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Links between phonological memory, first language competence and second language competence in 10-year-old children

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ABSTRACT

84 Norwegian 10-year-old children were tested in short-term memory, L1 language competence (semantics and grammar) and L2 skills (vocabulary and comprehension). While previous studies have shown strong relationship between short-term phonological memory and L1 competencies, the extent to which specific language competencies correlate which each other, and the extent to which competencies in the L1 correlate with skills in the L2, is still open to debate. We aimed to establish whether such links can be found in Norwegian children. Our results convincingly demonstrate that language competence is related to short-term memory, in support of previous studies. We find strong correlations between short-term memory, competencies in the L1 and skills in the L2, suggesting that memory may be a common underlying mechanism in language learning. We also find reliable correlations between specific competencies in the L1 (lexical knowledge/grammar), and between vocabulary size and sentence comprehension in the L2.

1. Introduction

Children face a variety of challenges when they grow up, especially at school where they are expected to acquire knowledge in several different areas. Oral language skills, reading skills and memory are essential, if the child is to process written and spoken information, store it for later use, and manipulate it in different ways. In the current study, we tested 84 Norwegian 9- to 10-year-old school children. Participants were tested on language tests in their first language (Norwegian), their second language (English) and short-term memory. Short-term memory has been suggested to play a crucial role in the development of academic skills (Gathercole & Alloway, 2008), and oral language skills determine the acquisition of literacy skills in the early school years. Still the exact nature and the direction of the relationship between these skills is subject to further research and interpretation. Of special interest to the current study is the fact that Norwegian children score low in reading skills among the OECD countries (Roe & Solheim, 2007). This calls for investigating oral language skills, and possible underlying cognitive skills and mechanisms.

While previous studies have addressed the links between specific language skills (e.g., vocabulary size) and memory, this is the first study to address the role of verbal short-term memory in overall language competence in the first language. The TOLD-I test (Hammill & Newcomer, 2008) assesses oral language competencies and skills in a number of areas, including semantic organization, lexical skills, grammar and meta-linguistic grammar awareness, and as such, provides an accurate estimate of overall language status for each individual tested, making results about links to verbal memory compelling.

1.1. Short-term memory and working memory

An early, well-known model of memory (Atkinson & Shiffrin, 1968) makes a distinction between *sensory memory*, *short-term memory* (STM), and *long-term memory* (LTM). While the first two components serve temporary information processing, long-term memory is the final store component. All the words a speaker knows are stored in LTM, in the so-called *mental lexicon*. A word is a stored association of phonological, syntactic, and semantic structures (Jackendoff, 2002b).

Baddeley and Hitch (1974) suggested that *working memory* (WM) could be added to the Atkinson–Shiffrin model. WM is active in tasks such as learning, comprehension and reasoning, and retrieves information both from the outside world and from LTM. WM both stores and manipulates information (Baddeley, 2003). On this model, WM consists of four components: *the central executive* (CE), which controls the attention and regulation of information flow within WM, and between LTM systems and WM, *the phonological loop* (PL), *the visuo-spatial sketchpad* (VSS), and *the episodic buffer* (EB). The PL offers temporary storage for verbal information, the VSS provides limited storage for visual and spatial representations, while the EB integrates representations from the

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components of WM and from LTM in a multi-dimensional code (Gathercole & Alloway, 2008).

Many studies support a distinction between STM and WM. It has been shown that the two systems, despite being closely interrelated, place different demands on the components of the memory loop. For example, Gathercole, Tiffany, Briscoe, Thorn, and The ALSPAC Team (2005) found that children with poor verbal STM got average scores on tasks measuring WM. Further support comes from the finding that children with specific reading difficulties typically get lower scores on measures of WM than verbal STM (Gathercole, Alloway, Willis, & Adams, 2006). Furthermore, in adults it has been shown that compared to STM, WM tasks place heavier demands on the central executive/attention function (Engle, Tuholski, Laughlin, & Conway, 1999).

For this reason, different kinds of tasks have been suggested to tap the capacities of WM and STM. In the backward digit recall task, a participant is presented with a sequence of digits and asked to recall them in reverse sequence (Morra, 1994). This task measures WM capacity, because it places significant demands on both processing and storage. In contrast, the forward digit recall task involves significant storage, but only minimal processing, and thus measures STM. Thus, STM tasks access primarily the specialized storage components of the WM system, whereas performance on complex span tasks additionally requires central executive involvement (Gathercole & Alloway, 2008). In this study we are concerned with the Phonological loop (PL) component of WM (STM verbal memory).

1.2. Language structure and language development

Language is characterized by specific sub-systems: phonology, grammar and semantics (Lyons, 1968). Traditionally, it is assumed that these sub-systems operate independently and rely on specialized systems of rules. More sophisticated views suggest that, while each sub-system depends on dedicated input/output rules, successful language use relies on a rich interface between them (Jackendoff, 2002a, b). Furthermore, a recent lexicalist perspective suggests that grammar and vocabulary are inseparable (Bates & Goodman, 1997). Evidence from research shows that developing grammar is dependent upon vocabulary size (e.g., Bates, Bretherton, & Snyder, 1988), and that grammar and vocabulary do not dissociate in typical children, early talkers and children with focal brain injury (e.g., Marchman, Miller, & Bates, 1991, review: Bates & Goodman, 1997). The language test battery used in the current study (TOLD-I), taps overall language competence by testing semantic skills, and grammar, and indirectly, phonology (Hammill & Newcomer, 2008).

