Effects of Programming in relation to Working Memory span on Cognitive Ability

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Abstract

This study compared the effects of programming and innovation on cognitive abilities and whether the effects varied with working memory span (high vs. low). Sixty-seven children in 5th grade in one elementary school in Iceland were randomly assigned to two groups, involving seven weeks of interventions; programming lessons and innovation lessons. Three cognitive ability tests, WISC-IV part 2, WISC-IV part 7 and Ravens, were administered before and after intervention. A working memory test, OSPAN, was used to measure children's working memory span. Mixed design ANOVA revealed that after innovation lessons children improved significantly from pre-test to post-test on WISC-IV part 2 post-test. Change in children's performance on WISC-IV part 7 depended on working memory span. Children with low working memory span performed significantly higher on WISC part 7 post-test after innovation lessons while children with high working memory span scored significantly higher on WISC part 7 post-test after programming lessons. These results indicate that working memory span is a factor in the relationship between programming and increased cognitive ability.

Útdráttur

Þessi rannsókn bar saman áhrif forritunarkennslu og nýsköpunarkennslu á vitræna getu. Þessi áhrif voru skoðuð með tilliti til vinnsluminnisspannar. Sextíu og sjö börnum í fimmta bekk í einum grunnskóla á Íslandi var skipt tilviljunarkennt í tvo hópa, sem fólu í sér sjö vikna íhlutun; forritunarkennslu og nýsköpunarkennslu. Þrjú hugræn próf, WISC-IV hluti 2, WISC-IV hluti 7 og Ravens voru lögð fyrir bæði fyrir og eftir íhlutun. Vinnsluminnispróf var notað til að meta vinnsluminnisspönn barnanna. Niðurstöður blandaðrar dreifigreiningar leiddu í ljós að eftir nýsköpunarkennslu var frammistaða barna á eftirmælingu á WISC-IV hluta 2 marktækt hærri en á grunnmælingu. Breytingar á frammistöðu barna á WISC-IV hluta 7 fór eftir vinnsluminnisspönn þeirra. Börn með lága vinnsluminnisspönn stóðu sig marktækt betur á WISC-IV hluta 7 eftirmælingu eftir nýsköpunarkennslu meðan börn með háa vinnsluminnisspönn stóðu sig marktækt betur á WISC-IV hluta 7 eftirmælingu eftir forritunarkennslu. Þessar niðurstöður benda til þess að vinnsluminnisspönn sé þáttur í sambandinu milli forritunar og aukinnar hugrænnar getu.

Foreword and acknowledgements

Submitted in partial fulfillment of the requirements of the BSc Psychology degree, Reykjavík University, this thesis is presented in the style of an article for submission to a peer-reviewed journal.

A great growth has occurred in the last decades in the use of computers in teaching (Liao & Bright, 1991; Pea, Kurland, & Hawkins, 1985; Plomp & Pelgrum, 1991). Computer and video games are a rapidly growing industry and the extensive availability of portable computers has led to an increased use in nations' schools (Papastergiou, 2009; Siegle, 2001; Squire, 2003; Tondeur, Van Braak, & Valcke, 2007). When discussing computer and video games the main focus has been on the social consequences, ignoring their educational potential (Squire, 2003). However considerations about the usefulness of computers in teaching have arisen, special consideration has been given to the effects of learning programming in schools on the cognitive ability of children (Kazakoff & Bers, 2012; Kazakoff, Sullivan, & Bers, 2012). Few studies have been conducted to examine how computers can be used specifically to improve children's performance since the eighties and nineties (Lehrer, 1986; Liao & Bright, 1991; Mayer & Fay, 1987; Pea, Kurland, & Hawkins, 1985).

Learning programming has been found to positively impact cognitive abilities (Kazakoff & Bers, 2012). During the eighties, Logo programming was a popular teaching tool in elementary schools (Kazakoff & Bers, 2012). Children in LOGO programming are taught to construct programs that design graphics by directing the movement of a small triangular pointer or "turtle" on the screen (Clements, 1986). Clements (1990) addressed in his article two complementary grounds that explain the strengthening effect of certain Logo programming environments on cognitive ability. First, Logo programming environment elicits processes that involve decision making and executive processes. Second, programming environments challenge children to compare and analyze problems, deciding the nature of the problems and solving them, which is beneficial for them in their own problem-solving process. There have been few studies involving the connection between programming and thinking skills

(Clements & Gullo, 1984; Degelman, Free, Scarlato, Blackburn, & Golden, 1986; Liao & Bright, 1991; Kulik, Banger, & Williams, 1983; Mayer, Dyck, & Vilberg, 1986). Researchers have speculated if gains in cognitive abilities depend on the length and amount of student's exposure to programming (Clements & Gullo, 1984; Mayer, Dyck, & Vilberg, 1986). For example, comparing children receiving LOGO programming to children receiving computer-assisted instruction, studies reveal that the programming groups score significantly higher on measures of cognitive ability compared to the computer-assisted group suggesting that programming rather than the use of computers for learning has beneficial effects (Clements & Gullo, 1984; Clements, 1986; McMahon, 2009).

