VISUAL WORKING MEMORY - GENDER AND AGE DIFFERENCES.

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Abstract

The visual working memory forms the basis for cognitive processes in learning, and it is therefore of interest to gain greater insight into gender and age differences in visual working memory among pupils. In this study, we wanted to see if there are differences between children in first, third, fifth, seventh and ninth grade in Norwegian schools when it comes to issues of visual working memory. The sample consisted of 458 students, 233 females and 225 males. We wanted to see if there is gender differences in visual working memory, and if there are differences in working memory effects for students in different grades. We also wanted to see how repetition and practice have an effect on visual working memory.

There were no significant between-gender differences. Students in fifth grade scored better on visual working memory than students in seventh grade when they were presented with 20 percent fewer symbols. This indicates that reducing the number of factors to be remembered increases learning effect. The results from this study support earlier studies that have demonstrated that visual working memory increases with age. There was a clear learning effect related to number of repetitions for students of all ages.

Keywords: *Visual working memory, gender and age differences, learning effect*

Introduction

According to Baddeley (1974), all learning is dependent on working memory. While long-term memory (LTM) has virtually unlimited capacity, information that is to be remembered and transferred to long-term memory, must first be stored in working memory, and therefore working memory plays a central role in learning. Importantly, while many studies have been conducted regarding auditory working memory, fewer have related to visual working memory, and since developmental changes are not only related to children’s auditory working memory, but also, to a great extent, their visual working memory, Vales and Smith (2014) claim that this is an unfortunate state of affairs for studies exploring learning. Therefore, in this study we address the subject of visual working memory.

Visual working memory has limited storage and processing capacity, and information is therefore normally forgotten after a given amount of time, unless the information is repeated. In such situations, remembering information refers to an attempt at recalling pictures one has encountered in earlier situations. According to Tetzchner (2012), attempts to recall information in this manner may be compared to a process of “recreation”, whereby one’s interpretations (and prior knowledge) influence that which is recalled. Students depend on working memory when they are trying to remember information for short periods of time, or when they work with cognitively demanding tasks. In such cases, visual working memory is responsible for successful outcome, that is, how well information is remembered. This outcome can be measured by the passage of time from the visual input and the student’s ability to recall verbal information.

Working memory is critical for successful cognition (Cowan 2010). Working memory represents an expansion and modification of the information that is stored in long-term memory, while reduced working memory capacity can lead to increased incidences of distraction, problems in instigating and sustaining tasks over time, difficulties with organizing work, as well as trouble with receiving and remembering instructions. Students with reduced auditory or visual memory may be at an increased risk of developing learning difficulties.

In light of this strong relation between working memory and students’ learning, in particular regarding mathematics and reading instruction, there is a great need for more knowledge about working memory processes and functioning.

There is a close relation between visual working memory and visual attention (Hollingworth and Maxcey-Richard, 2013:1047). Further, Baddeley and Hitch (1974) have demonstrated that working memory can be divided into three main elements; namely, central executive, phonological loop and visuo-spatial sketchpad. Information can be held in the phonological loop for approximately two to three seconds, possibly longer if the information is repeated. The visuo-spatial sketchpad’s function is to store information of visual and spatial character over shorted periods of time. Finally, control processes such as repetition, coding, and choice of recall strategies in short-term memory, all influence how information is sent to long-term memory, influencing children’s learning capacity, or storage of information.

Cowan (1988) presents a revised model of information processing that is depicted in a slightly simplified form. In his model the phonological and visuospatial stores are just considered instances of the temporary activation of long-term memory information.

Presentation of research questions

Reduced visual working memory is often related to mathematics and reading difficulties. Helland and Asbjornsen (2004) have shown that a subgroup of students with dyslexia also experience difficulties with visuo-sequential and visuo-spatial skills, and more recent research suggests that children with dyslexia may also have difficulties with visual attention (Bucholz and Almola Davies 2006). It is important to gain more knowledge about memory capacity in different age groups.

In a study of visual working memory among students attending scientific and humanistic studies at two university-colleges (Amundsen, Garmannslund & Stokke 2014) we found that students studying scientific subjects scored significantly higher than students that were studying the humanities. Since there are grounds to believe that the majority of students that choose scientific subjects are relatively competent in mathematics, this study may support similar studies that have concluded that there is a relation between visual working memory and mathematical skills (Adler 2007).

Further, since eight of ten students that studied scientific subjects in the investigation were male, and approximately the same proportion of the humanities students were female, the question of gender differences arose. However, in the aforementioned study, non-random sampling excluded the possibility of further investigating gender differences.

