A correlation study of mathematics proficiency VS reading and spelling proficiency

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Proficiency in mathematics, reading and writing/spelling has been tested for 2376 Norwegian students in grades 5, 6, 8 and 9. Proficiency in mathematics and reading comprehension was found to correlate as expected from previous studies. More interesting is that spelling, tested with a dictation, seems to correlate stronger with mathematics on grades 5 and 6 than comprehension does. This supports an assumption that there are more to the correlation between proficiency in language and mathematics than the ability to read and understand the mathematical task.

Keywords: Mathematics achievement, reading comprehension, spelling, short-term and working memory.

Linguistic skills, reading, writing and mathematics.

It is important for a student to have proficiency in reading comprehension when solving mathematical tasks (Adelson, Dickinson, & Cunningham, 2015; Fuchs, Fuchs, Compton, Hamlett, & Wang, 2015; Fuentes, 1998; Nortvedt, Gustafsson, & Lehre, 2016; Pearce, Bruun, Skinner, & Lopez-Mohler, 2013). The student has to read and comprehend the task in order to solve it. The effect of language and linguistic skills are prominent when students solve mathematics word problems (Abedi & Lord, 2001; Nortvedt, 2010; Vilenius-Tuohimaa, Aunola, & Nurmi, 2008), but are also related to solving other types of mathematics tasks (Vukovic & Lesaux, 2013). In the present paper, the correlation between reading comprehension and results on a mathematics test is studied.

Studies of mathematics and reading have mostly dealt with comprehension. Comprehension means to understand both what the words and the sentences mean. The process of reading is more than comprehension. It can be roughly split in two parts, decoding and comprehension. Decoding means to be able to identify the characters and combine them into words that are pronounced. Reading speed can be used as a measure of decoding. Gough and Tunmer (1986) and Hoover and Gough (1990) suggested *The simple view of reading (SVR)* as a measure of a person's ability in reading. They claimed that reading could best be understood as a combination of decoding and comprehension, and proposed the SVR-formula for reading, reading = decoding x comprehension (R = D x C). Several later studies give support to the SVR model (Adlof, Catts, & Little, 2006; Kendeou, Savage, & van den Broek, 2009; R. Malatesha Joshi, 2000). In this paper, we will also compare the SVR scores with proficiency in mathematics.

In Norway, students' proficiency in spelling are often tested with dictations. The teacher reads a text, sentence by sentence, and the students write down the sentence from memory. This is a rather complex process that relies on listening comprehension, short-term memory and writing. It has been shown that short-term or working memory (Baddeley & Hitch, 1974) influence language comprehension (Daneman & Merikle, 1996) and comprehension of oral messages and ability to follow directions (Engle, Carullo, & Collins, 1991). Solving a mathematical task is in some ways a similar process. It relies also on comprehension, this time reading, memory and writing. Studies show that the capacity of short-term or working memory (Baddeley & Hitch, 1974) has an influence on mathematics achievement (De Smedt et al., 2009; Gersten, Jordan, & Flojo, 2005; Raghubar, Barnes, & Hecht, 2010; Siegel & Linder, 1984). It has also been shown that measures of short-term memory at the age of 4 is a good predictor of later proficiency in mathematics (Bull, Espy, & Wiebe, 2008). These factors predict a possible correlation between scores on mathematics test and scores based on dictations.

The research questions are:

> How do results on a mathematics test correlate with results from reading and writing tests?
> How do these correlations compare to each other?

Method and data sources

The analyses in this paper are based on data collected by the Norwegian SPEED project (The Function of Special Education) (Haug, 2017). The project's principal aim was to study special education, not as an isolated subject, but as an integrated part of the overall education. Both special- and ordinary education, and both students with and without special needs, were studied with a variety of instruments. The SPEED-project is a rather large study with a sample of more than 2500 students and their teachers and parents. This is one of the strengths of the study reported in this paper. The students covered a wide range of both mathematics and language skills, and were tested with general mathematics and language tests, making it possible to study relations between these two over a wide range of skills.