Grammar competence involves two distinct, but interrelated components. Morphological competence presupposes knowledge of words and their structure, whereas syntax competence is reflected in the ability to build well-formed phrases and sentences. A third related skill, morphological awareness, is characterized by awareness of the internal structure of words (morphemes), and what inflections are essential for words to be well-formed. Morphological awareness appears to be a good predictor of vocabulary knowledge (McBride-Chang, Wagner, Muse, Chow, & Shu, 2005). For syntax, findings suggest an association with vocabulary learning through syntactic bootstrapping, which entails that grammatical knowledge provides important cues for semantic learning. A twin study by Dionne, Dale, Boivin, and Plomin (2003) supports this view, indicating that vocabulary and grammar share the same genetic influences, consistent with the lexicalist approach. Even though in the current study we are concerned with testing each language competence separately, our ultimate goal is to test for closer relationships among the separate competencies that underlie language use.

1.3. Language development: first and second language

It is common to make a distinction between first (L1) and second language (L2), the crucial distinction being onset time of acquisition. Typically a first language is acquired from, and even before, birth, while a second language is acquired later, and typically outside the sensitive period (Lenneberg, 1967; Penfield & Roberts, 1959). It has been suggested that (second) language acquisition is controlled by maturational factors, characterized by even subtler "sensitive" periods. For instance, it is well-known that the sensitive window in speech perception lasts only for the first 9 months of development (Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005; Weikum et al., 2007; Werker & Byers-Heinlein, 2008), while Meisel (2009) suggests that the critical period for morphology does not extend beyond the 4th year of life. The crucial question, however, is whether language acquisition proceeds similarly and relies on similar mechanisms both in the L1 and the L2. If we find evidence that the same cognitive mechanisms are involved, and correlate with language skills, irrespective of the status of the language (first or second), the strong dissociation between L1 and L2 learning is weakened.

1.4. Relationships between the factors

1.4.1. Short-term memory and language development

The PL is accessed by verbal STM, and is, as such, an STM system (Gathercole & Alloway, 2008). It has been implicated in language learning, and findings suggest that it supports both first and second language learning (Masoura & Gathercole, 1999). Baddeley, Gathercole, and Papagno (1998) and Perani (2005) identify it as the only viable candidate as Language Acquisition device. The strong involvement of STM in language acquisition is confirmed by studies demonstrating superior STM and WM in blind children compared to sighted peers (Withagen, Kappers, Vervloed, Knoors, & Verhoeven, 2013). Short-term memory is closely associated with other cognitive skills that play a role in language development, such as phonological awareness. There exist various explanations of this interrelation (Stanovich, Cunningham, & Freeman, 1984), including a common underlying phonological coding/processing component (e.g., Bowey, 1996). In a comprehensive discussion of these issues, Alloway, Gathercole, Willis, and Adams (2004) suggest that one reason for the difficulty in interpreting results from studies is that tasks believed to assess phonological awareness place demands on the memory system as well. One way to tap only PL is by using nonword-repetition tasks, as they provide a relatively pure measure of its capacity, and the size of the acquired vocabulary (Baddeley et al., 1998). However, non-word repetition tasks have also been used to tap working memory capacity. Alternatively, PL can be tested with a forward digit span task, which is less complex than nonword-repetition, and gives a clearer measure of PL (Gathercole & Alloway, 2008).

1.4.2. Short-term memory and semantics

Gathercole, Hitch, Service, and Martin (1997) used experimental word learning tasks to tap the cognitive components in vocabulary acquisition in 5-year-olds. Their findings indicated that the learning of new words is mediated by both the PL and long-term knowledge of the native language, such as the sound patterns of familiar words. They also found that a larger PL capacity makes it easier for children to learn new words, but that the learning of associate pairs of familiar words, which is a typical semantics task, is quite independent of the PL function.

In a review of a number of studies Baddeley et al. (1998) point to direct links between PL function and word learning, and suggest that the primary purpose of the PL is to store unfamiliar sound patterns. However, a Norwegian longitudinal study of children between 4 and 7 years showed no influence of nonword-repetition ability on later vocabulary knowledge. The authors speculate that non-word repetition ability is a consequence of vocabulary knowledge rather than its cause (Melby-Lervåg et al., 2012). Indeed, Gathercole, Willis, Emslie, and Baddeley (1992) state that the relationship between phonological memory skills and vocabulary development is strong, but complex, and bi-directional. For children between 4 and 5 years, phonological memory influences vocabulary development more than vice versa, whereas between 5 and 8 years this causal relationship weakens, and vocabulary knowledge seems to exert greater influence on further vocabulary development than does phonological memory.

For the acquisition of language as a whole, the WM function associated with the central executive has a greater impact than PL. This was confirmed when children were tested repeatedly on measures of WM, phonological awareness, vocabulary, language, reading and number skills (Gathercole et al., 2005). A study of 633 children between 4 and 6 years confirms the crucial role of the central executive in coordinating the flow of information through the memory system, and supports treating the PL as a closely linked, yet distinct, component (Alloway et al., 2004).

In vocabulary development, it may be increasingly important to acquire the meaning of new concepts. Since abstract words are harder to understand than words referring to physical objects, they are acquired later in vocabulary development. The ease of acquiring abstract words and more advanced vocabulary may depend on the semantic skills of each child, and as their semantic competence develops, phonological memory becomes less important (Gathercole et al., 1992; Nippold, 2006, 2007).

1.4.3. Short-term Memory and grammar

Phonological STM has been shown to play a role in sentence processing. A study of a patient with impaired STM suggested that the rehearsal component of the PL is involved in replaying syntactically complex sentences, and thus makes such sentences easier to comprehend (Papagno, Cecchetto, Reati, & Bello, 2007). Further support for an association between STM and syntax comes from findings in Majerus and Lorent (2009), suggesting that the capacities of *phonological STM* are active in phonological analysis during sentence processing. It also appears that the PL may mediate syntactic learning (Baddeley et al., 1998). Indeed, studies show that 3- and 4-year-old children with good phonological STM have a larger vocabulary, and produce longer utterances and a greater range of syntactic constructions than children with poor phonological STM (Adams & Gathercole, 1995, 2000).