Clements (1987) illustrates that learning LOGO programming enhanced cognitive skills like learning languages, learning to think within and outside the domain of programming, like semantics and transferring their knowledge from programming to other tasks. Children entered twelve weeks of computer training. Eighteen months following the end of training they were measured on achievement with the California Achievement Test, testing four basic content areas; reading, spelling, language and mathematics and cognitive ability tests measuring their ability to recall previously presented material, verbal reasoning and recognizing the relationship between pictures. Tu and Johnson's (1990) research supports those findings. Computer programming improved problem-solving skills from pretest to post test with undergraduate majors at the University of Illinois. It is, therefore, assumed that students learning to program a computer also learn about and improve their own thinking processes such as reasoning skills, planning skills, logical thinking and specifically problem solving skills (Mayer, Dyck, & Vilberg, 1986). Although previous studies indicate effect of programming on cognitive abilities these effects were neither simple nor straightforward (Clements, 1990). It cannot be determined what precisely was learnt and if cognitive skills of a wide generality were developed (Clements, 1990). Different studies have explored different aspects of cognitive abilities like problem solving, logical reasoning, rule learning and following instructions and directions, making it difficult to generalize about their results (Clements, 1986; Clements, 1987; Clements, 1990; Clements & Gullo, 1984; Degelman, Free, Scarlato, Blacburn, & Golden, 1986; Mayer & Fay, 1987; Tu & Johnson, 1990).

Research has indicated that programming increases intelligence (Lehrer, 1986). If programming can improve cognitive factors that underlie intelligence then teaching programming in schools would be an important part of the curriculum (Buschkuehl & Jaeggi, 2010; Phye & Pickering, 2006). Recent studies have for example shown that computer training has a positive effect on working memory (Carretti, Borella & De Beni, 2007; Holmes, Gathercole, & Dunning, 2009; Jaeggi, Buschkuehl, Jonides, & Shah, 2011; Klingberg, 2010; Klingberg, Forssberg, & Westerberg, 2002; Lee, Lu, & Ko, 2007; Turley-Ames & Whitfield, 2003). Carretti, Borella and De Beni (2007) examined the possibility of enhancing working memory performance with strategic training in both young and old adults. Procedures used to train working memory were the Immediate List Recall Task and Categorization Working Memory Span Task. Results showed that training enhanced performance on the working memory task and in prompt recall both for the younger and older group getting the strategic training. Participants significantly improved their performance after training. Strategic training has been shown to enhance performance on working memory tasks. Results have also shown children improving their performance on tests taken up to eight months after intervention and on different tasks that were not trained

(Jaeggi et al., 2011; Turley-Ames & Whitfield, 2003). Other studies, measuring different cognitive tasks, have, however, shown that improvement does not occur after training and show no significant difference occurring on tasks measuring both processing and storage of working memory (Chooi & Thompson, 2012; Lee, Lu, & Ko, 2007). Despite inconsistent findings regarding the effect of training the question whether programming can potentially improve cognitive factors has not yet been answered. One factor that has not been considered here is whether training effect can vary depending on the students working memory capacity. Working memory capacity refers to the preservation of information over a short period of time as well as the ability to work on the information, a function that is crucial for a wide range of cognitive tasks and for academic achievement (Klingberg, 2010). Working memory capacity can be used to predict performance on various cognitive and academic tasks (Klingberg, 2010). Studies are indicating that individuals with high working memory span perform better on academic tasks such as reading tasks and recall tasks (Garrison, Long, & Dowaliby, 1997; Lustig, May, & Hasher, 2001).

Studies are suggesting an effect of programming on cognitive ability but the precise effect is still unclear. The difficulty of comparing these studies and their effect on cognitive ability must be taken into consideration. The link between programming and intelligence raises the issue of whether working memory can be trained with programming lessons. Prior studies have mainly focused on the effects of programming on cognitive ability ignoring the role that working memory span can play in the training effect. The goal of the present study is to examine whether programming lessons increase performance on various cognitive ability tests compared to a course on innovation and whether the effect varies depending on the individuals' level of working memory capacity. Based on literature addressed above it was hypothesized that programming will increase performance on cognitive tests compared to innovation for children with high working memory span but not for children with low working memory span.

