Commentary on special issue: Syntax and verbal short term memory

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Abstract
Short term memory (STM) and working memory (WM) performance consistently predict language abilities in children with developmental language disorders. However, causality is not fully established. Moreover, evidence from the fine-grained analysis of STM/WM tasks and comprehension of complex sentences, suggests that long term memory (LTM) representations play an important role. Critical assessment of the articles in the special edition focuses on Zebib et al. and Stanford and Delage. Zebib et al. find that sentence repetition by bilingual language-impaired children more strongly reflects WM than overall linguistic ability. This suggests a dependence on WM when linguistic representations are impoverished. However, the process of ranking predictors is problematic. Stanford and Delage find that STM/WM difficulties affect the processing of complex sentences by individuals with Specific Learning Disabilities. Yet, LTM-based explanations focusing on input frequency may also explain this phenomenon. To make progress we need a combination of experimental studies and large-scale longitudinal studies.

Keywords
Developmental language disorders, short term memory, syntax, vocabulary, working memory

Over the past three decades, a host of studies have demonstrated a strong association between performance on short term memory (STM) and/or working memory (WM) tasks and language abilities in a variety of different populations. In a field where small sample sizes lead to conflicting claims, this has proven one of the most robust research

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findings. However, key questions remain regarding the role of STM/WM. Below I will outline the main questions, before discussing the contributions of the articles in this special issue of *First Language* to the field of enquiry.

The first question is to what extent can STM/WM be separated from long term memory (LTM), in particular the declarative component of LTM which contains the lexicon, and, depending on one’s theoretical orientation, knowledge about language structure? Numerous studies have demonstrated an impact of LTM representations on STM or WM tasks. For example, during non-word repetition, wordlikeness affects performance (Munson et al., 2005), and during sentence repetition, syntactic complexity impacts on recall. These effects are observable even when stimulus length is controlled (e.g. Kidd et al., 2007), suggesting that these effects are unrelated to STM/WM capacity. Such data indicate that performance on STM and WM tasks must involve access to representations in LTM, e.g. phonological and syntactic representations, and we use these during recall tasks, a process sometimes referred to as redintegration. The clear involvement of LTM representations problematises a strict separation between STM/WM and LTM.

A second issue is whether STM/WM difficulties affect language abilities, or whether they are influenced by an underlying variable. For example, assuming redintegration, the quality of representations in LTM could influence both performance on STM or WM tasks, and linguistic abilities as measured by standardised assessments. Consequently correlations between STM or WM tasks and language measures could be mediated by representations in LTM, rather than reflecting a direct causal relationship.

A final issue, which I will focus on in detail, is whether STM or WM provide the sole explanation for the relationship between sentence complexity and processing difficulty. The term ‘complex’ is frequently used to refer to sentences with more than one clause, e.g. object relative clauses.

(1) The boy that the girl chased was blond

The boy is the underlying object of the verb chased, and when we interpret the sentence, we may only thematically integrate this entity into the sentence (i.e. establish its role within the proposition) when we reach the trace, t. To do this we must temporarily maintain an unintegrated representation of the boy until we reach this point in the sentence. The ability to comprehend this kind of sentence is strongly associated with measures of STM and WM (e.g. Just & Carpenter, 1992), suggesting that STM/WM is used to maintain representations of unintegrated entities. However, the cost of maintaining/integrating the Noun Phrase (NP) is substantially reduced if the intervening NP is a pronoun, e.g.

(2) The boy that she chased was blond.

Many have argued that the processing difficulty of sentences such as (1) reflects interference in STM/WM between stored NPs (the boy), and NPs undergoing processing (the girl), which is reduced by use of a pronoun in (2) (e.g. Gordon et al., 2002). However, this account is problematised by data from Reali and Christiansen (2007), who found that the beneficial effect of a pronoun disappears when it is used in subject position. Such an effect is inconsistent with STM/WM accounts based on interference, as, in their stimuli,
it minimises differences between the two NPs, by ensuring that they differ in animacy. Using corpus data, they propose an input-driven account, whereby certain cues become established in LTM representations due to their high frequency. In the majority of English sentences, subjects tend to be animate pronouns, and exhibit nominative case-marking, and consequently she provides a strong cue to subject-hood, thereby facilitating comprehension at the level of who-did-what-to-whom. It, by contrast, fails to provide a strong cue being inanimate and lacking case-marking.