2. The aims of the current study

In the current study, 84 Norwegian 10-year-old children were tested on STM and language competence (including semantics and grammar) tasks. Our main goal was to investigate the extent to which performance on verbal memory tasks could be linked to language competence in the first language. Moreover we were interested in whether such links could be established between, competencies and skills in the L1 and skills in English as L2,[1] and whether verbal memory continues to exert an influence in performance on L2 tasks as well in that age group.

Consistent with previous findings, we expected to find high correlations between overall language competencies and specific competencies (semantic and grammar) in the native language (Norwegian) and short-term memory, as well as high internal correlation among the language competencies (semantics and grammar). We also expected to find similar high correlations, on the one hand, between competencies in the first language and the second language, and between performance on short-term memory tasks and skills in the second language, on the other.

3. Method

3.1. Participants

A group of 87 Norwegian children were asked to participate in the study, and 84 (44 girls, 40 boys)[2] of them got permission from their parents. They attended fourth grade at two different primary schools; one located in the countryside (14 children) and one located in the city (70 children). The children's mean age was 9.8 (SD = 0.29), and the overall range was 9.3–10.3 years. All children had Norwegian as their first language. A few of the children had dyslexia and/or AD/HD (N = 3). Their results did not deviate significantly from the mean of the group and they were included in the analysis. Moreover, by including them, we aimed to assess an ecologically valid group of children.

9- to 10-year-olds were chosen as participants because studies on rapid automatized naming indicate that the differences between children with and without learning difficulties are largest in this age group (Denckla & Rudel, 1976), with this gap beginning to close later. In addition, 9- to 10-year-old children have attended school for a few years, and have acquired both reading skills and more general knowledge. Furthermore, at this age, language skills are quite advanced and start approximating adult language knowledge (Kempler, Van Lancker, Marchman, & Bates, 1999; Vulchanova, Vulchanov, & Stankova, 2011).

3.2. Procedure

The participants were tested in language development with Test of Language Development-Intermediate (TOLD-I) (Hammill & Newcomer, 2008), in STM with the Forward Digit Recall test (FDR) from the Working Memory Test Battery for Children (Pickering & Gathercole, 2001), the Peabody Picture Vocabulary Test (PPVT-4, Dunn & Dunn, 2007) and the English Language Comprehension Test (ELCT, Vulchanova, Dahl, & Grønnesby, 2009) in English as L2.[3]

The testing was conducted at the schools, during the school hours. Parents filled out and signed consent forms for their child's participation in the project. The project was approved by The Norwegian Data Protection Authority (NSD).

For the TOLD-I, the PPVT and the FDR, the children were taken out of class one by one, and the experimenter conducted the test in a separate, quiet room. The ELCT was conducted electronically in the school computer room. For all the tests, the children were informed that they could quit the test at any time.

3.3. Tests

3.3.1. Test of Language Development

Language development was tested with Test of Language Development — Intermediate: Fourth Edition (TOLD-I, Hammill & Newcomer, 2008), which is a standardized, norm-referenced test of oral language development. It is used to identify students' abilities, and for research purposes. It measures all parts of language, except pragmatics. It does not measure phonological abilities separately, because in 10-year-olds they have become so integrated with semantic and grammatical skills, that they are difficult to measure alone (Hammill & Newcomer, 2008).

The test was adapted from English to Norwegian by the research team involved in the project. The test items were directly translated whenever possible, or changed into a more appropriate Norwegian counterpart if necessary, due to grammatical and semantic differences between the languages. The Norwegian TOLD-I is not yet standardized (cf. Appendix 1).

TOLD-I consists of six sub-tests: *Sentence Combining*, which measures syntax competence; *Picture Vocabulary*, which measures semantic comprehension and lexical skills (vocabulary); *Word Ordering*, which measures syntax competence; *Relational Vocabulary*, which measures semantic organization skills, and vocabulary; *Morphological Comprehension* which targets the ability to judge well-formedness in grammar, and *Multiple Meanings*, which measures semantic organization and vocabulary.

[1] English is taught as an obligatory subject in Norwegian state schools from first grade onwards (age 6 years).

[2] The ELCT was completed by 79 participants.

[3] The testing was part of a larger research project run in the spring of 2011 by the Language Acquisition and Language Processing Lab, NTNU.

The children were allowed to ask for the test items (words/sentences) to be repeated once. There were no time limits to responses. One point was awarded for each correct answer.

3.3.2. Forward Digit Recall from WMTB-C

Short-term memory was tested with the Forward Digit Recall (FDR) from the Working Memory Test Battery for Children (Pickering & Gathercole, 2001). The battery is used for assessing working memory capacities in children between 5 to 15 years and contains nine sub-tests. The FDR tests only short-term memory, because this test requires significant storage, but only minimal processing (Gathercole & Alloway, 2008).

In the FDR, the child heard spoken presentations of sequences of digits, and had to repeat the digits in the order they were presented. Maximum nine blocks of six sequences were presented, and the sequences were one digit longer for each block; the first block contained six single digits, the second block contained six sequences of two digits, and the ninth block contained six sequences of nine digits (see Table 1 for examples). The test was stopped if the child made errors in three trials in a particular block. Total score corresponds to the maximum number of digit sequences the child was able to repeat correctly.

3.3.3. The Peabody Picture Vocabulary Test

The Peabody Picture Vocabulary Test-4, version B (PPVT-4, Dunn & Dunn, 2007) was used to test vocabulary size in English as L2. The PPVT is a common tool used for this purpose in both monolingual and bilingual children (Vulchanova, Sharzanova, Vulchanov, & Eshuis, 2012 for a survey).

3.3.4. The English Listening Comprehension Test

The English Listening Comprehension Test (ELCT) is a test we designed as a sentence–picture matching task. It contains 30 authentic English sentences, and the child is asked to identify the picture that best matches the content of the sentence. The sentences were presented auditorily via headphones read by an English native speaker's female voice. To avoid chance responses, each stimulus set included 4 pictures, one that corresponds to the sentence, one that is completely wrong, and two pictures which only partly correspond to items mentioned in the sentence, but not to its full content. As such, the test measures comprehension accuracy.