In order to address the question of gender differences in working memory, we decided to address a different age group of students, namely, first to ninth graders in Norwegian elementary schools. In this study we used «Test of Visual Learning.» Our main aim was to investigate possible age and gender-related differences in visual working memory in Norwegian students in different grades, and we addressed the following three research questions:

- Is it possible to demonstrate gender differences in visual working memory?
- Is it possible to demonstrate that repetition and practice have an effect on visual working memory?
- Are there differences in working memory effects for students in different grades?

Method

Participants in the present study were from three different schools in Norway. Furthermore, participation was voluntary and anonymous. The study was also based on the principle of informed consent, meaning that the students were able to decide whether they wanted to participate in the study, and they had the right to withdraw from the study at any time, without any negative consequences for the individual students.

The «Visual Test for Learning» is a computer-based test that measures visual working memory. Students in first, third and fifth grades were presented with a computer screen with 16 black squares, whereas students in seventh and ninth grades were presented with 20 black squares on their screens (i.e., the test for the elder students was slightly more difficult).

The sample consisted of 458 students from first to ninth grade at elementary/lower secondary level (233 females, 225 males). The reported population is the total after the exclusion of 21 participants that did not complete the test. Table 1 (below) shows the distribution of students across the different grades.

Table 1. Distribution of participants in different grades

1st grade	3rd grade	5th grade	7th grade	9th grade
75 students	63 students	110 students	76 students	134 students

Procedure

In this study, a performance score was calculated on the basis of two dependent variables: time used to solve the task and the amount of "moves" used. A new latent variable, "Visual memory" (VM), was computed. VM was measured at five measuring points VM1 to VM5. Scale reliability was assessed by Cronbach´s alpha and indicates good internal consistency.

Table 2 Mean dependent variable, standard deviation and Cronbach´s alpha

Variable	Mean	SD	Cronbach´s alpha
VM1	94,05	27,23	0,67
VM2	75,33	25,66	0,74
VM3	69,49	26,24	0,88
VM4	65,22	26,49	0,91
VM5	70,73	27,28	0,88

All students were instructed to connect two symbols, specifically, socks, with another two socks that were the same color, and then to connect two more abstract symbols to their counterparts. All of the symbols could be located by turning the cards on the screen. In the case where a student successfully identified two identical symbols, they remained face up on the screen. This process was repeated five times. The concrete objects (the socks) and the abstract symbols were located under the same squares (or “cards”) during each trial, and the students could see the symbols for eight seconds at a time.

The students were first presented with five sets of concrete symbols, and subsequently, with five sets of abstract symbols. After five minutes, they were again presented with two sets with the same concrete symbols and the same abstract symbols. The computer program registered how much time each student used on the different tasks, as well as how many times they had to turn the cards in order to complete the task. Since there was an element of randomness regarding which cards the students would turn over, we chose to present the first round as a trial round. VM1 to VM4 in the tables shows learning- effect for the first four rounds, while VM5 shows the learning-effect after five minutes.

Students in seventh and ninth grade were presented with 20 concrete and abstract symbols, while the students in first, third, and fifth grade were presented with 16 (20% fewer squares).

Results

Gender differences

We investigated possible gender differences using an independent-sample *t*-test. The result of the test showed no significant gender differences regarding visual working memory.

Age differences

First grade

Table 3 Means and standard deviations at different measuring points (VM1-VM5)

	Mean	Std. Deviation	*N*
VM1	1,713	0,141	61
VM2	1,623	0,154	61
VM3	1,570	0,156	61
VM4	1,551	0,160	61
VM5	1,542	0,139	61

A repeated measures ANOVA was conducted to determine whether there were statistically significant differences in “Visual Memory”. Due to outliers data was moderately positively skewed, as assessed by boxplot and Shapiro-Wilk test (p>.05), and a "logarithmic" transformation was successfully applied. Mauchly´s Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi2(2)= .965$, p=.380. There was a significant change in “Visual Memory” (VM) over time, $F(4, 240)=29.478$, $p< .01$, partial $\eta^2 = .329$, with VM decreasing from 1.713 +/-

.141 at VM1 and to 1,542 +/- .138 at VM5. According to guidelines proposed by Cohen (1988) (.01=small, .06=moderate, .14 large effect) these results suggest a large effect size.