Method

Participants

A total of 67 children participated in this study. Participants were all students in 5th grade in one elementary school in Iceland. Children were randomly assigned into two groups, experimental group and active control group. The experimental group received computer programming lessons and the active control group received innovation lessons.

Materials and stimuli

Two parts of the Wechsler's Intelligence Scale for Children (WISC-IV) and a Ravens test were used to measure cognitive ability. A working memory span test (OSPAN) was used to measure children's working memory capacity.

Wechsler's Intelligence Scale for Children – Fourth edition. Two parts of the Wechsler's Intelligence Scale for children, fourth edition, Icelandic version, were used to measure cognitive ability, WISC-IV part 2 and WISC-IV part 7.

WISC-IV part 2. Part 2 of the Wechsler's intelligence scale for children is a verbal comprehension subtest measuring verbal reasoning and concept formation. It includes 21 pairs of words with two words that the researcher read one by one aloud for the children. Each child was asked to identify the similarity between those words. An example of such a question is: "How are an apple and a banana similar".

WISC-IV part 7. Part 7 of the Wechsler's intelligence scale for children is a letter-number sequencing measuring working memory. Each child was required to recall a sequence of numbers and letters the researcher read out loud, but in a numerical order and alphabetical order. It did not matter whether the children recalled the numbers or the letters first. An example of such a sequence is: “1 – B – 3 – G – 7”. Correct answer is either “1 - 3 – 7 – B – G” or “B – G – 1 – 3 – 7”.

Ravens test. Sixty pictures of complex patterns were used in the study. They were divided into two parts based on Jaeggis, Buschkuehls, and Shahs (2011) partition. Part A included thirty odd number pictures, that is, pictures 1, 3, 5 and so on. Part B included thirty even number pictures, that is, pictures 2, 4, 6 and so on. The first five pictures in each part were for practice. The pictures were missing one sector from the complex pattern and the child was required to choose from six to eight possible options the best completion.

Working memory span test. The working memory span task was based on Turners and Engels (1989) OSPAN task. This task required the children to read out loud a mathematical equation and remember a word that appeared following the equation. It was presented on a power point slideshow and in twelve parts. A slide appeared on the computer screen with a mathematical equation on the left and each child was required to read it out loud and tell the researcher if it was wrong or right. An example of such a mathematical equation is: “2 + 8 = 10”. Correct answer is right. On the right site of the screen a word appeared which the child was required to read out loud and memorize. An example of such a word is: “table”. After each part the children were required to write down the words they remembered on a specific answer sheet (see Appendix B). The first three parts contained two mathematical equations and words. The next three parts contained three mathematical equations and words. Next three parts after that contained four mathematical equations and words and the last three parts contained five mathematical equations and words (Turner & Engle, 1989).

Programming intervention. Lessons were based on programming games and the three dimensional-programming environment called Alice. Alice is used to help children to learn fundamental programming concepts in the context of creating simple video games and comic movies. In addition, mind maps and flowcharts for designing games were woven into the teaching.

Innovation intervention. Lessons were based on each child bringing up an idea of innovation or a design. They promoted their idea or design to their classmates and created a poster introducing the concept, like how it became an idea and why, whom it serves as well as combinations and materials. They later drew a picture of their ideas and every idea was sent to an innovation competition for all elementary schools in Iceland.

Equipment. A MacBook Pro computer was used for the tests.

Design and Procedure

The data were analyzed in a 2 time (pre-test vs. post-test) x 2 group (programming vs. innovation) x 2 working memory span (high vs. low) mixed design ANOVA for each of the three cognitive ability test.

