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Commentaries

Considering the (separable) influences of phonological sensitivity and working memory on language learning outcomes

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In their keynote article examining links between early experience, phonological working memory, and language outcomes, Pierce, Genessee, Delcenserie, and Morgan (2017) present, what I argue, is a two-pronged hypothesis. In brief, the thesis is that the timing of language exposure and the quality and quantity of language input during an early sensitive period of phonological development shape the quality of phonological representations later used by the phonological working memory system to support short- and long-term language learning. The hypothesis is two-pronged because it hinges on (a) qualitative differences in the development of phonological representations, resulting in (b) variations in the efficiency of working memory as the key constraint on language learning. In this commentary, I examine support for these two prongs in detail.

At first glance, it might appear that only the first tenet is required to advance the thesis. That is, accounting for qualitative differences in phonological representations may be sufficient to explain the link between early experience and language learning outcomes. If this is the case, we should see phonological influences not only on the operational efficiency of working memory, as Pierce et al. (2017) have described, but also on other cognitive processes important to language learning. Drawing on a wide range of evidence, Pierce et al. provide a convincing argument that the quality of developing phonological representations is shaped by experience. Evidence that these phonological skills may account for variations not only in phonological working memory but also in other language-related processing comes from studies of groups with phonological impairments. For example, children with a specific learning disability affecting the skills related to fluent word recognition and spelling known as dyslexia show a largely domain-specific working memory impairment affecting the verbal/phonological domain. The phonological errors observed in children with dyslexia, however, extend beyond explicit and immediate storage within working memory to tasks tapping phonological processes related to perception, articulation, and lexical access (Fowler, 1991). Similarly, children with weak phonological skills due to sensorineural hearing loss have been found to score poorly on phonological working memory measures imposing high (nonword repetition) but not low (digit span) phonological complexity (Briscoe, Bishop, & Frazier Norbury, 2001). Taken together, these results suggest that a fundamental phonological deficit may be sufficient to impair the functioning of an otherwise intact working memory system.

Of course, the notion that a phonological deficit will impair working memory functioning is consistent with the arguments presented by Pierce et al. (2017) in

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their keynote address. Nevertheless, Pierce et al. specifically implicate phonological working memory as linking early experience and language outcomes. One possible reason that Pierce et al. only considered the impact of qualitative differences in phonological representations in the context of working memory may be related to the breadth of the concept under consideration. To them, the machinery underlying a child's working memory is a "linked set of cognitive and language processing components." Such a broad definition, however, provides little guidance when seeking a better understanding of the processes involved. Tasks arguably specific to working memory include the rapid encoding and immediate storage and rehearsal of information necessary to maintain and manipulate information held in a capacity-limited focus of attention. Consistent with Pierce et al.'s definition, working memory functioning is supported by a number of linked noncapacity-limited resources recruited either implicitly or explicitly such as those related to phonological or semantic processing, or metacognitive strategy use.

In a seminal article, Cowan (2001) estimated the pure short-term memory capacity limit as consistently averaging about four chunks across a range of contexts in adults. Short-term storage capacity appears to be a relatively fixed resource showing little change even after training (St. Clair-Thompson & Holmes, 2008). Nevertheless, functional and developmental changes do arise in working memory measures largely owing to the additional processes supporting storage. As reviewed by Pierce et al. (2017), for example, phonological representations have the potential to influence initial encoding of presented stimuli (see Fowler, 1991). As well, semantic knowledge can support more efficient chunking of information (Fiegenson & Halberda, 2008), and redintegration of items partially forgotten (Gathercole, 1995). Neurocognitive evidence that such linked processes underlie working memory differences comes from Pierce, Chen, Delcenserie, Genesee, and Klein's (2015) study reporting different brain region activations in French monolingual versus Chinese–French bilinguals or internationally adopted children during phonological working memory tasks. It should be noted that the linked processes related to chunking, encoding, redintegration, and rehearsal involve implicit or explicit strategies often drawing on existing knowledge held in long-term memory. To the extent that experience contributes to the development of this knowledge store, Pierce et al.'s contention that phonological working memory links early experience and language outcomes is supported. However, employment of these strategies can only be described as impacting working memory functioning as part of Pierce et al.'s linked set of processes underlying working memory. Strategy use cannot be claimed to reflect core working memory differences per se.

Let us now turn our attention to the evidence for a relationship between working memory and language learning more generally. Drawing on evidence from international adoptees and those with cochlear implants, Pierce et al. (2017) argue that preexisting verbal memory capacity underlies language acquisition. Questions concerning the strength of this supposition, however, are warranted in light of the growing body of work documenting modest working memory–language relationships. For example, a deficit in phonological short-term memory has not been found to result in a persistent language impairment (Gathercole, Tiffany, Briscoe, Thorn, & the ALSPAC Team, 2005). Gathercole (2006) argued for a specific link between phonological short-term memory and native or foreign vocabulary

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acquisition that holds only for the early learning stages. Once early experience is gained and some vocabulary knowledge amassed, vocabulary building is lexically supported. Given this somewhat underwhelming evidence for a prolonged relationship between phonological short-term memory and language learning, Archibald and Gathercole (2006) suggested that a double deficit in the phonological loop and central executive components of working memory may be implicated in a persistent language impairment. The evidence however, has not supported this notion: Briscoe and Rankin (2009) found no evidence of a combined working memory deficit involving both the phonological loop and central executive in children with developmental language disorder. Similarly, Archibald and Harder-Griebeling (2016) reported no group differences between children with low or typical language abilities on tasks imposing a load on the central executive once adjusted for differences in phonological short-term memory. As Bishop and Snowling suggested (2004), it seems that children with developmental language disorder have both phonological and nonphonological deficits, but those nonphonological deficits do not appear to be in working memory. Finally, the now abundant evidence that training improvements in working memory consistently fail to show transfer to other cognitive abilities such as language (Melby-Lervåg & Hulme, 2013) also raises questions concerning the links between working memory and language.

Perhaps the key to understanding the relationship between working memory and cognitive tasks such as language performance is in considering the task demands. Tasks associated with high processing and storage demands can be expected to show a greater relationship with working memory. Much of language is learned implicitly, and processed implicitly, perhaps imposing relatively low working memory demands. Nevertheless, increased working memory loads may be associated with challenging language tasks, due to either the task demands themselves or limitations in the groups completing the task. As one example, Noonan, Redmond, and Archibald (2004) reported poorer grammaticality judgments under conditions of higher memory load for language-impaired developmental groups with but not without working memory impairments. Similarly, Gangopadhyay, Davidson, Wesimer, and Kaushanskaya (2015) observed an association between working memory skills and linguistic sensitivity in 8- to 10-year-old bilingual but not monolingual speakers. Finally, working memory but not short-term memory has been found to be related to reading comprehension in young children (Cain, Oakhill, & Lemmon, 2006). Taken together, these results suggest that working memory skills are recruited under linguistically demanding processing conditions, a speculation possibly extendable to other tasks imposing processing challenges sufficient to capture attention.

Pierce et al. (2017) have described a two-pronged framework suggesting that early language experience shapes phonological development, resulting in variations in phonological working memory, which in turn influence children's short- and long-term language learning. Certainly, early experience impacts the quality of phonological representations, which potentially influence a number of language learning processes including working memory. The extent to which working memory constrains language learning outcomes may be dependent on the task demands themselves.

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Lisa M. D. Archibald
University of Western Ontario

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