3.4. Data analyses

SPSS version 20.0 was used for statistical analysis. A Pearson's correlation analysis on the participants' scores on the three tests was run to test for a relationship between the factors. Both the total scores and the sub-test scores were analyzed. For the FDR, number of correct digit sequences/trials was used as score. For the PPVT the raw scores for each child were used. For the ELCT we used number of correct responses.

In addition, five linear regression analyses were run to test the contributions of STM and L1 on L2, and STM on L1. Two stepwise analyses were run with the PPVT and the ELCT as outcome, both with TOLD-I and FDR as predictors. In order to investigate if specific L1 competences predicted PPVT and ELCT, an additional pair of stepwise analyses was run. A simple analysis with FDR as predictor and TOLD-I as outcome was also run.

Sentence Combining and Word Ordering from the TOLD-I battery have been suggested to test working memory alongside language development (Sabers, 1996). For this reason we ran a separate analysis where these two sub-tests were analyzed separately and compared to performance on the remaining L1 sub-tests (TOLD-I PV, RV, MC, MM), the English L2 tests (PPVT and ELCT) and the STM test (FDR). This analysis has been taken into account in the discussion.

3.5. Results

3.5.1. Correlations

The means and standard deviations for scores on the FDR, the PPVT, the ELCT, and total scores and sub-test scores on the TOLD-I are shown in Table 2. The standard deviations seemed normal, but among the TOLD-I sub-tests, Morphological Comprehension had a larger standard deviation than the other sub-tests.

The means and standard deviations for total scores on the TOLD-I without the Sentence Combining and Word Ordering sub-tests, and scores on the Working Memory tests (Sentence Combining and Word Ordering) are shown in Table 3.

Correlations between scores on the FDR, the PPVT, the ELCT, and total score and sub-test scores on the TOLD-I, including level of significance, are shown in Table 4.

Correlations between scores on the FDR, the PPVT, the ELCT, the TOLD-I without the Sentence Combining and Word Ordering sub-tests, and the Working Memory tests (Sentence Combining and Word Ordering), including level of significance, are shown in Table 5.

The scores on the FDR were significantly correlated with the PPVT ($p < .05$), the ELCT ($p < .01$), and the total score and all sub-test scores on TOLD-I (all $ps < .01$), except for Morphological Comprehension (see Table 3 for r-values).

The scores on the TOLD-I-sub-tests were significantly correlated with each other and the total TOLD-I score, and with the PPVT and the ELCT (all $ps < .05$). The only exception was the score on Morphological Comprehension, which failed to show a correlation with the score on Sentence Combining and the score on the PPVT (see Table 3 for r-values).

The PPVT was significantly correlated with the ELCT ($p < .01$).

In the analysis of the alternative factors displayed in Tables 2 and 4, scores on the TOLD-I without the Sentence Combining and Word Ordering sub-tests, and scores on the Working Memory tests (Sentence Combining and Word Ordering) are significantly correlated with each other, and with the FDR, the PPVT and the ELCT (all $ps < .01$).

3.5.2. Regression

A stepwise regression analysis showed that the ELCT was significantly predicted by the FDR and the total TOLD-I score (all $ps < .05$). Among the sub-tests, Word Ordering was the significant predictor ($p < .001$).

Table 1
Examples of digit trials from the Forward Digit Recall test. (Not copied from the original test, but shows similar lengths of sequences.)

Trials	Span 1	Span 2	…	Span 9
1.	4	6 3		7 9 2 5 8 9 3 6 1
2.	2	8 2		6 3 4 9 1 5 8 2 7
3.	7	3 7		1 7 5 3 9 2 8 4 6
4.	3	2 5		9 8 2 6 3 5 4 1 7
5.	9	9 4		3 5 8 2 9 4 7 1 6
6.	8	5 1		8 5 2 7 1 3 9 6 4

Table 2
Number of participants (n), means (M) and standard deviations (SD) on the STM (FDR), the PPVT, the ELCT, the TOLD-I total, and the TOLD-I sub-tests: Sentence Combining (SC), Picture Vocabulary (PV), Word Ordering (WO), Relational Vocabulary (RV), Morphological Comprehension (MC) and Multiple Meanings (MM).

Variables	*n*	*M*	*SD*
STM (FDR)	84	29.850	3.659
PPTV	84	81.290	24.966
ELCT	79	25.000	4.288
TOLD-I	84	149.024	30.079
SC	84	16.429	6.141
PV	84	58.643	7.302
WO	84	14.631	4.340
RV	84	14.571	6.366
MC	84	15.464	11.929
MM	84	29.286	4.822

Table 3
Number of participants (n), means (M) and standard deviations (SD) on the TOLD-I without the Sentence Combining and Word Ordering sub-tests (TOLD-I ÷ 2), and the Working Memory tests (Sentence Combining + Word Ordering sub-tests) (WM).

Variables	*n*	*M*	*SD*
TOLD-I ÷ 2	84	117.964	23.484
WM	84	31.060	9.048

The other sub-tests were excluded from the analysis because of no significant values. The predictors of ELCT are shown in Tables 6 and 7. See Fig. 1a, b and c for scatterplots.

Moreover, the PPVT was significantly predicted by the total TOLD-I score ($p < .001$). A new analysis showed that Picture Vocabulary and Relational Vocabulary were the predicting sub-tests (all $ps < .05$), as the other sub-tests and the FDR were excluded from the analysis due to no significant values. The predictors of PPVT are shown in Tables 8 and 9. See Fig. 2a, b and c for scatterplots.

The TOLD-I was significantly predicted by the Forward Digit Recall test ($p < .001$). The predictor of TOLD-I is shown in Table 10. See Fig. 3 for scatterplot.