This study was conducted in collaboration with the company Skema and with the approval of an ethical committee in Iceland. Data collection took place from September until the beginning of December 2012. It took place in Hofsstaðaskóli, an elementary school in Garðabær, Iceland. All participants were pretested before intervention on three cognitive tests; WISC-IV part 2, WISC-IV part 7 and Ravens test as well as on a working memory span test (OSPAN). The programming intervention lasted 70 minutes, once a week, for a total of seven weeks. Innovation intervention lasted for one and a half hour, once a week for a total of seven weeks. The study took place in a small room in Hofsstaðaskóli, the researcher sat at a table facing the participants, welcoming them and asking them to sit down. Participants came one at a time. Each participant was given a specific participation number. Before participating in each test children received a formal introduction to the test (see Appendix A). During both parts of the WISC-IV tests the researcher wrote the participants answers in a specific answer key for WISC-IV tests in the computer. The participants sat opposite to the researcher and consequently did not see the computer screen. After the participants completed the two parts of the WISC-IV test they were handed a printout of the Raven's test. Before participants began the Raven's test they were instructed to draw a ring around one of either six or eight parts with different patterns they thought fitted best in each complex pattern picture. For the working memory task the researcher sat down next to the participant. After introducing the task to the participants an exercise containing two mathematical formulas and two words was given to the participants to ensure their understanding of the test. During the test a specific registration form was used to write if participants answered right or wrong to the mathematics. When participants finished the working memory test they were thanked for their participation. After interventions all participants were measured again on the three cognitive ability tests; WISC-IV part 2, WISC-IV part 7 and Ravens test.

Data analysis

Children were measured before and after intervention on three cognitive ability tests, WISC-IV part 2, WISC-IV part 7 and the Ravens test. On WISC-IV test part 2 children were evaluated with a standard answer key. They could receive between 0 and 2 points for each question. On WISC-IV test part 7 children were evaluated with points, where 1 point was given for correct order of letters and numbers and 0 if they answered in wrong order of letters and numbers. Total score was counted for how many correct parts children got on the Ravens test.

On the working memory span test (OSPAN) children were evaluated by how many correct words they remembered. A median split was used to divide participants into two groups, high and low, on the working memory span test.

During measurements some participants did not complete all three tests and some measurements were invalid in the data collection resulting in variability in number of participants for each test.

Results

A 2 time-(baseline vs. post measure) x 2 group-(programming vs. innovation) x 2 working memory span-(high vs. low) mixed-design ANOVA was used to analyze the data for each of the three cognitive ability tests. The alpha level of significance was set at .05.

Ravens

The analysis from the 2x2x2 mixed design ANOVA revealed no significant main effect of time of measurement, F (1, 48) = 0.161, p = .690 and the main effect of intervention was not significant, F (1, 48) = 0.282, p = .598. The main effect of working memory span was not significant, F (1, 48) = 0.282, p = .598. The interaction between time and intervention was not significant, F (1, 48) = 0.522, p = .473. No significant interaction was between time and working memory span, F (1, 48) = 0.522, p = .473 and the interaction between intervention and working memory span was not significant, F (1, 48) = 0.021, p = .885. No significant interaction was between time, intervention and working memory span, F (1, 48) = 0.161, p = .690 for the Ravens test.

As can be seen in Table 1, programming intervention and working memory span had little effect on children's performance on the Ravens test. Identical results are to be seen with children receiving innovation intervention with low working memory span. However, children with high working memory span receiving innovation intervention improved on average on performance from 1.44 (SD= 0.512) on baseline measure to 1.69 (SD= 0.479). However this improvement was not significant. Independent of intervention children with high working memory span improved their performance from baseline (M = 1.46, SD = 0.508) to post-test (M = 1.61, SD = 0.497) but this improvement was not significant.

Table 1.

Descriptive Statistics for Time and Group on Ravens Test

Programming vs. innovation lessons	WM span	Ravens baseline M	Ravens baseline SD	Ravens post-test M	Ravens post-test SD
Programming lesson					
	Low	1.5	.519	1.43	.514
	High	1.5	.522	1.5	.522
	Total	1.5	.51	1.46	.508
Innovation lesson					
	Low	1.5	.527	1.5	.527
	High	1.44	.512	1.69	.479
	Total	1.46	.508	1.62	.496
Total					
	Low	1.5	.511	1.46	.509
	High	1.46	.508	1.61	.497
	Total	1.48	.505	1.54	.503

WISC-IV part 2

Table 2 shows the mean and standard deviation on the WISC-IV test part 2 depending on working memory span and intervention. The result of the 2x2x2 mixed design ANOVA revealed no significant main effect of time, F (1, 45) = 2.251, p =

.140. The main effect of intervention was significant, *F* (1, 45) = 4.118, *p* = .048. Children in the innovation group scored higher both before and after intervention. No significant main effect was for working memory span, *F* (1,45) = 2.059, *p* = .158. No significant interaction was between time and working memory span, *F* (1,45) = 0.669, *p* = .418. The interaction between intervention and working memory span was not significant, *F* (1,45) = .2.658, *p* = .110. No interaction was between time, intervention and working memory span (*F* (1,45) = 1.778, *p* = .189). Interaction between time and intervention approached significance, *F* (1, 45) = 2.986, *p* = .091. Children in the innovation group improved more over time than the programming group.

