 0,148$). There was trend towards a significant difference in the increase between action-gamers and strategy-gamers ($p = 0,086$). There was no significant difference in the increase between non-gamers and strategy-gamers ($p = 0,698$). Figure 2 below display the development for the different gaming categories.

Figure 2. Visuo-spatial WM development for the game categories between T1 and T2.

Finally, as visuo-spatial development seemed to benefit from action-gaming, an interaction with time spent gaming would strengthen this effect further. A regression analysis was done with visuo-spatial WM at T2 as the dependent variable predicted of time spent gaming at T1, controlling for sex, age and visuo-spatial WM at T1, including only the action-gamers. However, there was no correlation between time spent gaming at T1 and visuo-spatial WM at T2 ($r = 0.025$, $N = 33$, $p = 0.888$, two-tailed).

Discussion

The purpose of this study was to investigate if there were any relations between gaming and development of WM, inattention, reading and math ability. The first aim was to look at gaming, regardless of game category, the second aim was to evaluate at the effect of game category. Overall, the present study found no support for gaming having any negative impact on development. Game category was a factor affecting development for visuo-spatial WM – action-gamers increasing more.

In relation to both the first and the second aim of this study, neither fluid cognitive abilities nor experience based measurements showed decreased development when comparing gamers to non-gamers. There were no effects of time spent gaming and none of the game categories showed an association to decreased development in any of the measurements in the present study. The non-existing negative effects from gaming go against several studies. Anand (2007) showed that gaming in general was associated with lower performance in academic performance markers (Grade Point Average and Scholastic Aptitude Test). Chan and Rabinowitz (2006) showed that more than one hour of gaming every day was associated with more symptoms of inattention. (Compare to figure 1.) However, one limitation of these studies was that they were based on cross-sectional analyses. The present study had the benefit of comparing analyses from one measurement with the development two years later. Whereas a negative correlation was found between hours spent gaming and math ability at T1, no negative effects were seen over time. This could imply a selection effect where those who perform poorly in math are likely to be involved in more frequent gaming. Important to acknowledge then is that the present study found no support for gaming resulting in a decreased math development. Furthermore, as none of the other measurements show any tendencies for gaming having any negative effect, the present study find it reasonable to question prior research arguing that gaming may produce effects based on one measurement point.

In relation to the second aim of this study, support was found for that different games develop different cognitive processes. The effects seen in development of visuo-spatial WM – action-gamers showing increased development in visuo-spatial WM – relate to previous research where action-gaming in an experimental setting improved visual attention abilities (Green & Bavelier, 2003; 2006). However, no prior study has to our knowledge shown any association between playing action-games and subsequent improvement in visuo-spatial WM. One possible interpretation is that the

visuo-spatial WM test taps into overlapping mechanisms of attention and visuo-spatial WM. Awh and Jonides (2001) argue that spatial WM and spatial selective attention have a functional overlap. The attentional aspects are believed to serve as a rehearsal system to keep information active in the WM. An alternative interpretation would be that these are two separate abilities and thus training effects from action gaming spreading further than previously shown. In either case it should be considered when characterizing the effects from gaming that such effects depend on what type of game that is played.

The magnitude of training effects in general can be characterized in three levels: 1) effects in the task that has been trained, 2) effects in non-trained tasks, 3) effects in real-life tasks. Prior research (Green & Bavelier, 2003; 2006) and the effects seen in the present study are in non-trained tasks. If action-games, more than other game categories, produce training effects in fluid cognitive abilities, the features of these games are of interest for understanding learning determinants in general. In a review of training induced learning by Green and Bavelier (2008) difficulty, motivation, arousal, feedback and variability were mentioned as possible characteristics which may be key determinants in successful learning. The authors suggest that it is the intertwined nature of these characteristics that produce a complex enough environment for achieving training effects. Moreover, gaming environments often display wide-ranging contexts generating task principles that are stretched beyond monotonous and repetitive psychological tasks. Yet another possible benefit that gaming may have compared to other computerized cognitive training paradigms, is the high level of multitasking. The present study did not have in its scope to investigate why action-games seem to produce a training effect in visuo-spatial abilities, but future studies should try to isolate the specificity of these games. Arguably, one of the main differences between action-games and strategy-games (the two game categories included in this study) is pace. Along with arousal, such a characteristic is perhaps more easy to test in an experiment than motivation, difficulty, feedback and variability which are characteristics in the strategy games as well. The inherent beneficial set up in action-games remains to be identified.

A strength in the present study was the combination of measurements for detecting the effects of gaming and being able to set them in relation to each other. The effects seen in visuo-spatial WM did not influence reading or math ability for example. Thus, the present study found no support for gaming having any effect in real life-behaviour. Furthermore, following up the correlations found at T1 and looking at the longitudinal effects, this study was able to differentiate between selection effects and training effects. Even though lacking the experimental set up to talk about causality; it was possible to look at the long term effects, which has been a shortcoming within the field of gaming research. Furthermore, as the present design included a general and a specific measurement for gaming, a more thorough picture was provided than when talking about gaming without distinguishing between game categories. Looking at only gaming in general, this study wouldn't be able to detect the increased development in visuo-spatial WM for action-gamers.