4. Discussion

This study looked at the relationships between STM and language development, as well as the internal relationships between various aspects of language development in the first language (grammar and semantics) and vocabulary size and listening comprehension in English as an (early) second language in Norwegian 10-year-old children. The expectations were that correlations would be found between all the factors. The results show significant correlations between all of them, except for Morphological Comprehension's relationships with Sentence Combining, PPVT and STM. We also found reliable correlations between measures of short-term memory, competencies in the L1 and vocabulary size and comprehension skills in the L2.

4.1. Memory, language competence and language development

Our results indicate that overall language competence in the L1 is closely related to STM. STM also shows medium sized correlations with each of the sub-tests in TOLD-I, except for Morphological Comprehension. This supports the findings by Baddeley et al. (1998) of the PL as a device for storing unfamiliar sound patterns. According to Baddeley et al., both vocabulary and syntax are mediated by PL. Furthermore, our results support proposals that the phonological loop is the best viable candidate, if we agree that there is a Language Acquisition Device (Baddeley et al., 1998; Perani, 2005). Even though the direction of the causal relationship between language competence and memory capacity is still an open question, the current results obtained from a relatively young group of participants, whose language is still developing, can be taken to indicate that, initially, memory exerts an influence on language. Our results further suggest that verbal memory performance can be used as a predictor of individual overall language attainment in the native and a second language in the early school years.

Table 5
Correlations between scores on the SMT (FDR), the PPVT, the ELCT, the TOLD-I without the Sentence Combining and Word Ordering sub-tests (TOLD-I ÷ 2), and the Working Memory tests (Sentence Combining + Word Ordering sub-tests) (WM).

	STM (FDR)	PPVT	ELCT	TOLD-I ÷ 2	WM
STM (FDR)	1	.241* .027	.337** .002	.310** .004	.426** .000
PPVT		1	.540** .000	.518** .000	.468** .000
ECLT			1	.298** .008	.401** .000
TOLD-I ÷2				1	.639** .000
WM					1

** Correlation is significant at the 0.01 level ($p < 0.01$).
* Correlation is significant at the 0.05 level ($p < 0.05$).

4.1.1. Short-term memory and syntax

Among the TOLD-I sub-tests, two of the syntax tasks, Sentence Combining and Word Ordering, show high correlations with STM, whereas Morphological Comprehension shows a non-significant correlation. These three sub-tests all measure grammar, which at first sight makes the divergent results a bit surprising. An explanation may be that Sentence Combining and Word Ordering measure syntax competence proper, in the sense that they tap the generation component of grammar, and, as such, perhaps depend more heavily on the PL. Indeed, Baddeley et al. (1998) suggest that PL mediates syntactic learning, while Fowler (1988) found only a weak correlation between STM and judgment about morphology errors in second-graders. We suggest that the absence of correlation may be due to the fact that Morphological Comprehension is a meta-linguistic task, and thus not directly linked to STM and memory processes (Lust, 2007).

Another reason for the high correlation between syntax and STM, may be that the syntax tasks Sentence Combining and Word Ordering measure memory, in addition to grammar (Sabers, 1996). In these two sub-tests, the participating children had to both remember and reorganize the words they heard. Since this requires both information storage and manipulation, performance on these two tasks largely depends on WM resources. In addition, the high correlations between syntax and STM suggest that PL is important for syntactic learning not only for 3- to 4-year-olds (Adams & Gathercole, 1995, 2000), but also for the 9- to 10-year-olds in the current study. These results also speak against a view of grammar belonging to a narrow language faculty (Chomsky, 1986), and not being particularly influenced by memory (Hauser, Chomsky, & Fitch, 2002). Furthermore, a separate analysis on the combined score of the Sentence Combining task and the Word Ordering

Table 4
Correlations between scores on the STM (FDR), the PPVT, the ELCT, the TOLD-I total, and the TOLD-I sub-tests: Sentence Combining (SC), Picture Vocabulary (PV), Word Ordering (WO), Relational Vocabulary (RV), Morphological Comprehension (MC) and Multiple Meanings (MM).

	STM (FDR)	PPVT	ELCT	TOLD-I	SC	PV	WO	RV	MC	MM
STM (FDR)	1	.241* .027	.337** .002	.371** .001	.402** .000	.249* .023	.320** .003	.253* .020	.183 .095	.348** .001
PPVT		1	.540** .000	.545** .000	.429** .000	.466** .000	.368** .001	.474** .000	.335** .002	.363** .001
ELCT			1	.353** .001	.348** .002	.273* .015	.352** .001	.333** .003	.112 .327	.335** .003
TOLD-I				1	.637** .000	.809** .000	.765** .000	.717** .000	.776** .000	.646** .000
SC					1	.472** .000	.475** .000	.443** .000	.211 .054	.455** .000
PV						1	.617** .000	.526** .000	.479** .000	.496** .000
WO							1	.432** .000	.544** .000	.416** .000
RV								1	.416** .000	.375** .000
MC									1	.335** .002
MM										1

** Correlation is significant at the 0.01 level ($p < 0.01$).
* Correlation is significant at the 0.05 level ($p < 0.05$).

Table 6
Regression analyses with the TOLD-I and the STM (FDR) predicting the ELCT.

	ELCT			
		Model 2		
Variable	Model 1 *B*	*B*		95% CI
Constant	17.70***	11.46**		[3.90, 19.01]
TOLD-I	0.05***	0.04*		[0.00, 0.07]
STM (FDR)		0.28*		[0.01, 0.55]
R^2	0.13		0.17	
F	10.96***		7.75***	
ΔR^2			0.05	
ΔF			4.10	

Note. CI = Confidence Interval.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

task, and the remaining sub-tests of the L1 language test, reveals a high correlation again. Therefore, we suggest that our results should be taken as evidence of the role of working memory in the development of language skills in the L1.