Table 2

Descriptive Statistics for Time and Group on WISC-IV Part 2

		WISC-IV part 2 baseline		WISC-IV part 2 post-test	
Programming vs. Innovation lessons	WM span	M	SD	M	SD
Programming lesson					
	Low	13.92	5.852	12.46	4.176
	High	16	4.29	17.18	3.401
	Total	14.87	5.195	14.63	4.461
Innovation lesson					
	Low	16.1	4.408	18.4	3.718
	High	16.2	4.828	17.87	3.623
	Total	16.16	4.571	18.08	3.593
Total					
	Low	14.87	5.277	15.04	4.922
	High	16.12	4.52	17.58	3.478
	Total	15.53	4.878	16.39	4.363

As can be seen in Figure 1, children receiving innovation lessons scored higher on part 2 of WISC-IV both before and after intervention. The innovation group also improved on the task whereas no improvement was seen for the programming group (interaction between time and intervention approached significance p=.091)

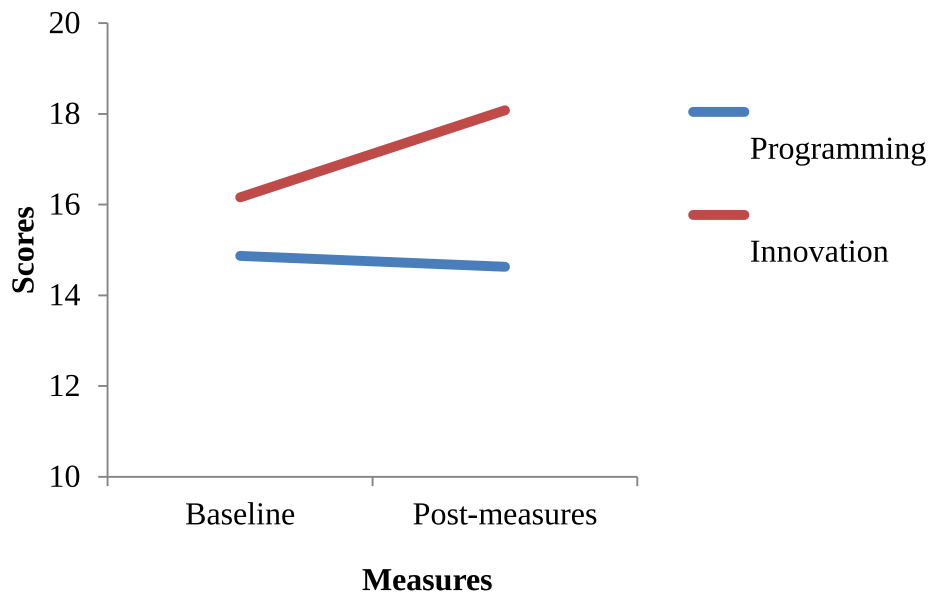

Figure 1. Children's performance on part 2 of WISC-IV for both interventions from baseline to post-measure.

WISC-IV part 7

Table 3 shows the mean, the standard deviation for WISC-IV test part 7 depending on working memory span and intervention. Analysis from the 2x2x2 mixed design ANOVA revealed a significant main effect of time, F (1, 45) = 8.573, p = .005. Children's scores on pre-test were significantly different than their scores on post-test. The main effect of intervention was not significant, F (1, 45) = 0.000, p = .998. There was however a significant main effect of working memory span, F (1, 45) = 5.153, p = .028. Children's working memory span affected their performance on the WISC-IV test part 7. Children with high working memory span scored significantly higher than the low working memory span children. No significant interactive effect was between time and intervention, $F < 1$. Interactive effect between time and working memory span was not significant, $F < 1$. A significant interactive effect was between time, intervention and working memory span, F (1, 45) = 12.496, p = .029.

Table 3

Descriptive Statistics for Time and Group on WISC 7.

		WISC-IV part 7 baseline		WISC-IV part 7 post-test	
Programming vs. Innovation lessons	WM span	M	SD	M	SD
Programming lesson					
	Low	14.77	4.304	14.54	3.929
	High	15.55	3.174	17.27	2.901
	Total	15.13	3.768	15.79	3.695
Innovation lesson					
	Low	13.6	3.307	15.2	1.687
	High	16.33	2.87	17	2.976
	Total	15.24	3.282	16.28	2.654
Total					
	Low	14.26	3.864	14.83	3.114
	High	16	2.966	17.12	2.889
	Total	15.18	3.492	16.04	3.182

As can be seen in Figure 2, children with low working memory span improved their performance after innovation intervention. Programming did not have an effect. As can be seen in Figure 3, programming intervention had more positive effect on children’s performance with high working memory compared to innovation intervention.

