Learning difficulties in dyslexia; is consolidation the key?

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Key words

Procedural learning, consolidation, automatisation, declarative learning, neural networks

Abstract

We have proposed influential causal theories at all levels in research spanning 25 years, building from automatization deficit (Nicolson and Fawcett, 1990. a cognitive level theory), cerebellar deficit (Nicolson, Fawcett and Dean, 1995; Fawcett, Nicolson and Dean, 2006 a brain level theory), and culminating in the procedural learning deficit (Nicolson and Fawcett, 2007, a neural systems level theory). Problems show up most strongly in literacy, where automaticity in phonological skills is key, demonstrating the importance of neuroscience findings for educational practice. Consolidation of learning skills is key to the learning process, and research has shown that this is impaired in dyslexia.

Introduction

I would like to present here one of our recent casual theories for dyslexia, the procedural learning deficit, and the research that led up to this, focusing for this talk on the importance of consolidation. In my PhD, I proposed that dyslexic children were not automatic in anything they did, and got by simply by working harder, in a process of conscious compensation (Nicolson and Fawcett, 1990). We followed this with a study of a range of primitive or simple skills that had been implicated in dyslexia, phonology, speed, memory and motor skill in 3 age groups of dyslexic children from 8-17 and controls matched for chronological and reading age (Nicolson and Fawcett, 1994). This study showed significant problems in all areas for the dyslexic children, with performance in some areas worse than their reading age controls. We reported these in terms of effect sizes, the difference between the dyslexics and controls based on the mean and standard deviation of control performance. This led us to an analysis of where in the long automatisation process the deficits occurred. (Nicolson and Fawcett, 2000). The best-established account dates back 40 years and suggests there are two key changes, first the skill gets proceduralised, and then it gets automatised. Our next major theory focused on locating the difficulty within the brain in dyslexia, including a study of deficits in cerebellar skills (Fawcett, Nicolson and Dean, 1996). A key to understanding neurosocience was the transformation of the role of the cerebellum from motor skill coordinator to 'all skills coordinator', and in particular the emerging evidence that the cerebellum was centrally involved in language fluency. This formed the basis for our cerebellar deficit framework (Nicolson, Fawcett and Dean, 2001), which can provide a causal explanation for the criterial deficits in reading, spelling and writing, as well as the problems in phonology, speed and motor skill. A further topic that has emerged more recently is the proof that many brain regions are involved in the acquisition and the execution of cognitive and motor skills, and that therefore it is important to consider the system as a whole, not just parts of it. This neural systems approach forms the basis for our integrative procedural learning difficulties framework (Nicolson and Fawcett, 2007). Interestingly, the systems for declarative (learning facts) and procedural (learning how to do things) are based in different regions of the brain that conspire and compete to take charge of processing (Ullman ,2004). Given the fundamental distinction between the declarative neural circuitry focused around the hippocampus and pre-frontal cortex, and the procedural circuitry including also the cerebellum and basal ganglia, we developed a new synthesis suggesting that many developmental disorders were related to proceduralisation problems, with dyslexia associated with specific difficulties in the language / cerebellar procedural circuit. It seems that in dyslexia there are strengths in declarative learning but procedural learning is impaired.

Learning and dyslexia

Returning to our interest in learning, our latest theory suggests that there is a specific problem in procedural memory or learning (Nicolson and Fawcett, 2007). Procedural learning is where you learn a skill or habit, as opposed to declarative learning where you learn facts. The processes involved are different. It used to be thought that only skills such as tennis were procedural, but now it turns out that most of our language 'habits' are also. A rule of thumb is that if it takes days to learn, and you can do it without being able to explain how you do it, it's procedural. Procedural learning has been shown to be involved in learning and computing sequences, in statistical learning, in probabilistic learning, and even in rule based systems such as grammar, including syntax and phonology.