Post hoc analysis with Bonferroni adjustment revealed that VM improved to a statistically significant degree from VM1 to VM2 (*M*= -.090, 95% CI[-.146 to -.035], *p* < .01) VM1 to VM3(*M*= -.144, 95% CI[-.202 to -.085], *p* < .01), VM1 to VM4 (*M*=-.162, 95% CI[-.222 to -.102], *p* < .01), VM2 to VM4 (*M*= -.072, 95% CI[-.123 to -.021], *p* < .01), VM1 to VM5 (*M*= -.171, 95% CI[-.225 to -.118], *p* < .01), VM2 to VM5 (*M*= -.081, 95% CI[-.129 to -.033], *p* < .01), but not from VM2-VM3 (*M*= -.053, 95% CI[-.108 to .001], *p* < .06), VM3 to VM4 (*M*= -.019, 95% CI[-.067 to .030], *p* =1 .000), VM3 to VM5 (*M*= -.028, 95% CI[-.085 to .030], *p* =1 .000) and VM4 to VM5

As shown in Table 3 (above), the learning effect corresponds with the number of repetitions. It is worth noting that this learning effect is also present from VM4 to VM5.

Third grade

Table 4 Means and standard deviations at different measuring points (VM1-VM5)

	Mean	Std. Deviation	*N*
VM1	1,629	0,133	63
VM2	1,540	0,137	63
VM3	1,497	0,156	63
VM4	1,483	0,164	63
VM5	1,479	0,121	63

A repeated measures ANOVA was conducted to determine whether there were statistically significant differences in “Visual Memory”. Due to outliers, data was moderately positively skewed, as assessed by boxplot and Shapiro-Wilk test (p>.05), and a "logarithmic" transformation was applied with success. Mauchly´s Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi 2(2)$= 13.794, p=.130. There was a significant change in “Visual Memory” (VM) over time, *F*(4, 248)=29.019, *p*< .01, partial η^2 = .319, with VM decreasing from 1.629 +/- .133 at VM1 and to 1,479 +/- .121 at VM5. The results indicate a large effect size accounting for 31.9 % of the variance in scores (Cohen, 1988; Richardson, 2011).

Post hoc analysis with Bonferroni adjustment revealed that VM changed to a statistically significant degree from VM1 to VM2 (*M*= -.089, 95% CI[-.137 to -.035], *p* < .01) VM1 to VM3(*M*= -.132, 95% CI[-.182 to -

.083], *p* < .01), VM1 to VM4 (*M*=-.146, 95% CI[-.195 to -.097], *p* < .01), VM2 to VM4 (*M*= -.057, 95% CI[-.106 to -.009], *p* < .01), VM1 to VM5 (*M*= -.150, 95% CI[-.199 to -.101], *p* < .01), VM2 to VM5 (*M*= -.061, 95% CI[-.116 to -.007], *p* < .01), but not from VM2-VM3 (*M*= -.043, 95% CI[-.090 to .003], *p* = .086), VM3 to VM4 (*M*= -.014, 95% CI[-.050 to .022], *p* =1 .000), VM3 to VM5 (*M*= -.018, 95% CI[-.068 to .032], *p* =1 .000) and VM4 to VM5 (*M*= -.004, 95% CI[-.050 to .042], *p* =1 .000).

As shown in the table above, third graders also demonstrated a clear learning effect that corresponds with number of repetitions. Also for the third graders, the learning effect is still present as measured from VM4 to VM5, and as can also be seen in the table, these students also clearly profit from repetition (set VM1 to VM4).

Fifth grade

Table 5 Means and standard deviations at different measuring points (VM1-VM5)

	Mean	Std. Deviation	*N*
VM1	0,031	0,010	110
VM2	0,038	0,011	110
VM3	0,042	0,013	110
VM4	0,047	0,013	110
VM5	0,043	0,012	110

A repeated measures ANOVA was conducted to determine whether there were statistically significant differences in “Visual Memory”. Due to unequal variances of data at different time points, as assessed by boxplot and Shapiro-Wilk test (p>.05), an "inverse" (or "reciprocal") transformation, was applied with success. Mauchly´s Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi 2(2)$=30,901, *p*< .01. Therefore a Huynd-Feldt correction was applied (ε= ,929). There was a significant change in “Visual Memory” (VM) over time, *F*(3,715, 404,894)=65,745, *p* < .01, partial η^2 = ,376, with VM improving from ,031 +/- ,010 at VM1 and to ,043 +/- ,012 at VM5. The results indicate a large effect size accounting for 37.6 % of the variance in scores (Cohen, 1988; Richardson, 2011).