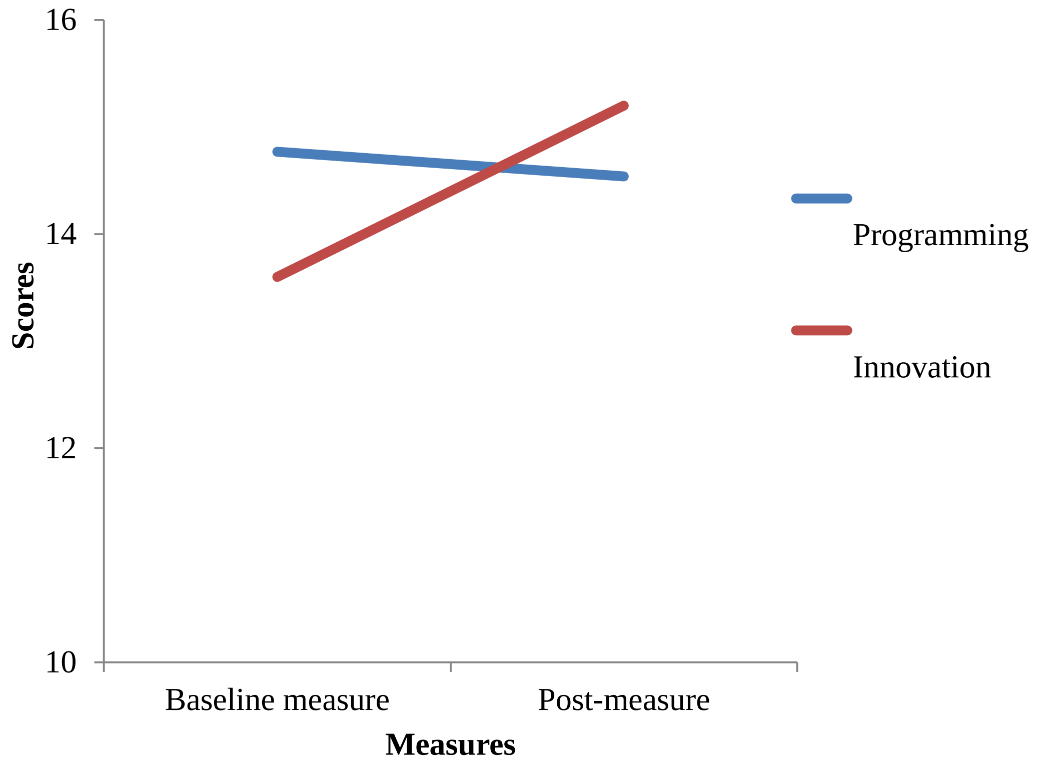

Figure 2. Effect of intervention on children's with low working memory span performance on part 7 of WISC-IV.