This paper use data from a mathematics test and a language test comprised of both a reading and a spelling test. Results from all students was included in the analysis, regardless of their level in mathematics or language, in order to bring to the fore results that are valid for the entire proficiency span.

For a more comprehensive account of the whole project see Haug (2017) and of the methods used see Topphol, Haug, and Nordahl (2017). Only the parts relevant for this paper will be explained here.

The sample

The SPEED-project collected data from students, teachers and parents in two medium sized municipalities. The two municipalities were from different parts of Norway, representing a variety of cultural, social and other backgrounds. The data collection was performed mainly during two periods, one year apart. All students in grades 5, 6, 8 and 9 were invited to participate the first year, winter and spring 2013 (T1). We did a follow up with the same students, and the same data instruments, one year later (T2). In this paper, data from T1 were used. At T1, we collected data from 2701 students from 29 schools, 82 % of all the students, and 98 % of those who had consented to participation. Although the sample did not meet the requirements of randomness needed for statistical generalization, we will argue that the broad coverage in background makes the results valid for a larger population than the two municipalities only. Analysis also showed that our data conformed to national statistics on important factors (Topphol et al., 2017).

The mathematics test

The mathematics test had 40 multiple-choice tasks for students in grade 5 and 6, and 52 tasks for grade 8 and 9. The first 40 tasks were common to all students, and grade 8 and 9 had 12 extra tasks. Every task had seven response alternatives including “do not know”. One of the alternatives were the correct answer, and the rest were so-called distractors. The assignments were paper-based with check boxes making digitizing through optical scanning possible. The tests were developed by the SPEED-project. The tasks covered mathematical topics, and had a level of difficulty, that were in accordance with the Norwegian curriculum. The majority of the tasks were based on situations the students could meet outside the classroom, in their daily life, such as understanding the clock, bus schedules, fractions, decimal numbers, geometry, arithmetic and statistics. There were a mixture of word problems and non-word problems. The construction of the mathematics test is discussed in more detail in Opsvik and Skorpen (2017).

For each student we used his or her percentage of correct answers as the mathematics score. In order to eliminate the effect of grade, and of the two tests being slightly different, the scores were normalized to have mean value equal to zero and standard deviation equal to one for each grade separately, z-scores.

A total of 2544 students completed the mathematics test at T1.

The language test

We used *Norwegian spelling and reading test for compulsory primary and secondary school*[1] (the Carlsten-test) (Carlsten, 2002) to measure the students’ proficiency in reading and writing. Carlsten developed this test primarily as a mapping test to identify students struggling with vital areas of the Norwegian language, and not as a research tool. Nevertheless, we chose to use this test mainly by two reasons. First, the test has been widely used in Norwegian schools for many years. The teachers know the test well, and can then easily relate our results to their classroom situation. Secondly, the test’s aim towards those who are struggling fitted well with the SPEED-project’s emphasis on special education and with the aim of the mathematics test. Since this paper use data from all the students, and not only those who had problems, the tests aim towards the weak students had to be considered when analyzing the data.

The test estimated reading proficiency as both reading speed and reading comprehension. The students read a narrative text, and the unit of speed was words per minute. Comprehension was measured through multiple-choice questions. Several places in the text, the reader was supposed to pick the correct word from three alternatives. An example from the 6th grade test: “Hard as (stone–wool–tree)”[2]. We used percentage of correctly chosen words as a measure of comprehension.

[1] The author’s translation of “Norsk rettskrivings- og leseprøve for grunnskolen».

[2] The author’s translation.

I will emphasize that reading proficiency in this context was related to verbal text. The test provided information about parts of the students' literacy, but gave us no information about the students' reading skills related to interpretation, evaluation and reflection.

The writing proficiency was tested with a dictation. The teacher read a text, sentence by sentence, and the students wrote down each sentence from memory. The test was thus more than a pure writing test. It relied on both listening comprehension, and on the ability to remember the sentence from hearing it read to writing it down. Two different dictation based scores were calculated from the number of errors the student made in the dictation. The number of spelling errors were used to calculate a *spelling score*. The total number of errors, both spelling errors and missing words or sentences, were used to calculate what I call a *dictation score*.