Post hoc analysis with Bonferroni adjustment revealed that VM changed to a statistically significant degree from VM1 to VM2 (*M*= .007, 95% CI[.004 to .010], *p* < .01) VM1 to VM3(*M*= .011, 95% CI[-.008 to .014], *p* < .01), VM2 to VM3 (*M*=0.004, 95% CI[.002 to .007], *p* < .01), VM1 to VM4 (*M*= .016, 95% CI[.013 to .019], *p* < .01), VM2 to VM4 (*M*= .009, 95% CI[.006 to .012], *p* < .01), VM3 to VM4 (*M*= .005, 95% CI[.002 to .007], *p* < .01), VM1 to VM5 (*M*= .012, 95% CI[.009 to .015], *p* < .01), VM2 to VM5 (*M*= .005, 95% CI[.002 to .008], $p < .01$), VM4 to VM5 (*M*= -.004, 95% CI[-.007 to .00], $p < .01$), but not from VM3 to VM5 (*M*= -.001, 95% CI[-.002 to .004], $p = 1.000$).

Please note that because of the inverted transformation, an increase in the *M* in table 4 actually reflects a decrease in time and moves used.

For the fifth grade students, we were able to observe a clear learning effect from the first to the fourth repetition. The learning effect for these students appears to be greater than for the younger students (partial η^2 = ,376). It is, however, worth noting that the learning effect decreases to a certain degree from VM4 to VM5 for these students, which was not the case for the 1st and 3rd graders.

Seventh grade

Table 3 Means and standard deviations at different measuring points (VM1-VM5)

	Mean	Std. Deviation	*N*
VM1	0,023	0,006	75
VM2	0,029	0,008	75
VM3	0,032	0,010	75
VM4	0,035	0,011	75
VM5	0,032	0,009	75

A repeated measures ANOVA was conducted to determine whether there was a statistically significant difference in “Visual Memory”. Due to unequal variances of data at different time points, as assessed by boxplot and Shapiro-Wilk test (p>.05), an "inverse" (or "reciprocal") transformation was applied with success. Mauchly´s Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi2(2)$= 20,092, p=,017. Therefore a Huynd-Feldt correction was applied (ε= ,936). There was a significant change in “Visual Memory” (VM) over time, *F*(3,743, 277,008)=44,564, $p < .01$, partial η^2 = ,376, with VM improving from ,023 +/- ,006 at VM1 and to ,032 +/- ,009 at VM5. The results indicate a large effect size accounting for 37.6 % of the variance in scores (Cohen, 1988; Richardson, 2011).

Post hoc analysis with Bonferroni adjustment revealed that VM changed to a statistically significant degree from VM1 to VM2 (*M*= .006, 95% CI[.004 to .008], $p < .01$) VM1 to VM3(*M*= .009, 95% CI[.007 to .012], $p < .01$), VM2 to VM3 (*M*=0.003, 95% CI[.000 to .006], $p < .01$), VM1 to VM4 (*M*= .012, 95% CI[.009 to .015], $p < .01$), VM2 to VM4 (*M*= .006, 95% CI[.003 to .008], $p < .01$), VM1 to VM5 (*M*= .009, 95% CI[.006 to .011], $p < .01$), VM4 to VM5 (*M*= -.003, 95% CI[.006 to .000], $p < .01$), but not from VM3 to VM4 (*M*= .002, 95% CI[.000 to .005], *p* 0 .108), VM2 to VM5 (*M*=-.002, 95% CI[-.001 to .005], *p* = .274) and VM3 to VM5 (*M*= -.003, 95% CI[-.006 to -.000], *p* =1 .000).

Thus, also for the seventh graders, we were able to observe a clear learning effect from the first to the fourth repetition, in a similar fashion to the fifth graders (partial η^2 = ,376). Also in this case, it is worth noting that the observed learning effect decreased to a certain degree from VM4 to VM5, showing the same tendency as we observed for the fifth graders.

Ninth grade

Table 4 Means and standard deviations at different measuring points (VM1-VM5)

	Mean	Std. Deviation	*N*
VM1	0,023	0,007	133
VM2	0,029	0,008	133
VM3	0,033	0,009	133
VM4	0,036	0,009	133
VM5	0,031	0,009	133

A repeated measures ANOVA was conducted to determine whether there were statistically significant differences in “Visual Memory”. Due to unequal variances of data at different time points, as assessed by boxplot and Shapiro-Wilk test (p>.05), an "inverse" (or "reciprocal") transformation was applied with success. Mauchly’s Test of Sphericity indicated that the assumption of sphericity had been violated, χ2(2)=21,726, *p*=,010. Therefore a Huynd-Feldt correction was applied (ε= ,943). There was a significant change in “Visual Memory” (VM) over time, *F*(3,771, 497,823)=107,681, *p* < .01, partial η^2 = ,441, with VM improving from ,0233 +/- ,007 at VM1 and to ,031 +/- ,010 at VM5. The results indicate a large effect size accounting for 44.1 % of the variance in scores (Cohen, 1988; Richardson, 2011).