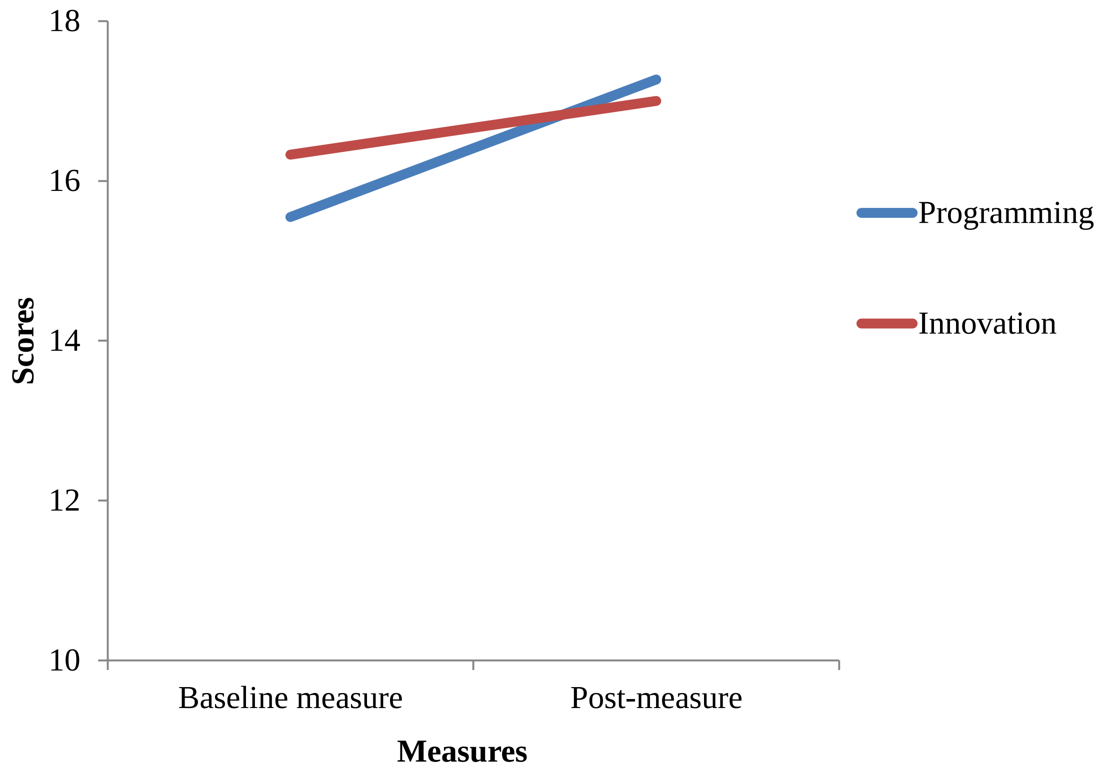

Figure 3. Effect of intervention on children's with high working memory span performance on part 7 of WISC-IV.

To summarize the results, the active control group (innovation) improved their performance on part 2 of WISC-IV after intervention. Effects of intervention on scores on part 7 of WISC-IV depended on working memory span. Children with low working memory span receiving innovation intervention improved more after intervention compared to children with low working memory span receiving programming intervention. Children with high working memory span scored significantly higher on part 7 of WISC-IV after programming intervention compared to innovation intervention. There was no significant effect of time, intervention or working memory span on Ravens.

Discussion

The main aim of the study was to examine the effect of programming in relation to working memory span on three cognitive tests; Ravens, WISC-IV part 2, WISC-IV part 7. This study yields two main findings. The active control group improved their performance after receiving innovation intervention on WISC-IV part 2. The experimental group showed no improvement on WISC-IV part 2 in posttest after intervention. The findings for WISC-IV part 7 revealed that the relationship between effects of intervention and performance depends on the individuals' working memory span. That is to say, children with low working memory span improved their performance on part 7 of WISC-IV after innovation. However, children with high working memory span in the experimental group outperformed the active control group on part 7 of WISC-IV after intervention. Thus, both interventions appear to improve performance of children with high working memory span, where children improved more after programming intervention compared to innovation intervention. The findings therefore support the hypothesis that programming improves performance on cognitive tests compared to innovation for children with high working memory span but not for children with low working memory span.

These findings suggest that programming does not necessarily on it's own have more impact than other interventions. These findings are inconsistent with previous literature that programming improves performance on cognitive tests (Clements & Gullo, 1984; Degelman, Free, Scarlato, Blackburn, & Golden, 1986; Kulik, Banger, & Williams, 1983; Liao & Bright, 1991; Mayer, Dyck, & Vilberg, 1986; Mayer & Fay, 1987). The findings highlight what Clements (1990) pointed out in his article, that perhaps programming does not affect all cognitive abilities, the effects might be more complex and specific and are confined to limited cognitive ability. It is possible that learning programming does not affect performance on part 2 of the Wechslers Intelligence Scale for Children, fourth edition, because it measures verbal comprehension. Maybe programming only affects specific cognitive skills, verbal comprehension not included. The findings for part 7 of WISC-IV have two implications. These results provide further support to previous research that programming affects cognitive abilities (Clements & Gullo, 1984; Degelman, Free, Scarlato, Blackburn, & Golden, 1986; Kulik, Banger, & Williams, 1983; Liao & Bright, 1991; Mayer, Dyck, & Vilberg, 1986; Mayer & Fay, 1987). In addition, since part 7 of the WISC-IV test is a working memory test, the findings support previous studies suggesting that programming affects individuals working memory (Clements, 1990) and their ability to recall (Clements, 1987). However, they provide us with new insights worthy to study further, mainly that these effects seem to depend on working memory span. Working memory span seems to be a factor in the relationship between learning computer programming and its affect on cognitive ability. Prior studies indicate that working memory span is a factor in academic achievement (Garrison, Long, & Dowalby; Lustig, May, & Hasher, 2001).

