Mental simulation of Action:

Does Working Memory Capacity Affect Mental Simulation when Solving a Meaningful Task with an Ultimate Goal?

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Submitted in partial fulfilment of the requirements of the BSc Psychology degree, Reykjavik University, this thesis is presented in the style of an article for submission to a peer-reviewed journal.
Abstract – English

Many studies on how learning and mental simulations interact have been conducted. The present study main aim was to examine if different types of instructions and cognitive capacity affected mental simulation. It was hypothesized that, following video instructions would facilitate the task of building LEGO figure more than following graphic instructions. It was also hypothesized that the effect of the instructions would vary with working memory capacity (WMc). Fortie one participants performed on the OSPAN working memory task, a mental simulation task and answered questions regarding workload. Participants were divided into high and low WMc. Participants mental simulation task was to build a LEGO figure from 16 traditional LEGO blocks by following randomly either video instructions or graphic instructions. Participants performance for building the LEGO figure was scored from 0 – 9 points, dependent on predeterment rules set for scoring and the time for completing the task was measured. Then participants evaluated the task difficulty by answering questions. In contrast with participants low on WMc, participants high on WMc earned more points and solved the task faster when following video instruction compared to graphic instructions. Workload was in general judged to be higher for graphic compared to video instructions.

Abstract - Icelandic

Margar rannsóknir hafa verið framkvæmdar til þess að skoða hvernig nám og hugræn eftirlíking samtvinnast. Meginmarkmið rannsóknarinnar var að kanna hvort vinnsluminnisspönn (VMs) og ólíkar gerðir leiðbeininga hefðu áhrif á hugræna eftirlíkingu. Tvær tilgátur voru settar fram; annars vegar að þeir sem fylgja myndbandsleiðbeiningum (MBleið) ættu auðveldara með að byggja LEGO karl heldur en þeir sem fylgja myndaleiðbeiningum (Mleið) og hins vegar að áhrif leiðbeininga væru breytileg eftir VMs. Fjörutufu og einn þátttakandi leystu OSPAN vinnsluminnispróf, próf fyrir hugræna eftirlíkingu og svöruðu spurningum tengdum álagi. Þátttakendur var skipt í tvo hópa; háa og lága VMs. Próf til að mæla hugræna eftirlíkingu fól í sér að þátttakendur byggðu LEGO karl úr 16 hefðbundnum LEGO kubbum með því að fylgja tilvilstunakennt annað hvort MBleið eða Mleið. Frammistaða þátttakenda við byggingu LEGO karlsins var metin eftir fyrirfram gefnum reglum og var metin frá 0 – 9 stigum. Að lokum mátu þátttakendur álægi við að byggja LEGO karlinn með því aða svara spurningum. Þátttakendur hár í VMs fengu fleiri stig fyrir að byggja LEGO karlinn og leystu verkefnið á betri tíma en þátttakendur með lága VMs. Ennfremur var frammistaða þátttakenda með háa VMs betri þegar þeir fylgdu MBleið en ef þeir fylgdu Mleið.
Mental Simulation of Action:

Does Working Memory Capacity Affect Mental Simulation of Action when Solving Meaningful Task with an Ultimate Goal?

In humans there is a cognitive function known as mental simulation (Grézes & Decety, 2001). Mental simulation is a moderately new concept in cognitive science and has been given closer attention in recent years (e.g., Decety & Ingvar, 1990; Alberto, Cihak & Gama, 2005; Thomas & McKay, 2010). Mental simulation is based on the thought of movements (e.g., Hegarty & Sims, 1994; Bonnet, Decety, Jeannerod & Requin, 1997; Chaminade, Meary, Orliaguet & Decety, 2001) and is grounded in the motor system in the brain (e.g., Hegarty & Frak, 1994; Fadiga, Fogassi, Pavesi & Rizzolatti, 1995; Decety, 1996; Jeannerod & Frak, 1999; Grézes & Decety, 2001; Fadiga & Craighero, 2001). Such mental simulations play an important role not only when predicting and understanding the consequences of our own movements but also when understanding other people’s movements. Mental simulations are shaped by units that include representations of non-visible semblance and can be used in combination with non-imagery operation but do not consist of scrutiny of a complete visual image in the ‘mind’s eye’ (Hegarty, 2004).

A number of studies on people’s mental simulation and factors that are believed to affect mental simulation have been carried out, both in order to understand the brain’s neuropsychological mechanism behind mental simulation (Grézes & Decety, 2001; Chaminade, Meary, Orliaguet & Decety, 2001) and to understand how mental simulation manifests itself when solving tasks (Kozhevnikov, Hegarty & Mayer, 2002; Lee, Plass & Homer, 2006).

