Investigating the relationship between syntactic and short-term/working memory impairments in children with developmental disorders is not a straightforward endeavour

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Commentary article accepted for publication in *First Language*

Abstract

The research studies presented in this special issue rest on two assumptions: firstly, that limitations in verbal short-term memory and verbal working memory (vSTM/WM) capacity are likely to be related to impairments in syntax, and secondly that this relationship is likely to be causal, with impairments in vSTM/WM causing impairments in syntax. In this commentary article I make two, linked, methodological critiques relevant to these studies. Firstly, vSTM/WM tasks, by definition, use verbal stimuli, and therefore they are unable to measure a STM/WM capacity independently of language. Secondly, the authors make causal claims on the basis of correlational data. I argue therefore that the authors' favoured explanation that impairments in vSTM/WM cause impairments in syntax might not be correct. I conclude that pinning down the relationship between syntax and vSTM/WM in children with developmental disorders is fraught with methodological challenges, and that if the ultimate goal is to devise effective language interventions, then continuing to explore this relationship might not be particularly fruitful.

The six empirical papers in this special issue aim to elucidate the relationship between syntax and verbal short-term memory and verbal working memory (vSTM/vWM)[1] in children with developmental disorders. A number of different disorders are covered, namely specific learning difficulties (Stanford & Delage), high functioning autism (Meir & Novogrodsky), deafness (Volpato), Down syndrome (Wimmer & Penke) and developmental language disorder (Talli & Stavrakaki, Zebib et al.). As a set, the studies rest on two assumptions (even if the authors do not explicitly articulate them), namely that (1) there is likely to be a relationship between impairments in vSTM/WM and impairments in syntax in the groups studied, and (2) this relationship is likely to be causal, in the direction of impairments in vSTM/WM causing impairments in syntax. Table 1 summarises whether the authors found the expected relationship, and how they interpreted the direction of this relationship. There is not complete consistency in the findings (which is not surprising given the different methods used and given that the relationship between syntax and vSTM/WM might be different in different groups of children). Nor is there complete agreement in how a relationship, when found, should be interpreted. Nevertheless, authors who do find a relationship between impairments in vSTM/WM and impairments in syntax tend to interpret the former as causing the latter.

INSERT TABLE 1 ABOUT HERE

The hypothesis that limitations in vSTM/WM capacity are responsible for impairments in language development goes back at least thirty five years (Ellis Weismer, 1996; Gathercole & Baddeley, 1990; Kirchner & Klatzky, 1985; Joanisse & Seidenberg, 1998, Montgomery, 1995; *inter alia*), although it has been challenged for almost as long (Howard & van der Lely, 1995; van der Lely & Howard, 1993; see also Bishop, Adams & Norbury, 2006). The mechanism proposed to link the two is that STM/WM is a fundamental cognitive system with a limited capacity, and that this capacity is even more limited in children with language impairments. When the verbal STM/WM demands of language learning and language processing exceed available resources, the storage and processing of linguistic information

[1] STM and WM are distinct but highly correlated constructs. While there is some debate as to how they are best characterised, for most purposes STM can be characterised as a component for storing information that is no longer externally available, while WM additionally contains an attention component for maintaining memory representations in the face of concurrent processing, distraction and attention shifts.

are degraded, thereby directly contributing to impairments in acquiring language. With respect to different groups of children with impairments in language development, this argument has been made most frequently for children with specific language development/ developmental language disorder. There is a need to address disorders beyond developmental language disorder and to investigate whether similar language difficulties across disorders have a similar underlying cause. With respect to the different aspects of language, the majority of studies have focused on how limited vSTM/WM capacity might cause difficulties with word learning (e.g., see Gathercole, 2006, for a review), and far fewer have considered the acquisition of syntax (e.g., Montgomery, 1995). This special issue's coverage of different developmental disorders and its focus on syntax are therefore very welcome.

Nevertheless, in this commentary I make two, linked, critiques about the line of research presented in this special issue. The first critique concerns the fact that vSTM/WM tasks, by definition, use verbal stimuli, and therefore performance on them is not independent of language. The second concerns the fact that the authors make causal claims on the basis of correlational data. I argue that the authors' favoured explanation that impairments in vSTM/WM cause impairments in syntax might not be correct.

The first critique concerns the tasks that are used to assess STM/WM. Five of the studies[2] use digit span tasks and four[3] use a non-word repetition task. The stimuli in these tasks are verbal. This means – crucially – that they do not allow STM/WM capacity to be assessed independently of language. If a child performs poorly on one or both of these tasks it is not clear whether that is because of an inherently limited STM/WM capacity or because impaired representations of the to-be-recalled linguistic material make that material harder to remember accurately (the latter has been suggested for non-word repetition by, for example, Marshall, van der Lely & Harris, 2003). If STM/WM capacity is not measured independently of language, then correlations between STM/WM scores and syntax scores might come down to nothing more interesting than the fact that both involve linguistic material.