The task we selected was blending together two simple reactions, simply press a button as fast as you can with your hand when you see a flash, and with your foot when you hear a tone. We chose these tasks because simple reaction turned out to be the only skill unimpaired in our study of primitive skills. On the simple reactions this group of 14-year old dyslexics were slightly but not significantly slower than the age matched controls. As predicted, both groups were slower when they had to perform a choice reaction task. But there were clear differences in the learning curves. The controls showed rapid improvement in performance, and ended up actually faster on the choice reaction than they were initially just on a simple reaction. This reflects one of the major benefits of the automatisation process. By contrast the dyslexic group showed little early learning, and ended up considerably slower than they were for the simple reactions. They also made more errors at asymptote than the controls. This suggested that there was a problem at all stages in learning, and by modelling, we found that the dyslexic group take the 'square root' longer to learn than the controls. Given that becoming expert normally takes 1000 hours, this can account for the difficulty teachers have in accelerating the performance of dyslexic children, even with interventions tuned to their pattern of needs.

It took us more than a decade to recognise that we ought to test learning and monitor improvement overnight, to see whether this was where the underlying learning failures occurred. Some of our most important evidence in support of our theory of Procedural learning deficit was drawn from this study of consolidation in procedural learning in adult dyslexics (Nicolson, Fawcett, Brookes and Needle, 2010, Nicolson, Fawcett and Needle, 2015). The task involved was a simple motor sequence task, where the subjects were asked to produce a series of key presses repeatedly, as fast and accurately as they could. Performance was compared with control students, and we looked to see not just how fast they learned, but how well they maintained that learning after sleep. One of the most extraordinary learning mechanisms humans have is the ability to consolidate learning overnight. This is something we do without any effort because it is simply a process that the brain undertakes automatically in our sleep. Interestingly, it seems that the brain may continue to learn for some tasks when it is 'offline' and sleeping, so that performance continues to improve without further practice. In this study we showed that our dyslexic students were slower to learn at the beginning and end of the first day, and when they came back the next day. But most intriguingly, if we looked at the data in terms of both speed and accuracy, it was clear that the dyslexic students were in fact significantly worse than the controls next day, and their performance never caught up with the control students. This is an important study, because it shows that one of the most basic methods of procedural learning is impaired, even in our most successful and high achieving dyslexic students. Moreover, problems with consolidation mean that one of the most basic involuntary learning mechanisms is impaired in dyslexia, and explains why dyslexic children's skills are so fragile and can fall back after a break, such as the summer holidays. This suggests that even the best teaching will not be enough, and that dyslexic children need specialised teaching to achieve mastery.

Further evidence on consolidation.

One of the key tasks used to measure procedural learning is the Serial reaction time task (Lum et al, 2013), and Hedenius and colleagues (2013) were the first to demonstrate impairment after sleep , indicating failure to consolidate, overlaid on a trend towards difficulties in learning for dyslexic adolescents in the original task. Of course, a major concern here is whether or not dyslexic children and adults can ever consolidate their performance. Encouragingly, a recent study of a very simple motor sequence acquisition task in 8-12 year olds, showed that 2 weeks daily practice for children with dyslexia and dyspraxia allowed them to consolidate their performance (Biotteau et al, 2015). Nevertheless, no comparison was made here with control children and it seems plausible to suggest that their performance would be impaired in comparison with a normally achieving group.

A series of studies from Gabay and colleagues have examined procedural learning and consolidation in adults with dyslexia. The original study, Gabay et al, 2012, showed an impairment on SRT, but demonstrated evidence of overnight consolidation. A later study with a more complex task involving divided attention, showed problems with consolidation, and suggested that dyslexic adults in the original study had used compensatory strategies to improve their performance, in line with our earlier research on conscious compensation (Nicolson and Fawcett, 1990), whereas controls had actually improved their performance under divided attention conditions. The issue of consolidation in dyslexia is clearly one that warrants further research and could be key to procedural learning difficulties in dyslexia.