Given that mental simulation allows people to simulate actions and understand movements, it is important to look at what potential role mental simulation could have in learning. For example, this simulation ability could mean that presenting learning material by
real life demonstration might work better than presenting it verbally or in pictures. Similarly, presenting material in pictures might work better than using verbal material. The literature on mental simulation and learning shows, however, that the impact of different types of instructions on learning can be dependent on other factors, such as cognitive capacity, prior knowledge and the type of task. Lee, et al., (2006) studied visual representation of gas laws and how computer-based science simulation improved cognitive load for learning among 257 middle-school chemistry students. The interaction between different levels of the learners' prior science knowledge and two different modes of visual representation of gas laws appropriate for these students' knowledge (13 to15 years) was investigated. The fundamental gas law characteristics were presented either in verbal form (i.e., temperature, pressure, volume and numerical values) or by adding iconic (image) representation (e.g., weights for pressure, burners for temperature) to the verbal representation. Lee and colleagues manipulated visual intricacy by splitting the display of the simulation into two screens (low complexity) or presenting all the information in one screen (high complexity). Lee and colleagues' main findings indicated that high prior knowledge learners gained more if only the verbal representations and not iconic representations were used. Low prior knowledge learners gained more if iconic representations were added to the verbal ones, compared to the verbal only format. High-knowledge learners performed better overall than low prior-learners.

Schnotz and Rasch (2005), studied how the effects of animated pictures could be beneficial in learning time-differences between locations near the North Pole and how different kind of animations - manipulation and simulation pictures - could affect this learning. The subjects were 66 university students with different levels of learning qualifications. By solving knowledge tests and intellectual tests, subjects were divided into high and low learning prerequisites. Subjects were then divided into two groups - a group which received text with animation and a group which received static pictures. The subjects in
the animation group could manipulate the pictures by specifying certain days or times for particular geographical locations. These subjects could also choose between various ways of circumnavigating the earth with a visual simulation of a particular navigation from pictures they were shown. The situation for the other group was identical, but in this group, subjects were shown static pictures which they could not manipulate or simulate. Schnottz and Rasch concluded that subjects’ ability to manipulate pictures in order to create various time-states of the earth by selecting information about time-differences, was undoubtedly helpful when answering time-difference questions later. High prerequisites subjects seemed to benefit especially from this function, as their resources made them well capable of using this option. In answering the circumnavigation questions, simulation pictures seemed to play the main role. The mental simulation process became less difficult with the external simulation (static pictures) process because of the analogue. Therefore, simulation pictures might be supportive for learners who need to rely on external support. The performance of high learning prerequisites subjects was significantly better if they learned from manipulation pictures rather than from simulation pictures and external support was not important in their learning. For lower learning prerequisites subjects, simulation pictures resulted in better learning. To Schnottz and Rasch’s surprise, low learning prerequisites subjects’ performances were even better with static pictures than with animated pictures.

In Kozhevnikov’s et al. (2002) research, a difference between people with high and low spatial ability was established. The research participants were university students who went through two experimental conditions. In study 1, 60 participants answered a questionnaire measuring whether participants preferred using imagery or verbal-logical modes when solving problems. Participants then solved some tests; the Card Rotation Test, the Cube Comparison Test, the Paper Folding Test, the Form Board Test and the Advanced Vocabulary Test. The results for study 1 indicated that visualizers fall into two groups; visualizers of high
spatial ability and visualizers of low spatial ability. Such findings were not found among verbalizers. In study 2, the researchers sought to compare the use of mental images in problem solving between these two groups of visualizers. Interviews with 17 participants - 8 high-spatial visualizers and 9 low-spatial visualizers - were administered. Participants were presented with a graph of motion and asked to visualize and construe a real situation depicted on the graph. The results showed that none of the participants managed to solve the problem without error, nor did any of the participants illustrate the graph as an abstract schematic representation but rather supposed the shape of the graph to resemble the path of the actual motion.

High-spatial visualizers formed more schematic images and manipulated them spatially while low-spatial visualizers formed the graphs as pictures and relied mainly on visual imagery. Kozhevnikov and colleagues (2002) compared the problem solving scheme used by visualizers to those of verbalizers. The results demonstrated that verbalizers of low and high spatial ability did not have any clear, apparent preference in using visual or spatial imagery in contrast to visualizers.

As prior research on mental simulation and learning has shown, the various ways in which learning material is presented are significant, but this seems to be dependent on the individual's cognitive capacity. As pointed out by Just and Carpender (1992), working memory plays an essential role in complex thinking, such as reasoning and solving complicated tasks.