Reali and Christiansen’s account belongs to a wider literature which casts doubt on the role of STM/WM as a primary mechanism underlying language processing, and instead focuses on the role of representations in LTM. For example, a monograph by Christiansen and Chater (2016) proposes of a theory of language which takes as its premise the assumption that the human focus of attention is extremely limited. Rather than proposing that STM or WM allows us to look beyond the focus of attention, e.g. by backtracking, the authors argue that the rapid storage, access and manipulation of LTM representations, e.g. multiword chunks, may enable us to overcome this apparent limitation. They provide support for a computational model whereby language is processed by retrieving chunks from LTM without the involvement of any kind of mechanism analogous to STM/WM.

Another line of research focuses on the richly-specified nature of linguistic representations in LTM. For example, Hay and Bresnan (2006) propose that /æ/ in hand is pronounced differently according to whether the word refers to a literal hand, or whether it occurs in an idiomatic expression such as lend a hand. Such phenomena have led to exemplar accounts of the language system (Ambridge, 2019; Bybee, 2013) which propose that all linguistic representations in LTM are detailed specific and experiential, rather than abstract. These accounts dovetail with theoretical models which propose a role for LTM in syntactic processing. For example, Reali and Christiansen’s (2007) account proposes that fine-grained statistical information related to relatively superficial aspects of a sentence, e.g. whether subjects are pronouns, is stored in linguistic representations. In order to contain such detailed information, LTM must rapidly and effortlessly store rich representations of lived experience. This is demonstrated by children’s ability to instantly acquire partial representations of words after a single encounter, i.e. ‘fast map’ (Carey & Bartlett, 1978). The rapid acquisition of new constructions (e.g. Kaschak & Glenberg, 2004) also suggests that the term ‘fast-mapping’ might be applied to syntactic learning (see also Casenhiser & Goldberg, 2005).

One final argument for shifting the burden of processing away from STM/WM is its poor capacity. For example, Miller (1956) famously estimated a span of seven items, plus-or-minus two. This arguably renders it ill-suited to the task of sentence comprehension. By contrast, LTM has no such capacity limitations, though the onus is on LTM accounts to demonstrate that LTM is sufficiently accessible and manipulable to support the processing of sentences which cannot be reduced to highly frequent chunks.

Having proposed an LTM-based account of linguistic representation and processing which questions the role of STM/WM, some caveats are necessary. Firstly, it may be misguided to propose that the same task is achieved via a single cognitive process, e.g. LTM versus STM. Research into phenomena ranging from reading aloud (Coltheart, 2005), to morphological affixation (Pinker & Ullman, 2002), to syntactic processing...
(Ferreira & Patson, 2007) suggests that a learning task may be achieved via different routes or processes. Therefore, a model of language learning and processing which is dependent on LTM, as outlined above, may not be applicable to all situations. For example, rehearsal in STM may be involved in processing a particularly complex sentence, or learning new vocabulary in a classroom context where an individual is able to dedicate substantial processing resources to this task. Moreover, the availability of different processing routes may vary across individuals and populations. For example, a language-impaired child may lack access to an LTM route for processing language, and thus may be more dependent on STM or WM mechanisms.

Secondly, even if tasks designed to exploit STM or WM tasks actually depend on representations in LTM, the ability to activate, maintain and manipulate such representations, which may involve executive functions (as a mechanism widely involved in the execution of complex tasks), might vary across individuals, and this ability could conceivably be labelled ‘STM’ or ‘WM’ (Cowan, 2008). Viewed in these terms, the distinction between such an account of STM or WM, and LTM-based accounts of the kind sketched above would be, to a large extent, terminological. However, models which are dominant in the UK and Europe, based on the Baddeley and Hitch model (1974), tend to insist on the separateness of STM and WM from LTM, thereby precluding the involvement of LTM.

Turning to the articles in this special issue, I approach them – unsurprisingly, given my theoretical stance – with a degree of scepticism. Nevertheless, I am impressed with how groundbreaking they are in terms of their recruitment of hitherto under-investigated populations, their willingness to push the envelope in terms of the linguistic phenomena they investigate, and their approach to data analysis. I will focus on Zebib at al., and Stanford and Delage as they focus on topics which I have investigated in my own research.