Development of learning difficulties

The division of the procedural learning system into 2 parts, for motor and language skills, allows us to understand both the development of learning difficulties and heterogeneity in profiles across individual children. A problem in the motor-PLS will lead to problems in motor skill, and show up as DCD (dyspraxia) by the age of 5 or so. If associated with the motor-language PLS it is likely to lead to early speech problems, and hence an early diagnosis of SLI. Problems in both parts are likely to lead to problems in writing and reading, and hence a later diagnosis of dyslexia. We therefore propose that the majority of problems in dyslexia will be found in the newer areas of the cerebellum, the language areas of the neo-cerebellum. ADD may well be associated with abnormalities in the PM system, perhaps this time reflecting problems in communication between the prefrontal cortex and the remainder of the system, but this would certainly be an issue for further investigation. The advantage of this framework is that it correctly identifies the coordination of the different learning processes and regions of the PLS as a key problem for dyslexia

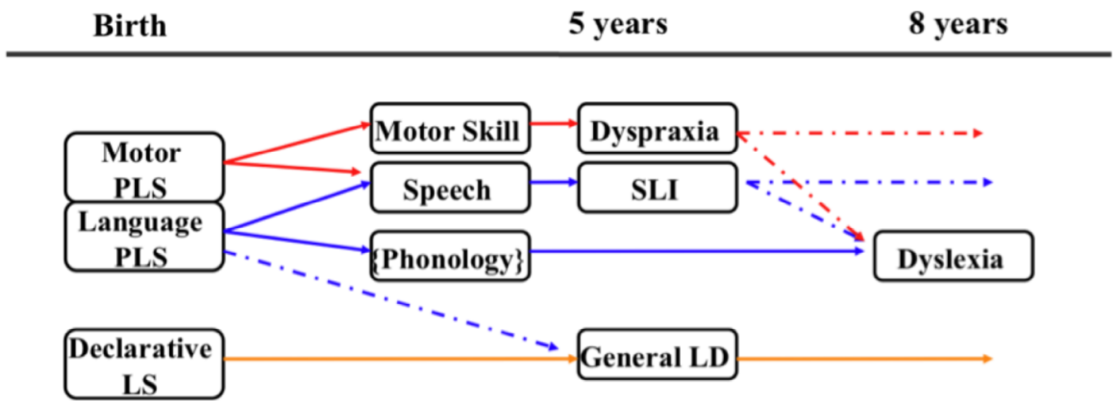

Figure 1 Development of learning difficulties (Nicolson and Fawcett, 207, 2008)

More recently we have considered the fluency of reading words and non-words under speeded time constraints in dyslexic students (Nicolson et al, 2010), establishing that high achieving dyslexic students are no more accurate given 260 ms than control students at 100 msecs, reinforcing the importance of automaticity, even at this level. From an applied viewpoint, this clearly justifies the importance of extra time in examinations for students with dyslexia.

What does this mean in practice for education?. For a given child, the specific pattern of declarative and procedural difficulties and strengths will be unique to that child. We therefore do need to find the way that that child learns best. Current educational tools tend to test attainment rather than potential, and there are very few for non-declarative learning. We therefore need to develop a series of tests for the different types of learning. Having done this we need (in principle) to be able to tailor the learning environment to the child's learning abilities and disabilities. In many cases this will mirror established methods but we need to update these methods to include our increased understanding of brain function, procedural learning and consolidation.

In conclusion, greater understanding of the role of the brain in learning could transform our understanding of how to help children with dyslexia. Early screening and intervention will allow the best possible outcomes for children with difficulties, before the overlay of self-esteem deficits can develop. It is clear that a deficit in procedural learning and consolidation will need extended practice in order to master skills, while building on the strengths that have been identified in declarative learning in dyslexia. The good news seems to be that sufficient practice can ensure that dyslexic children can consolidate their skills, at least in some areas, but these are likely to remain more fragile and vulnerable to breakdown under stress, which forces the system to rely on the less efficient procedural memory skills.

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