Kalyuga (2007) stated that the transformation of learners' knowledge in certain areas changes the form of learning and capability, so that when a relevant knitted is non-existent, the working memory can easily become overloaded when dealing with many new components of information. A primary factor affecting the efficiency of instruction is the limitation of the working memory in processing information and related cognitive load.
To sum up - in humans there is a cognitive function known as mental simulation, recognized as being important in learning. Aforementioned studies on mental simulations indicate that pictures (static/animated), verbal material and computer simulations are important in learning. The studies also indicate that the type of task, former knowledge and cognitive ability affect mental simulation. It is important to clarify the conjunction between cognitive process and mental simulation. How does working memory capacity affect mental simulation when solving a task? The objective of the present study was to compare two types of instructions- video and graphic (pictures) - for a particular problem solving task. In addition to performance measurement, participants were also asked to judge the task’s difficulty. Based on the above literature, two hypotheses were tested in this study, 1) following video instructions would facilitate the task of building a LEGO figure more effectively than following graphic instructions, and 2) that the effect of the instructions would vary according to working memory capacity. Evidence to confirm the former hypothesis would supply a verification of the hypothesis that the form of instruction in education needs to be carefully considered in advance, and evidence for the second hypothesis would supply a verification of the hypothesis that working memory can be overloaded when solving the task.

Method

Participants

Participants were all students at Reykjavik University. In total, 41 students, 23 females and 18 males. The ages of participants ranged from 19 to 38 years, with an average age of 23 years ($SD = 4.17$).

To be eligible to participate in the study, participants had to have both hands, index fingers and thumbs in full working order and participants with any visual impairments were eliminated (using glasses was not defined as visual impairment). Students from the research participant pool at the psychology department as well as from the general student population
at Reykjavik University were recruited. The students from the research participant pool gained course credits for their participation. There was no missing data in the present study.

**Stimuli, measures and equipment**

The time measurement for the working memory task and for the time it took participants to build the LEGO figure, was done with a stop-watch app (Stopwatch & Timer) downloaded onto a LG F70 mobile smartphone. The stop-watch measures hours, minutes, seconds and milliseconds.

**Working memory capacity task.**

Participants solved the WMc task based on OSPAN. In the OSPAN task there are equations and words. The OSPAN task is a reliable and valid indicator of WM capacity (Unsworth, Heitz, Schrock & Engle, 2005). Participants read out loud equation and answered if it was right or wrong and then participants read out loud the word followed. Example: “Is (7 x 1) + 5 = 13? Shower”. After each part of the OSPAN task, participants had to remember the words from the part in a right order. The task involved four parts. In the first part participants answered 2x3 equations and had 2x3 words to remember. In the second part participants answered 3x3 equations and had 3x3 words to remember. In the third part participants answered 4x3 equations and had 4x3 words to remember and in the fourth and last part, participants answered 5x3 equations and had 5x3 words to remember - in total 42 equations and 42 words. The researcher marked participants’ equations answers (right or wrong) on a sheet. Then participants’ correct answers to the equations and the words in the right order were counted and scored.

**Participants’ points building the LEGO figure.**

For measuring participants’ scores in building the figure a photo was taken of each figure using a Canon IXUS 80 IS camera and the researcher counted the scores by predetermined rules.
Participants’ evaluations of workload.

Participants evaluated the LEGO figure building by answering two questions (see Appendix A): “How hard in your opinion do you think the building of the figure was?” and “What do you feel about the time limits for building the figure?” The questions were on five level Likert-scale. For the former question, participants could choose: Very easy, rather easy, neither easy nor hard, rather hard and very hard. For the latter question, participants could choose: Very slow, rather slow, neither slow nor fast, rather fast and very fast.

Procedure

Participants assembled for the study at a small research room in the psychology department one by one, by agreement. The procedure was as follows: participants started by reading information about the study and were encouraged to ask questions if they had any. All participants agreed to take part in the study by signing an informed consent form (see Appendix B). Students were told that their identities were protected by anonymity and that it would be impossible to identify them from their answers as participants were assigned numbers. Then the study’s procedure was explained to the participants. Participants were told that they would start by solving a working memory task (OSSPAN) on a computer (LENOVO YOGA 2 with 15 inch screen). Before participants started solving the OSPAN task, they were received practice trials (two times two equations and two words). Then the task commenced. Participants were told that there were no time limits for solving the working memory task, but that the time was being measured to confirm the average time for all participants in the study. Participants were told they had to remember the words and write them down in the same order as presented in the task. Participants were politely asked to stay focused and to give their full concentration to solving the task.