For me, perhaps the most striking aspect of Zebib et al.’s article, which explores sentence repetition (SR) in bilingual children with Developmental Language Disorder (DLD) is their finding that there are different predictors of SR performance in different groups. In the Bi-DLD, SR performance was more strongly predicted by WM (backwards digit span) than overall linguistic ability (French omnibus assessment). This pattern is noteworthy as it is in direct contrast to one which I observed in my own research when comparing children with DLD (then referred to as Specific Language Impairment), with language-typical controls (Riches, 2012). An intriguing implication of this finding is that children with DLD use different mechanisms to perform the same task, which is consistent with the dual route accounts previously discussed (e.g. Pinker & Ullman, 2002). However the task of ranking predictors is inherently problematic. Zebib et al. employ a forward stepwise regression whereby predictors are entered into the model according to a pre-defined criterion (typically $p < 0.05$). This results in a winner-takes-all scenario, whereby, once the best predictor has been entered, it is unlikely that further predictors will explain sufficient unique variance in order to meet the criteria for entry. This gives the appearance that there is one main predictor. However, a quick glance at the table of correlations suggests that though language measures are weaker predictors than WM, they do not lag so far behind (0.654** for WM versus 0.637*** for WM for syntactic production). Therefore, the evidence that cognitive mechanisms involved in SR are
fundamentally different across groups is not as strong as the stepwise regression model would imply. Moreover, as both the language assessments and the SR test were conducted in the children’s second language (French), this would attenuate the putative influence of LTM representations. Nonetheless, despite these critical comments, I was struck by the fact that backwards digit span explained a large amount of variance in the Bi-DLD group. Because digit span tasks activate numerical representations they recruit linguistic representations to a lesser degree than tasks such as non-word repetition. Therefore the high association with SR performance is not readily explained by the red-integration/LTM accounts outlined above.

Stanford and Delage’s article deals with an important topic in developmental psycholinguistics: syntactic intervention. Here the term ‘intervention’ does not refer to treatment, but refers to the movement of a constituent crossing another constituent of the same type, e.g. the boy and the girl in (1) above. Stanford and Delage find that children with Specific Learning Difficulties (SLD) struggle to comprehend these types of sentences and furthermore, that performance on these sentences is strongly associated with performance on a WM task (backwards digit span). They argue that WM difficulties lead to both SLDs (dyslexia and dyscalculia) and difficulties comprehending complex sentences. This finding is consistent with numerous experimental studies implicating the involvement of WM in the comprehension of intervention sentences (e.g. Gordon et al., 2002). Nonetheless, a possible additional factor, referred to above, is that, due to their discourse properties, intervention sentences are vanishingly rare in the input (Kidd et al., 2007; Riches & Garraffa, 2017). Therefore these findings could be explained by input-dependence in the SLD group, i.e. a learning system which needs a relatively large input, and consequently struggles with low-frequency forms (see Wells et al., 2009, for a study which suggests that increasing the input frequency of complex structures may lead to improvements in comprehension). According to this account, STM/WM assessments are associated with tests investigating the comprehension of intervention sentences because performance on both of these tasks depends on representations in LTM, which, in input-dependent individuals, are compromised.

Looking to the future, there is a demand for studies which probe the causal relationship between STM/WM and language abilities. However, demonstrating causality by analysing correlations among variables is exceptionally difficult. A way forward is to conduct experimental research rather than correlational research, i.e. create studies which involve the within-subjects manipulation of different experimental conditions. For example, Gordon et al. (2002) used word lists to manipulate memory load during the comprehension of intervention structures. Comprehension was particularly poor when word lists contained items which exhibited similar syntactic/semantic properties to intervening NPs, suggesting that a prime driver of comprehension difficulties was interference between like NPs in WM. This kind of experimental design could be applied to language-impaired populations. For example, if language-impaired individuals are more prone to interference effects this would support a WM motivation for comprehension difficulties. An alternative to such an experimental approach is to conduct longitudinal studies measuring different abilities at different time points. Gathercole et al. (1992) demonstrated how this approach could be used to explore causal relationships between phonological STM and language abilities. We now have statistical techniques, e.g. structural equation models,
which can be used to make more robust claims regarding causality, though such methods are extremely data-hungry, requiring large-scale testing.