Several limitations of the study should be noted. The above findings should be interpreted with caution. First, participants were relatively few or only 67 in total, fewer in each sub-group, varying depending on test. This caused that within each group there were relatively few participants so the effects may be greater than this study reveals. Second, children were tested for all four cognitive tests at once. This demanded the children’s attention over a long period of time. Third, since all measures took place in the school and at school time, children missed classes and in some cases recess. This could affect the results since the children could have missed a class and recess he or she really enjoyed and, therefore, rushed through the tests without paying enough attention to performing as well as they could. It is also a concern that intervention was only once a week for seven weeks. It seems possible that programming innovation could have more impact on cognitive ability if intervention was more extensive like Clements & Gullo (1984) pointed out. Fourth, it is possible that the median split reduced the impact of the affect of working memory span. The difference between children with low span and children with high span is not clear because children with high span are pulled down because of the median while children with high span are pulled up resulting in the groups being more similar than they should be for comparison. However, when children’s grades were examined it was adequately clear that children with high working memory span had higher scores compared to children with low working memory span. An important factor in further research is to compare those interventions to a neutral group receiving no intervention. It might be a possibility that taking the same tests twice impacts the results on post measures making it difficult to assert that the intervention itself affects children’s performance.

Despite the above limitations, these findings indicate that working memory span plays a role as a factor in the relationship of intervention to performance on cognitive tasks. These findings give reason to the thought that working memory span could be an important factor and should not be ignored in the relationship between programming and cognitive ability. These findings add to the previous literature stating the positive effect of programming on cognitive ability and the importance of working memory span in that relation. It is important to study these effects further, mainly the precise effects of learning computer programming on similar cognitive tasks and expand research in the area of working memory to find out if the span of the working memory is possibly an important factor.

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Appendix A

WISC-IV hluti 2

Fyrirmæli

,,Fyrsta verkefnið er þannig að ég segi við þig tvö orð og þú átt að segja mér hvað þér finnst líkt með þessum tveimur orðum. Fyrst gef ég þér dæmi: ,,Hvernig er rautt og blátt líkt?"

Svar: ,,Það eru til dæmis bæði litir."

Ef barnið skilur ekki spurninguna þá spyrðu:

,,Hvað er sameiginlegt með rautt og blátt?"

,,Hvað eiga rautt og blátt sameiginlegt?"

WISC-IV hluti 7

Fyrirmæli

,,Nú ætlum við að fara í næsta verkefni og mun ég lesa upphátt fyrir þig tölur og bókstafi. Það sem þú átt að gera er að raða þeim í ákveðna röð: tölunum raðaru í stærðarröð (minnsta talan first) og bókstöfunum í stafrófsröð. Æfum okkur."

,,Ef ég segi til dæmis A – 3 er bæði rétt að svara:

A – 3 eða 3 – A"

,,Ef ég segi til dæmis H – 1 – 3 er bæði rétt að svara:

H – 1 – 3 eða 1 – 3 – H "

,,Bara svo lengi sem tölurnar eru í stærðarröð og bókstafirnir í stafrófsröð"

Raven's fyrirlögn og fyrirmæli

Fyrirmæli

,,Í þessu verkefni sérðu 30 myndir. Á hverri mynd má sjá að það vantar bút inn í. Fyrir neðan hverja mynd eru sex til átta bútar með mismunandi mynstri eða formi. Merktu við þann bút sem þér finnst passa best inn í myndina hverju sinni."

Vinnsluminnispróf

Fyrirmæli

,,Þetta verkefni skiptist upp í nokkra hluta. Verkefnið gengur út á að lesa upphátt dæmi og leggja orð á minnið. Þegar verkefnið byrjar, bið ég þig um að lesa upphátt reiknisdæmið sem kemur upp vinstra megin á skjánum og segja hvort dæmið sé rétt eða rangt. Svo skaltu lesa upphátt orðið sem kemur hægra megin á skjánum og leggja það á minnið. Í lokin á hverjum hluta skaltu svo skrifa orðin niður á blað.”

Appendix B

Þáttakandi: Dagsetning: Fyrirlagnaraðili:

Orðalisti 1	Orðalisti 5	Orðalisti 9
Orðalisti 2	Orðalisti 6	Orðalisti 10
Orðalisti 3	Orðalisti 7	Orðalisti 11
Orðalisti 4	Orðalisti 8	Orðalisti 12