When participants had completed solving the working memory task, the researcher closed the computer lab top, and laid a sheet of paper on the table which the participants were
MENTAL SIMULATION OF ACTION

asked to read. On the paper were instructions; either telling the participants that they were about to watch an instruction video (see Appendix C) on how to build a LEGO figure or that they were about to be shown graphic instructions (see Appendix D) on how to build a LEGO figure. In the paper, participants were informed how long the instructions were, how long they had to solve the task (building the LEGO figure) and that they had to use all the blocks. When the participants had read the paper the researcher pointed out the main information from the paper. The instruction video was shown on the computer and was 31 seconds in length. There was no sound on the video and only the hands up to the wrist of the person building the LEGO figure were visible to the participant. When the video ended, the researcher closed the computer and the participant was directed to the next table. In the middle of that table was a white cloth. The participant was told to make her/himself comfortable in the seat. Then the participant was told that under the cloth were LEGO blocks and that she/he was going to build the LEGO figure they saw in the instruction (either video or graphic). Participants were then told that they had 90 seconds to build the figure and that they would be told when to stop. Also, the participants were told that they did not have to use the whole 90 seconds - they could just say when they were finished (or thought they were finished). At that time, the researcher lifted the cloth and the blocks were visible to the participant for the first time. The same color (blue) as in the instructions. At the same time as the cloth was lifted, the stopwatch started. The procedure was the same for the graphical instructions, but instead of watching a video, participants watched one page at a time turned by the researcher with graphic showing how to build the figure. In total there were 14 pictures which the researcher turned in 31 seconds (+/- 3 seconds).

When the participants had finished building the LEGO figure, the last part of the study was to answer two questions. The question was on five-level Likert scale, where participants evaluated the task difficulty (building the figure) and said whether they felt they were under
pressure with regard to time while building the figure. The researcher asked the questions and marked participant’s answers on the questionnaire sheet.

The kind of instruction the participants followed - video or graphical - were randomized. In order to avoid any bias as to how many participants followed each form of instructions, the researcher ensured that there would be an equal numbers in both groups. In total, 21 participants followed the video instructions and 20 participants followed the graphic instructions.

**Design and data analysis**

Three two (Instructions: video or graphical) by two (WMc: high or low) Fixed factor ANOVAs were conducted to analyze the data. The dependent variables were - the time it took participants to finish the LEGO task (*time*), the points participants earned for building the LEGO figure (*points*) and subjects’ evaluations of the task difficulty.

Participants’ points in building the LEGO figure could vary from 0 – 9; one point for each rule met. Zero points indicated that participants did not manage to meet any of the nine rules set for gaining points and 9 points indicated that participants managed to meet all the nine rules set for gaining points. All the LEGO figures that participants built were imaged on a camera. The researcher verified each figure-building and gave participants points after the participants left the research room.

The best way to explain the rules for the awarding of points is to examine the photos the researcher made for determining points, see Figure 1.

![Figure 1](image1.png)

*Figure 1. The determining rules for determining points.*
Each stage of the LEGO figure gave one point. By completing the building of the LEGO figure, participants earned nine points (full house).

Participants were divided into two groups; high and low on working memory capacity using median split. In total 43.9% \((N = 18)\) of participants were defined as having low working memory capacity and 56.1% \((N = 23)\) were defined as having high working memory capacity. Of the two instructions for building the LEGO figure, 51.2% \((N = 21)\) followed the video instructions and 48.8% \((N = 20)\) followed the graphic instructions.

**Results**

The goal of this study was to examine the impact of different type of instructions on problem solving ability and whether this varied with working memory capacity. Following that aim, participants solved a task following different types of instructions and rated the task’s difficulty. Their WMc was also measured. Results demonstrating difference with alpha coefficient of less than or equal to .05 were accepted as significant. Two (Instructions: video or graphic) by two (WMc: high or low) Fixed factor ANOVA were conducted for; the time it took participants to finish the LEGO task \(\text{lego time}\), the points participants earned for building the LEGO figure \(\text{points}\) and questions being asked \(\text{evaluations}\).

In total, 11 participants low in WMc and 10 participants high in WMc followed the video instructions and 7 participants low in WMc and 13 participants high in WMc followed the graphic instructions.