Overall, the special issue makes a welcome contribution to our understanding of short term memory mechanisms in a variety of populations and their relationship to language. Having mapped out this variability across populations our next task is to turn to the issue of causality, which may be addressed using a combination of careful experimental studies and large-scale longitudinal studies.

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References
Ambridge, B. (2019). Against stored abstractions: A radical exemplar model of language acquisition. First Language. Advance online publication. https://doi.org/10.1177/0142723719869731
Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. Bower (Ed.), The psychology of learning and motivation (pp. 47–87). Academic Press.
Bybee, J. L. (2013). Usage-based theory and exemplar representations of constructions. In T. Hoffman & G. Trousdale (Eds.), The Oxford handbook of construction grammar (pp. 49–69). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780195396683.013.0004
Carey, S., & Bartlett, E. (1978). Acquiring a single new word. Papers and Reports on Child Language Development, 15, 17–29.
Casenhiser, D., & Goldberg, A. E. (2005). Fast mapping between a phrasal form and meaning. Developmental Science, 8(6), 500–508.
Christiansen, M. H., & Chater, N. (2016). Creating language. The MIT Press.
Coltheart, M. (2005). Modeling reading: The dual-route approach. In M. J. Snowling & C. Hulme (Eds.), The science of reading: A handbook (pp. 6–23). Blackwell Publishing.
Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? Progress in Brain Research, 169, 323–338.
Ferreira, F., & Patson, N. D. (2007). The ‘good enough’ approach to language comprehension. Language and Linguistics Compass, 1(1–2), 71–83. https://doi.org/10.1111/j.1749-818X.2007.00007.x
Gathercole, S. E., Willis, C., Emslie, H., & Baddeley, A. D. (1992). Phonological memory and vocabulary growth during the early school years: A longitudinal study. Developmental Psychology, 28, 887–898.
Gordon, P. C., Hendrick, R., & Levine, W. H. (2002). Memory-load interference in syntactic processing. Psychological Science, 13(5), 425–430.
Hay, J., & Bresnan, J. (2006). Spoken syntax: The phonetics of giving a hand in New Zealand English. The Linguistic Review, 23(3), 321–349. https://doi.org/10.1515/TLR.2006.013
Just, A. J., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99*(1), 122–149.

Kaschak, M. P., & Glenberg, A. M. (2004). This construction needs learned. *Journal of Experimental Psychology: General, 133*(3), 450–467. https://doi.org/10.1037/0096-3445.133.3.450

Kidd, E., Brandt, S., Lieven, E., & Tomasello, M. (2007). Object relatives made easy: A cross-linguistic comparison of the constraints influencing young children’s processing of relative clauses. *Language and Cognitive Processes, 22*(6), 860–897.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*(2), 81–97.

Munson, B., Kurtz, B. A., & Winsor, J. (2005). The influence of vocabulary size, phonotactic probability, and wordlikeness on nonword repetitions of children with and without Specific Language Impairment. *Journal of Speech Language and Hearing Research, 48*(5), 1033–1047.

Pinker, S., & Ullman, M. T. (2002). The past and future of the past tense debate. *Trends in Cognitive Sciences, 6*(11), 456–463.

Reali, F., & Christiansen, M. H. (2007). Processing of relative clauses is made easier by frequency of occurrence. *Journal of Memory and Language, 57*(1), 1–23.

Riches, N. G. (2012). Sentence repetition in children with specific language impairment: An investigation of underlying mechanisms. *International Journal of Language & Communication Disorders, 47*(5), 499–510. https://doi.org/10.1111/j.1460-6984.2012.0158.x

Riches, N. G., & Garraffa, M. (2017). A discourse account of intervention phenomena: An investigation of interrogatives. *Glossa: A Journal of General Linguistics, 2*(1), 74. https://doi.org/10.5334/gjgl.100

Stanford, E., & Delage, H. (2020). Complex syntax and working memory in children with specific learning difficulties. *First Language, 40*(4), 411–436.

Wells, J. B., Christiansen, M. H., Race, D. S., Acheson, D. J., & MacDonald, M. C. (2009). Experience and sentence processing: Statistical learning and relative clause comprehension. *Cognitive Psychology, 58*(2), 250–271.

Zebib, R., Tuller, L., Hamann, C., Abed Ibrahim, L., & Prévost, P. (2020). Syntactic complexity and verbal working memory in bilingual children with and without developmental language disorder. *First Language, 40*(4), 461–484.