In the same way as the mathematics test, scores were normalized to z-scores for each grade separately. Reading score understood as *simple view of reading* was calculated as the product of the speed and comprehension scores, and normalizes as above.

A total of 2555 students completed the language test at T1.

Analysis

Ordinary Pearson's product moment correlation coefficients between the mathematics score and the different language scores were calculated. Linearity was tested with simple scatterplots, which revealed no indications of non-linearity.

The distributions of the reading comprehension and the two dictation based scores were rather skew, with an accumulation towards the high values. They were negatively skew and in addition rather narrow. This was a result of the Carlsten test's aim towards the less proficient students. A substantial part of the students reached the maximal score. This could give smaller correlation coefficients than a test that also challenged the best students would do.

Upper and lower bounds of a 95 % confidence interval were estimated for each correlation coefficient using bootstrapping in SPSS.

I used statistical tests to compare correlation coefficients. Since all the coefficients were calculated with the mathematics score as one of the variables, the null hypotheses were of the form $\rho_{xz} = \rho_{yz}$. This means tests of equality of dependent correlations. William's (1959) formula was used to calculate p-values, in accordance with Steiger (1980) and Chen and Popovich (2002) suggesting to use this formula for such tests.

Results

Table 1 contains Pearson's correlation coefficients between the students' mathematics results and their results on the language tests; the reading scores: *decoding*, *comprehension* and *simple view of reading*, and the two dictation based scores: *spelling score*, based solely on spelling errors, and *dictation score*, based on both spelling errors and missing words and sentences. Results are presented for all the students together and split by grade; 5, 6, 8 and 9. The table also contains upper and lower bounds of a 95 % confidence interval for each coefficient.

Grade		Reading decoding	Reading compre-hension	Reading (Simple View of Reading)	Dictation score	Spelling score
All	Pearson *r*	.317**	.397**	.388**	.453**	.428**
N=2376	95 % CI[b]	.277–.356	.361–.432	.351–.423	.416–.491	.390–.465
5	Pearson *r*	.403**	.354**	.459**	.491**	.478**
N=560	95 % CI[b]	.333–.470	.274–.429	.396–.521	.421–.555	.408–.545
6	Pearson *r*	.279**	.346**	.317**	.443**	.437**
N=626	95 % CI[b]	.197–.353	.270–.412	.236–389	.367–.510	.365–.503
8	Pearson *r*	.292**	.469**	.395**	.491**	.446**
N=619	95 % CI[b]	.208–.372	.401–.531	.313–.466	.425–.555	.376–.513
9	Pearson *r*	.303**	.415**	.388**	.387**	.352**
N=571	95 % CI[b]	.224–.383	.334–.494	.313–.462	.295–.482	.261–.444

**. Correlation is significant at the .01 level (2-tailed).

b. The estimated confidence intervals are based on 1000 bootstrap samples

Table 1: Correlation coefficients (Pearson) between mathematic results and five different language scores

All the correlation coefficients were significantly higher than zero, all p-values smaller than 10^{-11}.

From Table 1 we can see that, except for 5th grade, comprehension correlated more strongly with the mathematics score than reading speed did. This was as expected. When a student faces a mathematical task, there is no use in speed if she does not understand what she reads. The difference between speed and comprehension correlation was statistically significant for all students ($p = .0005$), for grade 8 ($p < .0001$) and for grade 9 ($p = .015$).

The correlation coefficients between mathematics and simple view of reading fell in between those with speed and with comprehension. This was not surprising, since it was constructed as the product of them. This will not be followed up any further in this paper.