Post hoc analysis with Bonferroni adjustment revealed that VM changed to a statistically significant degree from VM1 to VM2 (*M*= .006, 95% CI[.004 to .008], *p* < .01) VM1 to VM3(*M*= .010, 95% CI[-.008 to .012], *p* < .01), VM2 to VM3 (*M*=0.004, 95% CI[.002 to .006], *p* < .01), VM1 to VM4 (*M*= .013, 95% CI[.0011 to .015], *p* < .01), VM2 to VM4 (*M*= .007, 95% CI[.005 to .009], *p* < .01), VM3 to VM4 (*M*= .003, 95% CI[.001 to .005], *p* < .01), VM1 to VM5 (*M*= .008, 95% CI[.006 to .010], *p* < .01), VM2 to VM5 (*M*= .002, 95% CI[.000 to .004], *p* < .01), but not from VM3 to VM5 (*M*= -.002, 95% CI[-.003 to -.001], *p* < .05) and VM4 to VM5 (*M*= -.005, 95% CI[-.007 to -.003], *p* < .01).

The ninth graders displayed the greatest learning effect of any of the grades from the first to the fourth repetition (partial η^2 = ,441). In addition, the learning effect decreased slightly from VM4 to VM5 for these students, a decrease we also observed with the seventh graders.

The effect size estimates (partial η^2) differs from .319 (grade 3) to .441 (grade 9). The results for all grade levels indicate that there is a learning effect on repeated exercises for the participants.

Discussion

Learning outcome

Working memory improves with age. We know that pre-school children also spontaneously use working-memory strategies, and Wellman (1988) found that these strategies are goal-directed in a similar way to the strategies that are used by elder students. However, the strategies children use in first grade tend to be less effective and less suitable for given tasks than the strategies that elder students tend to use. Younger children are also less likely to use one strategy and then further develop and refine it in the same way as elder students do. Children as young as four years old are able to apply simple memory strategies by, for example, focusing visual attention only on that which is to be remembered. However, they tend to not always use the best strategies, and they profit less from use of these strategies than elder children do (Schwenk, Bjorklund & Schneider 2009). Thus, in a typical Norwegian first grade class, where the average age is six years old, it is likely that we will observe a distribution of scores in the class that can be related to maturity or cognitive ability. By organizing, or structuring information, encoding becomes easier and students also remember better.

Facoetti and colleagues (2003) have demonstrated that in children with dyslexia, the ability to read nonsense (meaningless) words are related to difficulties with visuo-spatial tasks. For example, students that strive with reading meaningless words (non-words), have been shown to visual attention related weaknesses. Moreover, those researchers found connections between dyslexia and specific visuo-spatial skills that are related to the rapid naming of abstract figures, especially when these tasks are related to the ability to process visuo-spatial information in its entirety, rather than in a piecewise fashion. Likewise, Beneventi (2010) concluded that students with dyslexia have reduced visual and auditory working memory.

In a study by Skattebo-Throndsen (2002:207) where students were characterized as «excellent», «above average» and «below average», connections were found between student performance, strategy-use and metacognition in early-years education. Notably, for the students that performed best in mathematics, recall strategies were already dominantly used in problem solving tasks in second grade, with the strategy use of these students indicating good mathematical skills. Moreover, metacognitive knowledge about strategies and evaluation and control over calculations was also apparent for the above average students. On the other hand, the below average students made use of more basic strategies, such as simple counting strategies, and these students also displayed lower levels of metacognitive knowledge.

It is worth noting that while Tetzchner (2012) claims that children tend to be able to apply categorization strategies from the age of ten, so around third grade level, the participants in the present study also showed a significant learning effect from first grade level. This indicates that repeated presentation of visual stimuli may lead to learning effects for students of all ages.

At the same time, Siegler (1994) has demonstrated that children tend to have a repertoire of strategies at their disposition, some of which may be redundant in given situations, whilst others may be acquired. Furthermore, students' strategy choices tend to be dependent on earlier experience, the task at hand, as well as their success in using the various strategies. This gives grounds to believe that making students aware of their use of different strategies may lead to further learning gains.

Another factor that should be taken into consideration is the number of figures or symbols that are to be remembered. In the present study, the discrepancy between number of symbols in the fifth and seventh grade lead to significant differences between the two grades, with the fifth graders actually performing better than the seventh graders.

Thus limiting the number of factors to be remembered may lead to increased visual working memory capacity, which is supported by Cowan and colleagues (2014). They found that when the presented matrices are at a simple enough level, children's attentional processes can reach a level that compares to that of adults.

