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Running head: The procedural deficit hypothesis: we see problems

The procedural deficit hypothesis of language learning disorders: we still see some serious problems

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West et al. (2018) examined the relationship between implicit learning and reading and language attainment in 7- to 8-year-old children. The implicit learning tasks had poor reliability and did not correlate with language or reading skills. These findings raise problems for the claim that Developmental Language Disorder (DLD) and Dyslexia are caused (at least in part) by a deficit in procedural learning (the Procedural Deficit Hypothesis (PDH)).

The commentary by Conway, Arciuli, Lum, & Ullman (in press) claims our findings are irrelevant to the PDH because we studied a representative sample of children. However, both DLD and Dyslexia are "dimensional" disorders (Hulme & Snowling, 2009). The best established causal risk factors for dyslexia (phoneme awareness, letter-sound knowledge, Rapid Automatized Naming) show strong correlations with reading ability in unselected samples, and robust deficits in children classified as dyslexic. It is always possible that risk factors will be found that only play a causal role at the bottom end of the ability range, but no such factors have been identified for DLD or dyslexia to date. There was no sign in our data that implicit learning related to language or reading attainment in the bottom of the distribution only.

The commentary claims that only SRT tasks involve procedural learning, while other tasks involve implicit (but not procedural) learning. Their arguments about the neural bases of different learning tasks are highly speculative: both the sequence learning and contextual cuing tasks we employed are known to involve the basal ganglia (van Asselen et al., 2009; Wilkinson, Khan, & Jahanshahi, 2009). A major challenge is whether implicit/procedural learning tasks do indeed recruit different **cognitive** mechanisms; this requires the development of a clear taxonomy of tasks, and evidence that different tasks recruiting the same hypothetical mechanism are reliable and correlate well together. Our article was an attempt to address these issues.

The criticism that we used an inappropriate measure of learning on the SRT task is also incorrect. No task is a process pure test of procedural learning (Shanks & John, 1994). The aim in studies of procedural learning must be to minimize the contribution of declarative learning. Both alternating and probabilistic SRT tasks have been used to do this (e.g. Howard et al., 2006; Gabriel et al., 2011). It is clear from our data that differences between the predictable and unpredictable sequences on the SRT task emerge early. However, the problem of low reliability remains if we use measures of performance from the end of our task.

Conway et al. (in press) claims that poor reliability can only attenuate relationships. This is true but having reliable measures is nevertheless essential. The claim that "meta-analyses have... shown that individuals with SLI or dyslexia perform significantly worse than TD controls on the SRT task" is misleading. In reviewing the literature investigating the PDH using SRT tasks, we counted 46 published studies (up to April 2017); approximately 50% reported null findings for their principal measure of procedural learning.

The second commentary (Saloni & Watkins, in press) concludes that we need "better measurements of sequential learning…" and "clearer definitions of what kind of learning … is being measured by a behavioural task". We heartily agree and hope our paper contributes to these aims.

A pre-requisite for making progress in psychology is to have reliable and valid measures of theoretical constructs (cf Cronbach, 1957). Measures that are not reliable cannot be valid. We find it remarkable that our paper is the only study we are aware of in this field to have reported the reliabilities of measures of implicit learning. Work in this area will be greatly improved by being united with psychometric theory– we hope our article has contributed to this important aim.

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