[2] Meir and Novogrodsky; Stanford and Delage; Talli and Stavrakaki; Volpato; Zebib et al.
[3] Talli and Stavrakaki; Volpato; Wimmer and Penke; Zebib et al.

Indeed, the notion of a dedicated and fundamental cognitive system that can be labelled vSTM/WM is not unchallenged in the literature. For example, G. Jones et al. (2020) reject the notion that age-related increases in verbal span arise through developmental increases in STM capacity. Instead, they argue that improved digit and word span performance arises from knowledge of language acquired through basic sequential learning mechanisms. More specifically, they argue that performance on vSTM span tasks increases with age because exposure to language increases with age, and that the reason for the well-established finding that digit recall is superior to the recall of lists of other words is that natural language has a much higher prevalence of random sequences of digits than random sequences of other words. In other words, what verbal span tasks tap into is language ability. We know that many children with developmental disorders have language impairments. On Jones et al.'s account it is therefore not surprising that many also have difficulty with digit span tasks, but this does not mean that they have an independent vSTM/WM capacity that is inherently more limited than that of children whose language is developing typically.

Schwering and MacDonald (2020) make a similar point, arguing that vWM is emergent from language processing and challenging the notion of a working memory architecture that comprises a short-term store separate from long-term memory. On this account, vWM is the activated portion of linguistic long-term memory. They review evidence for non-word repetition performance being linked to knowledge of phonological patterns and vocabulary, and they argue that non-word repetition tests measure the quantity and quality of language skill and experience relevant to the specific demands of this particular task, rather than a separate memory capacity. Similarly to G. Jones et al.'s (2020) argument for span tasks, Schwering and MacDonald (2020) argue that what non-word repetition tests measure is language ability.

One solution to the challenge of measuring the capacity of STM/WM independently of language is to use tasks with non-verbal stimuli. This was the strategy used in a longitudinal study of deaf and hearing children initially aged 6-11 years (A. Jones, Atkinson, Marshall, Botting, St Clair, & Morgan, 2020), where the aim was to investigate the developmental

relationship between vocabulary and executive functions (including WM). The two non-verbal WM tasks were an odd one out task (Henry, 2001) and a backward spatial span task (Wechsler & Naglieri, 2006). The former task requires children to process which shape is the odd one out while storing the location of each odd shape in a grid. At the end of each trial, children must recall the locations of the odd shapes in the correct sequence by pointing to the correct box on a series of empty grids. The backward spatial span task requires children to tap blocks in a sequence reversed from one shown by the experimenter. In both tasks, the number of items in each trial increases as the testing period progresses, until a discontinue point is reached. Importantly, the stimuli are not labelled verbally and no verbal response is required from the child.

Using cross-lagged panel models with the data from the deaf and hearing groups combined, A. Jones et al. (2020) found that expressive vocabulary at Time 1 predicted WM scores two years later (taking into account WM scores at Time 1), but that WM scores at Time 1 did not predict expressive vocabulary scores two years later (taking into account vocabulary scores at Time 1). In other words, expressive vocabulary predicted WM growth, but not vice versa[4], despite the WM tasks being non-verbal. There was no evidence that this relationship was different in the two groups of children. An obvious caveat is that the main finding of this study – that language development drives WM development – might not be replicated with children who have developmental disorders (such as developmental language disorder and autism). Nevertheless, it does provide a useful model for how questions of the relationship between STM/WM and language can be investigated more cleanly than by using verbal stimuli.

A. Jones et al.'s study design also has advantage of being longitudinal, which allows changes over developmental time to be tracked. This brings me to my second critique of the studies in this special issue, which concerns the attribution of causality. As Bishop (1992) long ago cautioned researchers, correlation does not equal causation when we are trying to uncover the causes of impaired language. All the studies presented here are cross-sectional in

[4] Unfortunately, this study was unable to investigate the relationship between WM and syntax, because the deaf children used English and/or British Sign Language – languages with very different and therefore not directly comparable grammars.

design, and therefore less well placed to address issues of causality than longitudinal studies. However, even longitudinal studies cast doubt on a causal relationship between vSTM/WM and language.