Repetition seems to also lead to clear positive learning effects for children of all ages. However, the learning effect for the students in fifth grade seems to be greater than for the younger students, and the learning effect seems to be greatest for the students in ninth grade. These findings support previous research that has shown that age, specifically cognitive maturity, plays an important role in children's memory.

Concretes versus abstracts

As can be seen from the results presented above, there are significant differences in children's visual short-term memory for concrete as well as abstract symbols. Students in the first and third grades need longer time, and a greater number of «moves» (attempts) in order to remember abstract symbols, in relation to concretes. This is hardly surprising in light of earlier findings that show that children's ability to remember depends on the degree to which they are able to assign meaning to the objects. In this case, socks are recognizable objects, that children are able to code in relation to different colors, whereas the abstract symbols may be more difficult to separate from one another, therefore also creating difficulties in relation to coding.

Another possible explanation for the results is that younger children may be less able to oversee irrelevant elements, thereby creating a situation where they are trying to remember too many elements. This hypothesis may be seen in light of the study done by Luck and Vogel (1997), where they concluded that participants were similarly proficient at memorizing single objects that were related to color, size, direction or shape, as they were at memorizing objects that were only related to color or direction alone. This also suggests that memory capacity is limited by number of objects, rather than the number of visual functions that are to be stored.

The manner in which children experience their surroundings is also dependent on the ways in which they experience the visual input with which they are presented. For example, children's spatial awareness is related to how they relate to the physical room, as well as how they interpret distances, sizes and positions. While Bjørklund (2014) claims that spatial abilities contribute to our perception of surrounding features, such as connections between surfaces, lines and space, Butterworth (1999) showed that students' ability to process a long row of numbers also contains a spatial aspect that supports reasoning related to the numbers' positions in relation to one another. In other words, students' attempts to remember abstract symbols by attending to similarities, number, direction, length and position may influence their performance.

Cowen (2010) has also shown that memory capacity may be reduced when participants are unable to repeat the information that has to be remembered. This may also be a possible explanation for the difference in results for students' memory for concrete versus abstract symbols, since it is easier to name colors than abstract symbols.

While it is difficult to remember abstract symbols by combining them to form meaningful units of information, it is, however, possible to try to associate meaningless symbols with more concrete figures, for example, airplanes, birds, cubes, or the likes. The question is whether students would be able to profit from being made aware of strategies such as identifying similarities, orderly patterns, colors, number, or other useful associations.

Alexander and Schwanenflugel (1994) showed that when objects in known categories are easier to remember than objects in less well-known categories, this tends to be a result of working memory capacity being used to a greater degree to encode and organize the less well known objects. Schneider and Bjørklund (1992) also found that children that had higher knowledge about football were able to remember a greater number of objects from a picture relating to this subject than from a picture depicting objects that could not be related to football.

Gender differences

Females tend to score somewhat higher than males on math computation tasks in elementary school, but not in high school. By the end of the 12th grade, males are slightly better at problem solving and geometry than females. Gender differences have been found in two types of spatial ability. Males tend to have better spatial perception than females, as well as a greater ability to sense horizontality or verticality, and better mental rotation ability. However, there are no gender differences when it comes to spatial visualization, or the ability to locate a simple figure within a complex one. Females however, tend to have better memories for word-lists, personally experienced events, novel associations (e.g. name-face associations) and spatial locations (Sattler 2008).

Despite similarities in performance between girls and boys during the early school years, Skattebo-Throndsen (2002) showed that girls' problem solving strategies consisted predominantly of inaccurate finger-counting strategies, but that this lack of effective strategic behavior could not be linked to a lack of metacognitive knowledge, since this was equally good in the girls as in their male counterparts.

In this study we were unable to show significant gender differences regarding visual working memory, which means that the previously reported differences between humanities students and science students, cannot be related to gender, but may rather be a result of individual preferences that form the basis of students' choice of study-path. Furthermore, differences between boys' and girls' performance in mathematics during the later school years, cannot be explained by gender differences in visual working memory, despite research showing that mathematics difficulties may be related to deficiencies in visual working memory (Adler 2007).

Limitations

Hollingworth and Maxcey-Richard (2013:1047) have shown that there is a strong relation between visual working memory and visual attention. The concrete and abstract symbols that were presented in the task appeared in the same place every time they were presented. The students that developed an understanding of this were able to achieve higher scores than those that did not, and this means that students that have been tested with similar tasks may have had an advantage over those that have not.