The results I found most interesting emerged when comparing the correlations between the mathematics score and the two dictation based scores, with the correlation between mathematics and the different reading scores. Except for the 9th grade, the two results from the dictation scores seemed to correlate at least as strong with the mathematics score as reading did. For the 5th and 6th grades the *dictation score* correlated significantly more strongly with mathematics than reading comprehension do (p-values < .001). For the 8th grade, the difference was too small to be statistically significant. There seemed to be an age dependent effect, strongest with the youngest students in our sample. The same effect was present if we restrict the dictation data to the *spelling* *score* only, but now the difference was statistically significant only for the 5th grade (p = .0009). The *dictation score* correlated slightly more strongly with mathematics than the *spelling score* did.

Discussion

In this paper the correlations between proficiency in mathematics and proficiency in reading and dictation is studied. The correlation between mathematics and reading was found to be as expected from previous studies (Adelson et al., 2015; Fuchs et al., 2015; Fuentes, 1998; Nortvedt et al., 2016; Pearce et al., 2013). This agreement with earlier research serves primarily as a validation of the study, and will not be further discussed.

I have shown that the two scores based on dictation correlated as strong as, and even stronger for grades 5 and 6, with mathematics score than reading comprehension did. Correlation with reading can partly be explained by the necessity of reading and understanding a mathematics task before solving it. Correlation with the dictation scores, a writing test, cannot be explained in a similar way, by the necessity of writing to solve these tasks. The mathematics tests required just a small amount of writing. The tasks were multiple choice and the writing was thus limited only to some drafting on a separate paper. The relation between mathematical task solving and dictation must therefore be of a more complex nature. I will bring to the fore one possible explanation based on similarities in the process of solving mathematical tasks and in taking down dictations, similarities involving memory and memory effects.

Solving mathematics tasks, taking down a dictation and reading are all processes that are affected by the student's memory, through how memory influence comprehension (Daneman & Merikle, 1996; Engle et al., 1991) and proficiency in mathematics (De Smedt et al., 2009; Gersten et al., 2005; Raghubar et al., 2010; Siegel & Linder, 1984). Memory capacity and memory function will thus contribute to the correlation between all three of them. I will now argue that memory is a more crucial factor in mathematics task solving and dictation than in reading.

Solving mathematical tasks and taking down a dictation starts with an element of comprehension, one with reading and the other with listening to oral messages or instructions, both previously shown to be affected by memory capacity (Daneman & Merikle, 1996; Engle et al., 1991). This contributes indirectly to the correlation between them. The next step in both processes involve a more direct use of memory. When taking down a dictation the student has to remember the sentence, with the exact wording, long enough to be able to write it down, and when writing the words with correct spelling, she has to remember the words not written down yet. The mathematics student must remember the task, both the structure and the pieces of information, during the solving process. The last thing she does is to "write" down the answer by placing a mark in the correct check box. Of course, short-time memory is also involved in the reading process: the entire sentence has to be "remembered" to be understood, but this memory use is not to the same extent competing with other mental processes. The processes of mathematics task solving and dictation make in this way a more direct use of memory, and relies more heavily on it, than reading does. Memory will thus contribute more to the correlation with dictation than with reading. This can explain why the mathematics score correlated more strongly with the dictation scores than with reading. The result that the *dictation score*, with missing words and sentences, correlated more strongly with mathematics than the pure *spelling score* did, supports the assumption that memory plays a part, since missing words and sentences can be related to memory.

In Norway one can often hear teachers complain about too much use of word problems in mathematics. They claim that students with reading difficulties get extra difficulties with mathematics because of their struggle in reading the tasks, especially tasks with a lot of text. This could of course be part of the explanation, but there are probably more to it than that. The results in this paper show that the relation between a student's proficiency in language and mathematics is more complex than the student's ability to read and understand the mathematical task. It involves also factors that influence the students' proficiency in taking down dictation. Memory can play a substantial part. If teachers do not take the influence of memory into consideration, the may miss an important factor.

Concluding remarks

Based on a large sample of students, covering a wide range of mathematics and language skills, this study has revealed that students' scores on a dictation, correlated more strongly with mathematics than did their scores on a reading test. Based on similarities between the two activities, one possible explaining factor, working memory, has been discussed. More dedicated studies should be done to investigate this further.

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