If, in children with language impairments, vSTM/WM impairments are causal to language impairments, then one might expect to find such a causal relationship between vSTM/WM and language amongst typically developing children too. However, there is actually little evidence for this being the case. For example, Melby-Lervåg et al. (2012) carried out a longitudinal study of over 200 children, assessing their non-word repetition ability and vocabulary knowledge each year between the ages of 4 and 7 years. Although the authors found considerable longitudinal stability in children's non-word repetition and vocabulary skills, they found no evidence that non-word repetition ability influenced later vocabulary knowledge. And although Gathercole, Willis, Emslie, and Baddeley (1992) in their longitudinal study of the relationship between non-word repetition and vocabulary had argued that the former measured at 4 years influenced the latter measured at 5 years, Melby-Lervåg et al.'s (2012) reanalysis of that dataset found no evidence to support that claim. In fact, their reanalysis found some weak (but non-significant) evidence for the opposite pattern: vocabulary knowledge at age 4 tended to predict nonword-repetition ability a year later.

Melby-Lervåg et al.'s (2012) study used vocabulary as its measure of language, and the pattern might be different for syntax. But there is some suggestive data that syntax development might drive STM/WM development. For example, Amici et al. (2019) demonstrated that the typology of one's language affects performance on WM tasks. Adolescent and adult speakers of left-branching languages (where, for example, modifiers such as genitive noun phrases or relative clauses generally precede head nouns) were found to be more accurate at recalling the initial items than the final items in a list. In contrast, speakers of right-branching languages (where modifiers typically follow the head) were more accurate at recalling final items compared to initial items. A particularly strong feature of this study was its use of three types of stimuli in the recall tasks: words, digits, and spatial stimuli (all presented visually): the effect of language type was evident even for spatial (i.e. non-verbal) stimuli.

Training studies[5] are considered to provide the strongest evidence of causal relationships (Hulme & Snowling, 2014; Melby-Lervåg et al., 2012). Could training vSTM/vWM in children with language impairments lead to improvements in their syntax? A plethora of studies have shown that it is possible to train children's STM/WM, but that transfer effects to domains outside STM/WM – such as literacy, numeracy and language – are unreliable (see meta-analyses by Melby-Lervåg, Redick, & Hulme, 2016, and Sala & Gobet, 2017). Therefore, it is unlikely that training STM/WM will benefit children's syntactic skills. However, little of the research on STM/WM training has focused on children with language impairments and on the possible far transfer of STM/WM gains to syntax, despite the importance of this issue. After all, one of the most important reasons for trying to understand the role of STM/WM in children with developmental disorders is to help devise effective interventions.

Stanford and Delage are the only authors in this special issue to suggest that training STM/WM might positively influence syntax. Indeed, together with Durrelman they have carried out a study to test exactly that prediction (Stanford, Durrleman & Delage, 2019). In this study, forty-three French-speaking children with developmental language disorder aged 6-12 years were randomly assigned to either a bespoke vWM training condition or an active control condition. Training in both conditions lasted for a total of 12 hours, and the measure of syntax was a production task eliciting 3rd-person accusative clitics.

As well as finding a near-transfer effect (i.e., the children who received the vWM training improved their vWM scores at post-test), it is impressive that Stanford et al. (2019) also found far transfer effects: the accuracy of clitic production improved after the vWM training but not after the active control training, even though clitics had not been trained directly. And yet, no intervention that focused directly on clitics was carried out, and so no comparison could be made between such an intervention and the vSTM/WM training. Therefore, despite the study being a very welcome addition to the field, it remains unknown whether vSTM/WM training is a particularly efficient form of training compared to direct intervention, and therefore whether it is the best use of children's time.

[5] Amici et al.'s 2019 study is, of course, a form of training study, albeit in a natural language-learning environment

With respect to the studies in this special issue, the methodological limitations discussed here (i.e., the absence of a measure of a measure of STM/WM capacity independent of language, and the making of causal claims on the basis of correlational data) mean that the authors' favoured explanation that impairments in vSTM/WM cause impairments in syntax might not be correct. Instead, it might be wise to heed Schwering and MacDonald's (2020: 11) advice that "we can view tasks that are described as vWM tasks not as assessments of a separate vWM capacity but rather as measures of a person's skill in encoding and maintaining verbal information." Relevant also is the conclusion of G. Jones et al. (2020: 9) that "although our findings do not undermine the use of simple STM tasks as a means of predicting outcomes or identifying atypicalities, they do implicate a reappraisal of what such tasks measure, and therefore the sorts of possible underlying mechanisms that might give rise to those diagnostic or predictive properties." There is no doubt that vSTM/WM tasks such as span tasks and non-word repetition are very useful diagnostic tools when it comes to identifying language impairments (Conti-Ramsden, Botting, & Faragher, 2001; van der Lely, Payne & McClelland, 2011, *inter alia*), and non-word repetition tasks are also useful for investigating genotype-phenotype links (e.g., Bishop et al., 2006; Simpson et al., 2015). Nevertheless, pinning down the relationship between syntax and vSTM/WM in children with developmental disorders is not a straightforward endeavour. Efforts should be made to overcome methodological limitations, by avoiding the over-interpretation of correlational data and by investigating causality using more appropriate methods such as intervention studies. But ultimately – and despite the promising results of the study by Stanford et al. (2019) – exploring this relationship might not be particularly fruitful, and our research energies and resources might be better deployed elsewhere.