Self-regulation in learning situations can be related to complex processes that involve more than just the use of strategies. For example, use of metacognition, experience-based knowledge, internal motivation, attention, and the ability to sustain attention, effort and concentration over time, factors that are closely related to mastery, are all involved. In this study however, we have not examined further possible causal relations, which may be a weakness. However, there is no reason to believe that one of the above factors would have played a greater role for one specific set of students.

Finally, we have not assessed students' performance motivation in the present study, which may also be viewed as a limitation, since motivation is closely related to students' performance. Eisenberger and Cameron (1996) demonstrated that external motivation contributes to undermining internal motivation. We cannot exclude the possibility that the students that chose to participate in this study did so because they felt that it was expected of them, thereby undermining their internal motivation to perform optimally. However, the fact that the learning profile for each of the grades is so consistent and clear, suggests that the students have all performed to the best of their ability.

Summary of results

- There were no significant between-gender differences in the visual working memory of students in different grades.
- Students in fifth grade scored better on visual working memory than students in seventh grade when they were presented with 20% fewer symbols. This indicates that reducing the number of factors to be remembered increases learning effect.
- The results from this study support earlier studies that have demonstrated that visual working memory increases with age (i.e., cognitive maturation).
- Regarding visual working memory, students of all ages demonstrated a clear learning effect related to number of repetitions.

Conclusion

Gathercole and Baddley (1993) concluded that memory capacity increases in relation to children's age, which is supported by the findings in the present study. These findings may be explained by more effective application of memory strategies, better conceptual understanding, and in older students - a larger repertoire of experiences that information can be connected to.

However, visual working memory is not only dependent on students' cognitive skills and ability. It is also dependent on their ability to use constructive strategies in specific learning situations. Unfortunately, the learning perspectives that are adopted in modern Norwegian schools are often based on a view of working memory as a fixed biological entity, despite it being well-known that students' ability to use varied and constructive strategies is related to performance.

Once students are able to use strategies appropriately, that is, that they are applied automatically and constructively in different situations, this may become a natural part of the students' cognitive learning strategies. This suggests that opportunities for training visuo-motoric skills and spatial awareness should be provided at an early age. Children must be given opportunities to sort and group objects and symbols, find similarities and differences, as well as becoming comfortable with use of basic concepts.

Furthermore, experience is a necessary foundation regarding questions of perception, because it is easier to remember information that already has meaning. Such meanings will be based on earlier experiences that will be represented mentally, and recalled on a needs basis. Therefore, facilitating use of constructive strategies and repetition that leads to automation of such skills will influence later learning.

Finally, in relation to learning, it is also important to remember that reducing the number of units to be remembered also increases working memory capacity. This means that it is important that teachers also have knowledge of individual students' working memory capacity, as giving students tasks and work that requires working memory beyond the students' current capacity may cause undue stress and learning difficulties.

References

Amundsen, M-L., Garmannslund, P. E., Stokke, H. (2014) *Differences in visual working memory among students*, European Educational Science, 2:123-132.

Adler, B. (2007) *Dyskalkuli & Matematik*, Kristiansand, Nationella Utbildningsforlaget.

Alexander, J. M. and Schwanenflugel, P. J. (1994) Strategy regulation: The role of intelligence, metacognitive attributions, and knowledge base. *Developmental Psychology*, 30:709-723.

Andreassen, T. H. (2013) *Test of Visual Learning.* In press. www.psykotest.no

Atkinson, R.C. and Shiffrin, R.M. (1971) The control of Short-Term Memory, *Scientific American*, 224, 82-90.

Baddeley, A. (2007) *Working Memory, Thought and Action*, Oxford, Oxford University Press.

Baddeley, A.D. and Hitch, G. (1974) Working memory. I: Bower (ed.) *The psychology of learning and motivation* (Vol. 8: 47-89). New York, NY: Academic Press.

Beneventi, H. (2010) *Neuronal correlates of working memory in dyslexia*, Department of Biological and Medical Psychology, University of Bergen.