4.1.2. Short-term memory and semantics

All the three semantic tasks (Multiple Meanings, Relational Vocabulary and Picture Vocabulary) are significantly correlated with STM. The observed differences in standard deviations in scores on these tasks (with higher SDs for Picture Vocabulary and Relational Vocabulary) are consistent with the notion of treating the tasks as tapping distinct aspects of lexico-semantic knowledge, and as reflecting individual differences in these competencies. In the Multiple Meanings sub-test, the children were actively accessing their LTM store (the mental lexicon) in the search for multiple sense matches to the words they heard (homophones), whereas in the Relational Vocabulary and the Picture Vocabulary sub-tests they are working with different levels of semantic organization (hypo-/hyperonyms) and (semantic) word categories. These tasks tap different aspects of lexical knowledge (the mental lexicon). While the Multiple Meanings task accesses the lexicon store directly and tests the ability to distinguish among similar sounding words (word phonological representations), the Relational Vocabulary task and the Picture Vocabulary task probe semantic categorization and the ability to form semantic categories and to label them. The difference in SD between performances on these tasks may also be explained by the administration of the tasks. In Multiple Meanings, all children could suggest multiple meanings for all the words (and thus get scores), whereas children who failed to answer correctly on a certain number of categories in Picture Vocabulary and Relational Vocabulary, moved on to the next block or were stopped, respectively.

Table 7
Stepwise regression analysis with the TOLD-I sub-tests and the STM (FDR) predicting the ELCT.

	ELCT			
		Model 2		
Variable	Model 1 *B*	*B*		95% CI
Constant	20.03***	12.31***		[4.92, 19.71]
WO	0.34***	0.27*		[0.05, 0.48]
STM (FDR)		0.30*		[0.04, 0.55]
R^2	0.12		0.18	
F	10.90***		8.35***	
ΔR^2			0.06	
ΔF			5.20	

Note. CI = Confidence Interval. SC, PV, RV, MC and MM were excluded from the analysis because their significance values were less than 0.05.
* $p < .05$.
*** $p < .001$.

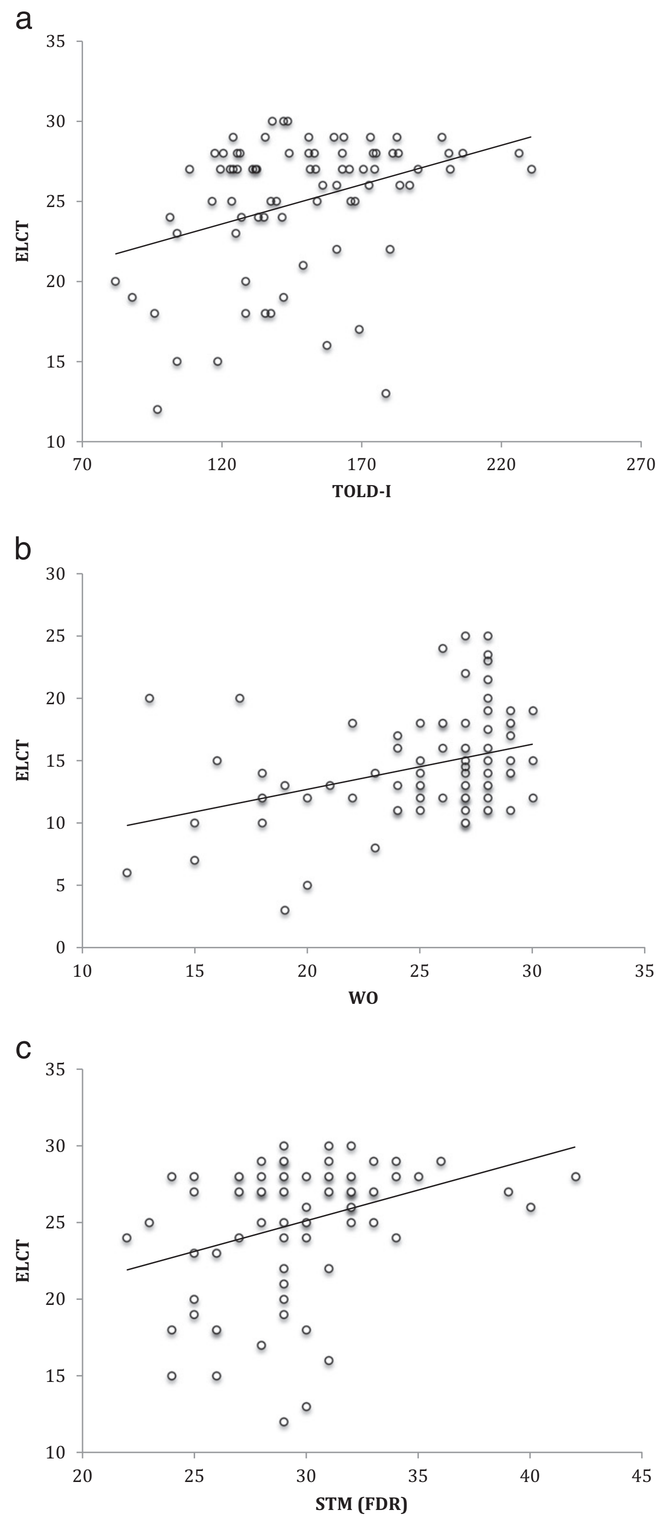

Fig. 1. a. Scatterplot of the TOLD-I and the ELCT. b. Scatterplot of Word Ordering (WO) and the ELCT. c. Scatterplot of the STM (FDR) and the ELCT.

On the whole, the current findings of a correlation between semantic organization and STM are in line with previous research (Baddeley et al., 1998; Gathercole et al., 1992), suggesting a strong relationship between vocabulary development and STM. Also, despite the different nature of the competencies being tested, all three tasks measure organizational skills and all three are related to STM. The current study has documented that this applies to 10-year-old children, and that the strong link

Table 8
Regression analyses with the TOLD-I and the STM (FDR) predicting the PPVT.