Acknowledgements

I am very grateful to Stavroula Stavrakaki and Judith Rispens for their thoughtful comments on an earlier version of this commentary article.

References

Amici, F., Sánchez-Amaro, A., Sebastián-Enesco, C., Cacchione, T., Allritz, M., Salazar-Bonet, J., & Rossano, F. (2019). The word order of languages predicts native speakers' working memory. *Scientific Reports*, 9, Article 1124. doi: 10.1038/s41598-018-37654-9

Bishop, D. V. M. (1992). The underlying nature of specific language impairment. *Journal of Child Psychology and Psychiatry*, *33*, 3-66. doi: 10.1111/j.1469-7610.1992.tb00858.x

Bishop, D. V. M., Adams, C. V., & Norbury, C. F. (2006). Distinct genetic influences on grammar and phonological short-term memory deficits: Evidence from 6-year-old twins. *Genes, Brain and Behavior*, *5*, 158-169. doi: 10.1111/j.1601-183X.2005.00148.x

Conti-Ramsden, G., Botting, N. & Faragher, B. (2001). Psycholinguistic markers for specific language impairment (SLI). *Journal of Child Psychology and Psychiatry*, *42*, 741–748. doi: 10.1111/1469-7610.00770.

Ellis Weismer, S. (1996). Capacity limitations in working memory: The impact on lexical and morphological learning by children with language impairment. *Topics in Language Disorders*, *17*, 33-44.

Gathercole, S. E. (2006). Nonword repetition and word learning: The nature of the relationship. *Applied Psycholinguistics*, 27, 513-543. doi: 10.1017/S0142716406060383

Gathercole, S. E. & Baddeley, A. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language*, *29*, 336–360. doi: 10.1016/0749-596X(90)90004-J

Gathercole, S. E., Willis, C. S., Emslie, H., & Baddeley, A. (1992). Phonological memory and vocabulary development during the early school years: A longitudinal study. *Developmental Psychology*, *28*, 887-898. doi: 10.1037/0012-1649.28.5.887

Henry, L. A. (2001). How does the severity of a learning disability affect working memory performance? *Memory*, *9*, 233–247. doi:10.1080/096582100 42000085

Howard, D. & van der Lely, H. K. J. (1995). Specific language impairment in children is not due to a short-term memory deficit: Response to Gathercole & Baddeley. *Journal of Speech Language and Hearing Research*, *38*, 466-472. doi: 10.1044/jshr.3802.466

Hulme, C. & Snowling, M. J. (2014). The interface between spoken and written language developmental disorders. *Philosophical Transactions of the Royal Society B, 369*. doi: 10.1098/rstb.2012.0395

Joanisse, M. & Seidenberg, M. (1998). Specific language impairment: a deficit in grammar or processing? *Trends in Cognitive Sciences*, *2*, 240-247. doi: 10.1016/S1364-6613(98)01186-3

Jones, A., Atkinson, J., Marshall, C. R., Botting, N., St Clair M. C., & Morgan, G. (2020). Expressive vocabulary predicts nonverbal executive function: A 2-year longitudinal study of deaf and hearing children. *Child Development, 91,* e400-e414. doi:10.1111/cdev.13226.

Jones, G., Justice, L. V., Cabiddu, F., Lee, B. J., Iao, L.-S., Harrison, N., & Macken, B. (2020). Does short-term memory develop? *Cognition, 198*, Article 104200, 10.1016/j.cognition.2020.104200

Kirchner, D. M. & Klatzky, R. L. (1985). Verbal rehearsal and memory in language-disordered children. *Journal of Speech Language and Hearing Research*, *28*, 556-565. doi: 10.1044/jshr.2804.556

Marshall, C. R., Harris, J., & van der Lely, H. K. J. (2003). The nature of phonological representations in children with grammatical-specific language impairment. In D. All, T. Markopoulous, A. Salamoura and S. Skoufaki (eds.). *Proceedings of the University of Cambridge First Postgraduate Conference in Language Research*, 1, 511-517.