**Points for building the LEGO figure**

Participants could earn 0 to 9 points in building the LEGO figure. Figure 2 illustrates participants’ points distributions.
As can be seen from Figure 2, the largest number of participants earned zero points ($N = 12$) and 3 participants met all the rules while building the LEGO figure and earned 9 points (two followed video instructions and one followed graphic instructions). The mean number of points was below 3 ($M = 2.68$) with rather high distribution in the points range ($SD = 2.62$).

The results of the 2x2 ANOVA for earned points revealed no main effect of participants’ WMc, $F (1,37) = 1.03, p = .32$. The main effect of the instruction followed, was not significant, $F (1,37) = .80, p = .38$. There was no significant interaction between participants’ WMc and the instructions they followed, $F (1,37) = .67, p = .41$. 

*Figure 2.* Participants´ points distribution for building the LEGO figure.
Even though there were no significant interactions between participants’ WMc and the instructions they followed for the points earned building the figure, Figure 3 indicates that for low WMc participants mean earned points for building the figure were almost twice as high when they followed graphic instructions ($M = 3.00$) as when they followed video instructions ($M = 1.55$).

**Time building the LEGO figure**

In table 1 participants’ average time building the LEGO figure, the instruction they followed, and their WMc is viewed. As can be seen in the table participants low in WMc average time was very alike, whether they followed video or graphic instruction. But for participants high in WMc there are nearly 20 seconds (19.11) difference if they followed video or graphic instructions with much better (lower) time for building the LEGO figure, if they followed video instructions.
Table 1

Mean and standard deviations for the time it took participants to build the LEGO figure for high and low WMC and different instructions

<table>
<thead>
<tr>
<th>Participants WMC</th>
<th>Video instruction</th>
<th>Graphic instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>Low WMC</td>
<td>11</td>
<td>80.98</td>
</tr>
<tr>
<td>High WMC</td>
<td>10</td>
<td>67.17</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>74.40</td>
</tr>
</tbody>
</table>

Note. WMC = working memory capacity.

The results of the 2x2 ANOVA for the time it took to build the figure showed no significant main effect of participants WMC. Participants high in WMC were not faster building the LEGO figure than participants low in WMC, $F(1,37) = .37, p = .55$. The main effect of the type of instructions participants followed was also not significant, $F(1,37) = 2.56, p = .12$ - but the interaction between participants’ WMC and the instructions they followed, was significant, $F(1,37) = 3.95, p = .05$. The interaction is clear as Figure 4 indicates.
Figure 4. The interaction between participants’ WMc and the instructions they followed for the time it took participants to build the figure.

As can be seen in Figure 4 for participants low in WMc, the type of instructions did not matter for their performance. The Figure indicates that for participants high in WMc, type of instructions influence their performance as they performed faster following the video instruction, with time difference close to 20 (19.11) seconds between video and graphic performance.

Evaluations of the workload (time pressure and difficulty)

Table 2 indicates participant’s evaluations of the time pressure experienced while building the LEGO figure.
Table 2

Participants’ ratings of the time pressure experienced while building the LEGO figure

<table>
<thead>
<tr>
<th>Answer options</th>
<th>Participants low in working memory capacity</th>
<th>Participants high in working memory capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very slow</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Rather slow</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Neither slow nor fast</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Rather fast</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Very fast</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Total answers</td>
<td>18</td>
<td>23</td>
</tr>
</tbody>
</table>

Participants’ ratings of the time pressure experienced while building the LEGO figure demonstrates some difference between participants high and low in WMc. Close to one-third (39.13%) of participants high in WMc rated the time pressure as rather or very slow. Nearly one-sixth (16.67%) of participants low in WMc rated the time pressure rather or very slow.

Table 3

Mean and standard deviations for participant’s rating of the time pressure for low and high WMc and different instruction

<table>
<thead>
<tr>
<th>Participants WMc</th>
<th>Video instruction</th>
<th>Graphic instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>Low WMc</td>
<td>11</td>
<td>3.09</td>
</tr>
<tr>
<td>High WMc</td>
<td>10</td>
<td>2.50</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>2.81</td>
</tr>
</tbody>
</table>
Note. WMc = working memory capacity.

Table 3 demonstrates that participants high or low in WMc evaluate more time pressure following the graphic instructions than the video instructions, but the difference is more for participants low in WMc.

The 2x2 ANOVA for evaluated time pressure revealed no significant main effect of participants’ WMc, participants low in WMc did not evaluate the time pressure when building the LEGO figure, more than participants high in WMc, $F (1,37) = .91, p = .35$. There were a significant main effect for instructions participants followed, $F (1, 37) = 5.42, p = .025$. The interaction between participants’ WMc and the instructions they followed, was not significant, $F (1,37) = .73, p = .40$. As Figure 5 indicates, both high and low WMc participants judged the time pressure higher when receiving the graphic instructions compared to the video instructions.