	PPVT	
Variable	*B*	95% CI
Constant	13.85	[−9.39, 37.08]
TOLD-I	0.45***	[0.30, 0.61]
R^2	0.30	
F	34.69***	
ΔR^2	0.30	
ΔF	34.69	

Note. CI = Confidence Interval. STM (FDR) was excluded from the analysis because its significance values was less than 0.05.
*** $p < .001$.

between lexico-semantic competence and verbal memory persists also later in the school years.

4.1.3. Language competencies

Most of the language sub-categories show high correlations with each other. This was expected, and supports the lexicalist perspective that grammar and vocabulary are inseparable (Bates & Goodman, 1997; Dionne et al., 2003). Still, Morphological Comprehension shows no significant correlation with Sentence Combining. Both sub-tests measure grammar, but Morphological Comprehension measures morphological skills, whereas Sentence Combining measures syntactic skills. According to research, morphology shows some dissociability with other aspects of language in older children and adults with language impairments (Bates & Goodman, 1997). Why does Morphological Comprehension fail to show a significant correlation with Sentence Combining, but a high correlation with the other syntax sub-test, Word Ordering?

This tendency was also evident in a study of the internal reliability of TOLD-I (Hammill & Newcomer, 2008), testing the relationships among the sub-tests, even though this study did not find any non-significant correlations. Sentence Combining assesses discourse-oriented syntax competence. Morphological Comprehension, on the other hand, assesses meta-linguistic awareness (Lust, 2007), and taps overall grammar competence, including word inflections of relevance to syntax. They thus assess two different aspects of language competence. Word Ordering taps building minimal phrase-structure (basic sentences), by using morphological information from word inflections. This explains its correlation with Morphological Comprehension. In other words, the variation in correlations among the subcategories of language seems to be caused by the linguistic nature of the tasks, and the specific language competencies they tap.

An additional explanation may be that the scoring on both Sentence Combining and Morphological Comprehension was more problematic

Table 9
Stepwise regression analysis with the TOLD-I sub-tests and the STM (FDR) predicting the PPVT.

	PPVT			
		Model 2		
Variable	Model 1 *B*	*B*		95% CI
Constant	54.20***	3.24		[−35.89, 42.36]
RV	1.86***	1.24**		[0.38, 2.10]
PV		1.02**		[0.27, 1.77]
R^2	0.13		0.17	
F	23.77***		16.49***	
ΔR^2			0.07	
ΔF			7.37	

Note. CI = Confidence Interval. STM (FDR), SC, WO, MC and MM were excluded from the analysis because their significance values were less than 0.05.
** $p < .01$.
*** $p < .001$.

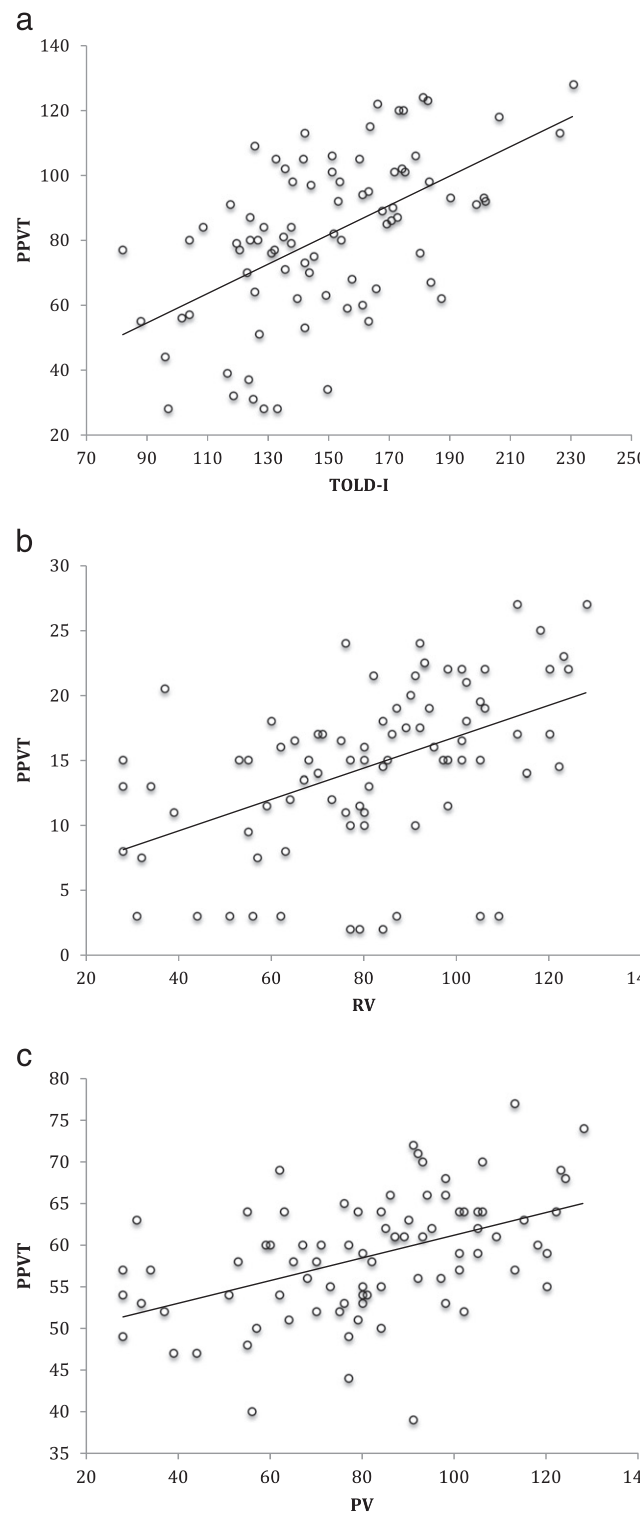

Fig. 2. a. Scatterplot of the TOLD-I and the PPVT. b. Scatterplot of Relational Vocabulary (RV) and the PPVT. c. Scatterplot of Picture Vocabulary (PV) and the PPVT.

than the scoring on the other language sub-tests. In Sentence Combining, the children had to combine two or more short sentences in order to make one complex sentence. The freedom this task allows leads to differences in the scoring, with all children getting at least one point. In contrast, in Morphological Comprehension, participants were awarded no points, if they judged more than one of the correct sentences to be wrong. This may also explain the high standard

Table 10
Regression analyses with the STM (FDR) predicting the TOLD-I.