Meir, N. & Novogrodsky, R. (2019). Syntactic abilities and verbal memory in monolingual and bilingual children with high functioning autism (HFA). *First Language*, doi: 10.1177/0142723719849981

Melby-Lervåg, M., Lervåg, A., Halaas Lyster, S. A., Klem, M., Hagtve, B., & Hulme, C. (2012). Nonword-repetition ability does not appear to be a causal influence on children's vocabulary development. *Psychological Science*, *23*, 1092 –1098. doi: 10.1177/0956797612443833

Melby-Lervåg, M., Redick, T. S., & Hulme, C. (2016). Working memory training does not improve performance on measures of intelligence or other measures of "far transfer": Evidence from a meta-analytic review. *Psychological Science*, *11*, 512 –534. doi: 10.1177/1745691616635612

Montgomery, J. (1995). Sentence comprehension in children with specific language impairment: The role of phonological working memory. *Journal of Speech, Language and Hearing Research, 38*, 187-199. doi: 10.1044/jshr.3801.187

Sala, G. & Gobet, F. (2017). Working memory training in typically developing children: A meta-analysis of the available evidence. *Developmental Psychology*, *53,* 671–685. doi: 10.1037/dev0000265

Schwering, S. C. & MacDonald, M. C. (2020). Verbal working memory as emergent from language comprehension and production. *Frontiers in Human Neuroscience*, 14:68. doi: 10.3389/fnhum.2020.00068

Simpson, N., Ceroni, F., Reader, R. *et al.* (2015). Genome-wide analysis identifies a role for common copy number variants in specific language impairment. *European Journal of Human Genet*ics, *23*, 1370–1377. doi: 10.1038/ejhg.2014.296

Stanford, E. & Delage, H. (2019). Complex syntax and working memory in children with specific learning difficulties. *First Language*, doi: 10.1177/0142723719889240

Stanford, E., Durrleman, S., & Delage, H. (2019). The effect of working memory training on a clinical marker of French-speaking children with developmental language disorder. *American Journal of Speech-Language Pathology*, *28*, 1-23. doi: 10.1044/2019_AJSLP-18-0238

Talli, I. & Stavrakaki, S. (2019). Short term memory, working memory, and linguistic abilities in bilingual children with developmental language disorder. *First Language*, doi: 10.1177/0142723719886954

van der Lely, H. K. J. & Howard, D. (1993). Children with specific language impairment: linguistic impairment or short-term memory deficit? *Journal of Speech Language and Hearing Research*, *36*, 1193-207. doi: 10.1044/jshr.3606.1193

van der Lely, H. K. J., Payne, E., & McClelland, A. (2011). An investigation to validate the grammar and phonology screening (GAPS) test to identify children with specific language impairment. PLoS One, 6 e22432. doi: 10.1371/journal.pone.0022432

Volpato, F. (2020). Verbal working memory resources and comprehension of relative clauses in children with cochlear implants. *First Language*, doi: 10.1177/0142723719900739

Wechsler, D. & Naglieri, J. A. (2006). *Wechsler Nonverbal Scale of Ability*. San Antonio, TX: Harcourt Assessment.

Wimmer, E. & Penke, M. (2020). Verbal short-term memory and sentence comprehension in German children and adolescents with Down syndrome – beware of the task. *First Language*, doi: 10.1177/0142723719899587

Zebib, R., Tuller, L., Hamann, C., Abed Ibrahim, L., & Prévost, P. (2019). Syntactic complexity and verbal working memory in bilingual children with and without developmental language disorder. *First Language*, doi: 10.1177/0142723719888372

Table 1. The studies' findings and the authors' interpretation of their findings.

Study	**Did the study find a relationship between syntax and verbal STM/WM measures?**	**The authors' interpretation of their findings**
Meir & Novogrodsky	No	Syntactic difficulties are *not* attributable to deficient verbal memory.
Stanford & Delage	Yes	WM capacity influences the ability to comprehend complex syntactic structures.
Talli & Stavrakaki	Yes	STM and WM both contribute to production and comprehension of monolingual and bilingual individuals with language impairments, but WM functions as a stronger predictor for bilinguals.
Volpato	Yes	Forward digit span predicts the comprehension of some types of relative clauses. Memory skills might not develop in children with cochlear implants in the same way as hearing children, probably due to limited language exposure before implantation.
Wimmer & Penke	Mixed findings	STM predicted performance in two out of three sentence comprehension measures. STM capacity is not a decisive factor for sentence comprehension
Zebib et al.	Yes	Children who have deficient linguistic knowledge may rely more on their general processing abilities, and thus WM, when repeating sentences.