![Figure 5. Participants` evaluations of the time pressure for high and low WMc and the instructions.](image-url)
Table 4

Mean and standard deviations for evaluation of how difficult the task was for high and low WMc and different instructions

<table>
<thead>
<tr>
<th>Participants WMc</th>
<th>Video instruction</th>
<th>Graphic instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>Low WMc</td>
<td>11</td>
<td>3.09</td>
</tr>
<tr>
<td>High WMc</td>
<td>10</td>
<td>3.10</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>3.10</td>
</tr>
</tbody>
</table>

Note. WMc = working memory capacity.

Table 4 demonstrates little difference between participants low or high on WMc and how they evaluated the difficulty building the LEGO figure, independent of the instruction they followed. The mean and standard deviation are very alike, both within and between participants low or high on WMc.

The 2x2 ANOVA for the evaluation of task difficulty showed no significant main effect of participants’ evaluations of the task difficulty, participants low in WMc did not evaluate the task more difficult than participants high in WMc, $F(1,37) = .004, p = .95$. Also, there were no significant main effects of which instruction participant’s followed, $F(1, 37) = 1.20, p = .28$. The interaction between participants’ WMc and the instructions they followed, was not significant, $F(1, 37) = .001, p = .97$.

Figure 6 indicates that participants’ mean evaluations of the task difficulty and the instructions they followed, was not different, weather participants were high or low in WMc.
Figure 6. The interaction between participants’ WMc and the instructions they followed for the points earned building the figure.

Discussion

The main goal of this study was to examine whether participants’ abilities to use different forms of instructions to solve a task would vary according to their WMc. Hypothesis 1) Following video instructions would facilitate the task of building a LEGO figure more effectively than following graphic instructions, was partly supported by the study findings. The form of instructions did affect how participants evaluated time pressure when solving the task regardless of participants’ WMc. With hypothesis 2) The effect of the instructions would vary according to working memory capacity - the study findings partly support the hypothesis. Participants’ ability to use different types of instructions varied according to whether their WMc was high or low. When it came to evaluating workload, however, participants experienced more workload for graphic than for video instructions, whether they were high or low in WMc.

The study’s task, building a LEGO figure by following video instructions, was carried out more successfully than when following graphic instructions by participants with high
WMc. The form of instructions for participants with low WMc did not change their performance. The findings that participants with high WMc did better in the time measurements if they followed video instructions are consistent with other researches that have indicated that movement (e.g., video, motion-sentences, body-movement) works better than static pictures, diagrams and sentences which do not include movements, for example (Hegarty & Frak, 1994; Schnotz and Rasch, 2005). Even though the difference between participants with low or high WMc, the instructions they followed and the points earned building the LEGO figure was not significant, the mean score indicates some difference. Participants low in WMc averaged score was 1.55 points for the video instructions and 3.00 points on average when they followed the graphic instructions. This demonstrates that participants with low WMc did better building the LEGO figure when following the graphic instructions, than when they followed the video instructions. This is in line with Schnotz and Rasch's (2005) findings that low learning prerequisites subjects performed tasks better when following static pictures rather than animated instructions and is also in line with Lee and colleagues' (2006) conclusions, that low prior knowledge learners gained more if iconic representations were added to the verbal ones compared to using the verbal only format. These differences were not found with participants with high WMc, with average points of 3.10 for the video instructions and 3.15 for the graphic instructions.

The findings that types of instructions (video/graphic) make a difference between good and bad performance for participants high in WMc is in line with Kozhevnikov et al.'s (2002) findings that high-spatial visualizers manipulate graphs of motion spatially but low-spatial visualizers construe the graph as pictures and mainly hold on to iconic imagery. The main focus of previous studies on mental simulation has been on language and people’s visual imagery when reading/listening to sentences or stories and in sports training. To the author’s
knowledge, fewer studies have focused on how mental simulation works when performing tasks or solving problems which do not involve sentences or stories.