	TOLD-I	
Variable	*B*	95% CI
Constant	58.08*	[7.65, 108.72]
STM (FDR)	3.05***	[1.37, 4.73]
R^2	0.14	
F	13.06***	
ΔR^2	0.14	
ΔF	13.06	

Note. CI = Confidence Interval.
* $p < .05$.
*** $p < .001$.

deviation in this sub-test. These issues should be further addressed in the future standardization of the Norwegian adaptation of TOLD-I.

4.2. First language, second language and STM

The current study shows high correlations between the first and second language measures, as well as between STM measures and language skills. These results suggest that language development and learning depend on some more general mechanisms, such as e.g., verbal memory, irrespective of the status of the language (first or second). In turn, we take this as evidence, that the parallels between first and second language acquisition may be more than the differences (modulo maturational factors), in that the process of learning exploits the same cognitive resources (Enfield, 2010). Furthermore, the regression analysis shows that performance on the L1 test predicts performance on both of the L2 tests, suggesting that L1 competence supports L2 learning. In particular, the scores on the L1 Word Ordering subtest were a significant predictor of comprehension in the L2, a result which supports the idea that grammar (syntax) is at the heart of first language competence and, as such, can enhance second language learning. For L2 vocabulary, as reflected by performance on the PPVT, both L1 Relational Vocabulary and Picture Vocabulary scores predicted significantly vocabulary scores in the L2. This suggests that semantic organizational skills are more important in L2 vocabulary growth, rather than just vocabulary size in the L1. Finally, we see that phonological STM is an important mediating factor in both types of acquisition and predicts both L1 overall language competence (TOLD-I) and L2 comprehension (ELCT).

An important finding in the current study is that, in the second language, comprehension showed high correlation with the L2 vocabulary size measure. These results support similar findings in the area of reading comprehension, where a strong dependence for reading

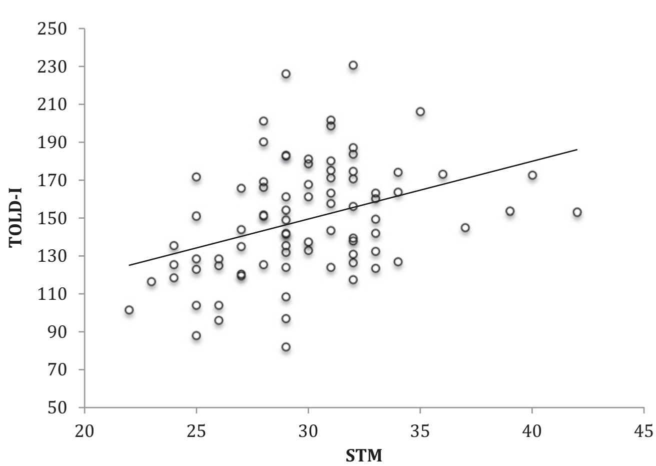

Fig. 3. Scatterplot of the STM (FDR) and the TOLD-I.

comprehension on vocabulary was found in child second language (Lervåg & Aukrust, 2010).

4.3. Limitations of the current study

The results cannot be interpreted without bearing in mind that the Norwegian TOLD-I is not yet standardized. It was used for the first time in the current study, and is currently being revised for the purposes of testing Norwegian children in different age groups.

5. Conclusions

Previous research shows strong connections between language competence, and short-term memory (STM). The phonological loop (PL), which is accessed by STM, has been found to support vocabulary development (Baddeley et al., 1998; Gathercole et al., 1992). Studies indicate also that grammar and vocabulary are strongly connected in development (Bates & Goodman, 1997). While previous studies have addressed the links between specific language skills (e.g., vocabulary size) and performance on specific tasks, and memory, this is, to the best of our knowledge, the first study to address the role of verbal short-term memory in overall oral language competence in the first language. We set out to investigate whether such reliable correlations could be found in Norwegian 10-year-olds. We were also interested in the extent to which a relationship could be established between skills in the first language and skills in the second, and whether such a relationship is mediated by some underlying factor of a more general nature, such as e.g., memory capacity, as sometimes indicated.

Our expectations were met. Among the three main factors, a high correlation was found between overall language competence and STM, and STM significantly predicts L1 competence. Thus, not only vocabulary, but overall language competence and STM seem to be strongly related in 10-year-old children. STM tended to be more related to syntax than to morphology as measured on the Morphological Comprehension task, which failed to show a significant correlation with STM. This is consistent with the suggestion that the PL mediates syntactic learning (Baddeley et al., 1998), and indicates that the PL is somewhat less important for morphological learning. The fact that the standard deviation for Morphological Comprehension was higher than for the other language sub-tests suggests that 10-year-olds are at quite different stages in the process of acquiring morphological awareness, which requires meta-linguistic skills. This in turn implies a bigger inter-individual variation in meta-linguistic skills in language development.

We interpret the high correlation between Sentence Combining and Word Ordering with the rest of language competence measures as confirming the role of working memory (WM) in first language development. To the extent that these tasks are part of the same overall test, the role of WM in the development of language and reading skills in Norwegian children should be investigated further in future experiments using appropriate tasks.

In addition, the Norwegian adaptation of TOLD-I will hopefully be standardized in the near future, making well-informed conclusions possible on the basis of a larger representative sample.

Finally, our results concerning the relationship between competencies and skills in the first language and in the second language support theories of language development which take into account the role of mediating cognitive factors.

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