Although this study had a longitudinal design, measurements were only made at two time points. This limits the sensibility for making conclusions about development. Other weaknesses were that the effect was small and that the present sample only displayed a trend towards significance in visuo-spatial WM. Moreover, as there was no correlation between time spent gaming and increase in visuo-spatial WM for action-gamers, an interpretation of the effects of action-gaming is complicated. However, the results are in line with previous research, and estimates of gaming were very crude, which decreases the ability to detect an interaction with time.

In sum, this study has shown that gaming shouldn't be regarded as a potentially damaging leisure activity. On the contrary, playing an action-game could result in enhancement in visuo-spatial abilities. Future research should focus on what it is that makes action-games more beneficial than other game categories and how this effect is produced.

References

- Achenbach, T. (2001). Manual for the child behaviour checklist/ 4-18. Burlington, VT: University of Vermont, Department of Psychiatry.
- Alloway, T. (2007). Automated Working Memory Assessment, Harcourt Assessment.
- Anand, V. (2007). A study of time management: the correlation between video game usage and academic performance markers. [Electronic version]. *Cyber Psychology & Behaviour*. 10 (4), 552-560.
- Awh, E., & Jonides, J. (2001). Overlapping mechanisms between attention and spatial working memory. [Electronic version]. *Trends in Cognitive Science*. 5 (3), 119-126.
- Bioulac, S., Arfi, L., & Bouvard, M. (2008). Attention deficit/hyperactivity disorder and video games: a comparative study of hyperactive and control children. [Electronic version]. *European Psychiatry*, 23(2), 134-141.
- Boot, W., Kramer, A., Simons, D., Fabiani, M., & Gratton G. (2008). The effects of video game playing on attention, memory, and executive control. [Electronic version]. *Acta Psychologica*, 129, 387-398.
- Bull, R., & Scerif, G. (2001) Executive functioning as a predictor of mathematics ability: inhibition, switching, and working memory. [Electronic version]. *Developmental Neuropsychology*. 19 (3). 273-293.
- Chan, P., & Rabinowitz, T. (2006). A cross-sectional analysis of video games and attention deficit hyperactivity disorder symptoms in adolescents. [Electronic version]. *Annals of general psychiatry*, 5,1-11.
- Dye, G., Green, S., & Bavelier, D. (2009). The development of attention skills in action video game players. [Electronic version]. *Neuropsychologica*, 47, 1780-1789.
- Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. [Electronic version]. *Psychological Science*, 18, 850-855.
- Ferguson, C. (2007). The good the bad and the ugly: A meta-analytic review of positive and negative effects of violent video games. [Electronic version]. *Psychiatric Quarterly*, 78, 309-316.
- Gathercole, S., Brown, L., & Pickering, J. (2003). Working memory assessments at school entry as longitudinal predictors of national curriculum attainment levels. [Electronic version]. *Educational and Child Psychology*. 20(3), 109-122.
- Gillham, B., & Hesse, K. (2001) Basic Number Screening Test. London: Hodder and Stoughton International.
- Green, S., & Bavelier, D. (2003). Action video game modifies visual selective attention. [Electronic version]. *Nature*, 423, 534-537.

Green, S., & Bavelier, D. (2006). Effect of Action Video Games on the Spatial Distribution of Visuospatial Attention. [Electronic version]. *Journal of Experimental Psychology: Human Perception and Performance*, 32(6), 1465-1478.

Green, S., & Bavelier, D. (2008). Exercising your Brain: A review of human brain plasticity and training-induced learning. [Electronic version]. *Psychology and aging*, 23, 692-701.

Holmes, J., Gathercole, S., Place, M., Alloway, T., Elliott, J., Hilton, K. (2010). The diagnostic utility of executive function assessments in the identification of ADHD in children. *Child and Adolescent Mental Health*. 15(1). 37-43.

Landhuis, C., Poulton, R., Welch, D., & Handcox, R. (2007). Does childhood television viewing lead to attention problems in adolescence? Results From a prospective longitudinal study. [Electronic version]. *Pediatrics*, 120, 532-537.

Meijs, C., Hurks, P., Feron F., Wassenberg R., & Jolles, J. (2007). *Gaming, memory functions, and other neuropsychological skills in children aged 5-16*. Un-published Thesis. School for Mental Health and Neuroscience, Faculty of Health, Medicine and Life Sciences, University Maastricht.

Martin, M., Mullis, S., & Chrostowski, S. (2004). TIMSS 2003 Technical Report Chestnut Hill, MA: TIMSS & PIRLS International Study Centre, Boston College.

Quasier-Pohl, C., Geiser, C., & Lehmann, W. (2005). The relationship between computer-game preference, gender, and mental rotation-ability. *Personality and Individual differences*, 40, 609-619.

Schmidt, M., & Vandewater, E. (2008). Media and attention, cognition, and school achievement. [Electronic version]. *The Future of children*, 18, No.1

Yuji, H. (1996). Computer games and information processing skills. [Electronic version]. *Perceptual and Motor Skills*, 83, 643-647.