Bjorklund, D.F., Dukes, C. and Brown, R. D. (2009) The development of memory strategies. I: Courage, M. L. and Cowan, N. (red.) *The development of memory in infancy and childhood*. Hove, UK, Psychology Press.
Bjørklund, C. (2014) *Den første matematikken*, Cappelen-Damm A/S, Oslo.
Butterworth, G. (1999) Neonatal imitation; Existence, mechanisms and motives. I: Nadel J. & Butterworth, G. (red.). Imitation in infancy: 63-88, Cambridge, Cambridge, University Press.
Bucholz, J. and Almola Davies , A.M.(2006) Do visual attention factors contribute to phonological ability? Studies in adult dyslexia *Neurocase* 12(2): 111-121.
Bråten, I. (1998) Cognitive strategies in mathematics, Part.1: On children`s strategies for solving simple addition problems, *Scandinavian Journal of Educational Research*, 42,1: 5-24.
Carr, M. and Jessup, D.L. (1997) Gender differences in first grade mathematics strategy use: Social and metacognitive influences. *Journal of Educational Psychology*, 89, 2 :318-328.
Chi, M.T.H. (1978) Knowledge structures and memory development. I: Siegler, R.S. (red.) *Children`s thinking, What develops?* 1978:73-96, New Jersey. Lawrence Erlbaum.
Cowan, N. (2010) The magical mystery four: How is working memory capacity limited, and why? *Current Directions in Psychological Science*, 19: 51-57.
Cowan, N. (1988) Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information processing system. *Psychological Bulletin*, 104:163-191.
Cowan, N., Morey, C. C., AuBuchon, A.M., Zwilling, C. E. and Gilchrist, A. L. (2010). Seven-year-old allocate attention like adults unless working memory is overloaded. *Developmental Science*, 13: 120-133.
Facoetti, A., Lorusso, M.L., Paganoni, P., *et al.* (2003) Auditory and visual automatic attention deficits in developmental dyslexia. *Brain Res Cogn Brain Res* 16 (2): 185–91.
Gathercole, S.E. and Baddley, S.D. (1990) Phonological Memory Deficits in Language Disordered Children: Is There a Causal Connection*? Journal of Memory and Language*, 29,3: 336-360.
Helland, T. and Asbjornsen, A. (2004) Digit span in dyslexia: Variations according to language comprehension and mathematics skills. *Journal of Clinical and Experimental Neuropsychology*, 82 (3).
Hollingworth, A. and Maxcey-Richard, A. (2013) Selective Maintenance in Visual Working Memory Does Not Require Sustained Visual Attention, *Journal of Experimental Psychology: Human Perception and Performance*, Vol.39, Nr.4: 1047-1058.

Le Fevre, J-A., Fast, L., Skwarchuk, S-L., Smith-Chant, B., Bisanz, J., Kamawar, D. and Penner-Wilger, M. (2010) Pathways to mathematics. Longitudinal predictors of performance. *Child Development*, 81(6): 1753-1767.

Luck, S.J. and Vogel, E.K. (1997) The capacity of visual working memory for features and conjunctions. *Nature*, 390:279-281.

Richardson, J. T. E. (2011) Eta squared and partial eta squared as measures of effect size in educational research. *Educational Research Review, 6* (2), 135-147.

Sattler, J. M.(2008) *Assessment of Children. Cognitive Foundations*, Fifth Edition, San Diego. Jerome Sattler, Publisher, Inc.

Schneider, W. and Bjørklund, D.E. (1992) Expertise, aptitude and strategic remembering. *Child Development*, 63: 461-473.

Schneider, W. and Weinert, F. E. (1990) The role of knowledge, strategies and aptitudes in cognitive performance, Concluding comments. I: Schneider, W og Weinert F:E: (red.) *Interactions among aptitudes, strategies, and knowledge in cognitive performance* (286-302), New York, Springer Verlag.

Schwenk, D.F., Bjorklund, D.F. and Schneider, W. (2009) Developmental and individual differences in young children`s use and maintenance of a selective memory strategy. *Developmental Psychology*, 45:1034-1050.

Siegler, R.S. (1994) Cognitive variability; A key to understanding cognitive development. *Current Directions in Psychological Science*, 3: 1-5.

Pressley, M. and Afflerbach, P. (1995) *Verbal protocols of reading: The nature of constructively responsive reading*. Hilsdale, N. J. Lawrence Erlbaum Associates.

Tetzchner, S. (2012) *Utviklingspsykologi*, 2.utgave, Gyldendal Norsk Forlag, Oslo.

Thorell, L. B. et al. (2009) Training and transfer effects of executive functions in preschool children, *Developmental Science*, 2009, 12 (1):106-113.

Vales, C. and Smith, L.B. (2014) Words, shape, visual search and visual working memory in 3-years-old children. *Developmental Science*, 2014: 1-15

Schneider, W. and Bjorklund, D.E. (1992) Expertise, aptitude and strategic remembering. *Child development*, 63:461-473.

Skattebo Throndsen, I. (2002) Selvregulert læring av matematikkferdigheter En studie av elever på begynnertrinnet, Universitetet i Oslo.

Wellman, H.M. (1988) First steps in the child`s theorizing about the mind. I: Astington, J., Olson, P. and Harris, D. (red.) *Developing theories of mind*. 1988: 64-92.