Aforementioned studies have shown that it is not only the form of instructions, former knowledge and cognitive ability which affect people’s performance when solving a task, but also the type of task. It is worth considering whether the LEGO task was too difficult to show a significant difference between participants with high WMc and participants with low WMc. Factors such as the video quality, brightness and clarity and whether these could have been better also need to be considered. It is possible that to benefit more from the video instruction, participants needed to have a higher, rather than lower, WMc. Nevertheless, it is interesting to have results that indicate that video instructions do not necessarily result in better performance of the task than graphic instructions. The efficiency of the instructions seems to go hand in hand with the type of project and working memory capacity, which is consistent with Kalyuga’s (2007) findings. A primary factor affecting the efficiency of instructions is the limitation of the working memory in processing information and related cognitive load (Kalyuga, 2007). Taken together, participants, whether high or low in WMc, experienced more workload for the graphic instructions than for the video instructions. It is possible that, if the task had been easier, a totally different result would have been demonstrated. The reason the study failed to support the hypothesis that the type of instructions (video/graphic) for participants low in WMc make a difference, may be the task difficulty. The instructions participants followed when solving the LEGO figure building task relied on their visual representations with no verbal instructions to follow. Thomas and McKay (2010) stated that persons’ cognitive style and instructional materials go hand in hand in task solving, which supports the speculation that this task study was too difficult. The video instruction quality may have affected participants’ cognitive style and, more importantly, the time given to follow the instructions (31 and 31+/-3 seconds) may have been insufficient and have affected
performance of the task. It should also be considered that the study’s failure to demonstrate a
difference for the type of instructions with participants low in WMc followed, is explained by
the fact that, overall, these participants were doing poorly in the task. This again turns our
attention to the time given to follow the instructions.

Seeing that the inhibitory system is a part of the mental simulation function (Bonnet, et al., 1997), it is worth asking whether this system is somehow affected by the WMc. Future
researches could work on supporting or rejecting findings on that topic. Can it be that
inhibiting behavior is somehow harder for people with low WMc, resulting in poorer
performance in task solving because lack of inhibition decreases the cognitive process in
mental simulation?

This study is not without limitations. Firstly, the sample size is rather small - 41
subjects - as well as the fact that the subject sample is homogeneous, with all subjects being
students at the University of Reykjavik. It is possible that the quality of the instructions
hindered some participants’ performances and by increase the instructions quality it can be
prevent the quality is being measured. The study task may have been too difficult to
demonstrate the difference between participants high or low in WMc and it should be asked
whether the time participants had to watch/view the instructions and the time participants had
to build the figure (90 seconds) were insufficient. Finally, it should be mentioned that the
supervisor of the study noticed that many participants engaged in self-talk while building the
LEGO figure. Self-talking in problem solving is a known phenomenon. Taking self-talk as a
variable in a study on mental simulation could be informative. The aforementioned
disadvantages could be ruled out with a new study.
References


Appendix A

Participants evaluations on the task difficulty

1. **Hversu erfitt fannst þér kubba-verkefnið?**
   
   ( ) Mjög auðvelt  ( ) Frekar auðvelt  ( ) Hvorki auðvelt né erfitt
   
   ( ) Frekar erfitt  ( ) Mjóg erfitt

2. **Hvernig upplifði þú hraðann við verkefnið?**
   
   ( ) Mjóg hægt  ( ) Frekar hægt  ( ) Hvorki hægt né hratt  ( ) Frekar hratt  ( ) Mög hratt
Appendix B

The consent form all participants agreed participation by signing

Rannsókn: Áhrif vinnsluminnisgetu á úrvinnslu verkefns.

Ábyrgðarmaður rannsóknar: X

Háskólinn í Reykjavík, sími: X

Tilgangur þessa eyðublaðs er að tryggja að þáttakandi skilji bæði tilgang rannsóknarinnar og hvert hans hlutverk er í rannsókninni. Eyðublað þetta verður að veita nægar upplýsingar svo þáttakandi geti tekið upplýsta ákvörðun um þátttöku sín í rannsókninni. Vinsamlegast leitið til rannsakandans ef einhverjar spurningar vakna eftir lestu þessa eyðublaðs.

Starfsfólk rannsóknarinnar: Auk ábyrgðarmanns rannsóknarinnar, sem nefndur var hér að ofan, eru eftirfarandi aðili einnig starfandi vegna rannsóknarinnar og má hafa samband við hana hvenær sem er ef þörf er á frekari upplýsingum varðandi þessa rannsókn: Huldís Franksdóttir Daly (huldis11@ru.is). Framkvæmd rannsóknarinnar og mælingar eru í höndum Huldísar Franksdóttur Daly og er þessi rannsókn BSc verkefni hennar við Háskólan í Reykjavík.

Tilgangur: Tilgangur þessarar rannsóknar er að skoða áhrif vinnsluminnisgetu á úrvinnslu verkefns.

Verkefni: Í þessari rannsókn verður þú beðin(n) um að leysa vinnsluminnispróf, og að leysa verkefni (byggja úr LEGO kubbum) eftir leiðbeiningum. Einnig verður þú beðin um að svara stuttum spurningalista.

Tími og staðsetning: Þátttaka í rannsókninni mun taka u.h.b. 30 mín. og fer fram í Háskólanum í Reykjavík.


Nafnleynd/trúnaður: Algerrar nafnleyndar og trúnaðar er gætt varðandi hlut þátttakenda í þessari rannsókn.

Þær upplýsingar sem fengnar eru í þessari rannsókn verður farið með sem trúnaðarmál og aðeins notað af rannsakendum sem tengjast þessari rannsókn. Öll gögn eru merkt með þátttakandannúmeri.

Rétturn til að hætta þátttöku: Þú hefur fullan rétt á að hætta þátttöku í þessari rannsókn hvenær sem er.

Ég hef lesið ofantalda lýsingu á rannsókninni og ég geri mér grein fyrrir skilyrðum þátttöku minnar.

Nafn: __________________________________________

Dagsetn.:_____________________________________

Undirskrift: ____________________________________________ Vottur:________________________________________
Appendix C  
Participants instructions for video instructions

Leiðbeiningar af myndbandi

Gefðu þér þann tíma sem þú þarf til þess að lesa leiðbeiningarnar. Ekki hika við að spyrja sé eith hvaða óljóst eða ef þú hefur spurningar. Vinsamlegast mundu að þú getur hætt þátttöku á hvaða stig rannsóknarinnar sem er.

Þetta eru þættir rannsóknarinnar:

1. Þú tekur stutt vinnsluminnispróf í tölvu. Vinsamlegast leggðu þig alla/allan fram um að leysa það vel af hendi.

2. Þú horfir á myndband. Á myndbandinu eru leiðbeiningar. Þú hefur 31 sekúndu til þess að horfa á leiðbeiningarnar á myndbandinu. Að þeim tíma liðnum lýkur myndbandinu.


4. Þegar tíminn sem þú hefur til þess að byggja úr kubbunum er liðinn er aðeins einn liður rannsóknarinnar eftir. Þú svarar stuttum spurningum. Vinsamlegast leggðu þig alla(n) fram um að svara þeim eftir bestu getu og samvisku.

Vinsamlegast leggðu þig alla/allan fram um að leysa verkefnið vel af hendi.

Í apríl verða almennar niðurstöður rannsóknarinnar tilbúinar. Ekki verður hægt að greina frammistöðu einstaklinga í rannsókninni; því verða niðurstöðurnar almennar. Hafirðu áhuga á að fá niðurstöðurnar sendar í tölvupósti til þín, vinsamlegast skráðu netfang þitt hér að néðan.

Netfang:

Kærar þakkir fyrir þátttökuna.
Appendix D

Participants instructions for grpic instructions

**Myndrænar leiðbeiningar**

Gefðu þér þann tíma sem þú þarf til þess að lesa leiðbeiningarnar. Ekki hika við að spyrja sé eith hvað óljóst eða ef þú hefur spurningar. Vinsamlegast mundu að þú getur hætt þátttöku á hvaða stig rannsóknarinnar sem er.

Þetta eru þættir rannsóknarinnar:

5. Þú tekur stutt vinnsluminnispróf í tölvu. Vinsamlegast leggðu þig alla/allan fram um að leysa það vel af hendi.

6. Þú skoðar leiðbeiningar og hefur 30 sekúndur til þess (rannsakandi er tímvörður). Að þeim tíma liðnum, fjarlægir rannsakandinn leiðbeiningarnar.

7. Þú hefur 45 sekúndur til þess að leysa verkefnisandamt leiðbeiningunum. Þú þarft að nota alla kubbana sem eru á borðinu. Þegar rannsakandi fjarlægir klútinn af borðinu, hefst tímatakan.

8. Þegar tíminn sem þú hefur til þess að byggja úr kubbunum er liðinn er aðeins einn liður rannsóknarinnar eftir. Þú svarar stuttum spurningum. Vinsamlegast leggðu þig alla(n) fram um að svara þeim eftir bestu getu og samvissku.

Vinsamlegast leggðu þig alla/allan fram um að leysa verkefnisand vel af hendi.

Í apríl verða almennar niðurstöður rannsóknarinnar tilbúna. Ekki verður hægt að greina frammistöðu einstaklinga í rannsóknini; því verða niðurstöðurnar almennar. Hafirðu áhuga á að fá niðurstöðurnar sendar í tölvupósti til þín, vinsamlegast skráðu netfang þitt hér að neðan.

Netfang:

Kærar þakkir fyrir þátttökuna.