Chapter

Introductory Chapter: The Application of Cognitive Science in Supporting Learners with Dyslexia

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1. Introduction

According to the Education Endowment Foundation [EEF] [1], 'Cognitive science is being used increasingly to inform interventions, practice and policy in education' (p. 5). However, to date, there is a paucity of research which explores the benefits of applied cognitive science to learners with dyslexia. This chapter will explore the benefits of spaced/distributed learning, dual coding, interleaving and retrieval practice for students with dyslexia. It will start by exploring working memory and cognitive load before moving on to consider the benefits of these specific approaches. According to the EEF, 'Cognitive science principles of learning can have a real impact on rates of learning in the classroom. There is value in teachers having working knowledge of cognitive science principles' (p. 7). Despite this, it is important to acknowledge that the research base on the impact of cognitive science on student outcomes is currently limited and there is a need for further research which investigates the impact of these approaches on students with disabilities. The principles of cognitive science are derived from both cognitive psychology and cognitive neuroscience and therefore it is important to consider the role of memory in the process of learning. This chapter does not present evidence of the efficacy of the identified approaches but instead opens a debate about the possibility of the identified approaches for students with dyslexia.

2. Working memory

The model of the working memory was developed by Baddeley and Hitch [2]. The following diagram is an adapted version of the original model (**Figure 1**).

The central executive controls the working memory. The information which is received *via* the central executive is sent to either the visuospatial sketchpad or the phonological loop for processing. These are slave systems of the working memory. The visuospatial sketchpad processes visual and spatial information. The phonological loop processes spoken language and written information. The episodic buffer is a temporary storage system for holding information and was a later addition to the original model proposed by Baddeley and Hitch [2]. Information is processed in the relevant processing chambers and then sent to the long-term memory for storage. The capacity of the working memory is extremely limited. The working memory can only process a small amount of information at any time, unlike the long-term memory. If the working

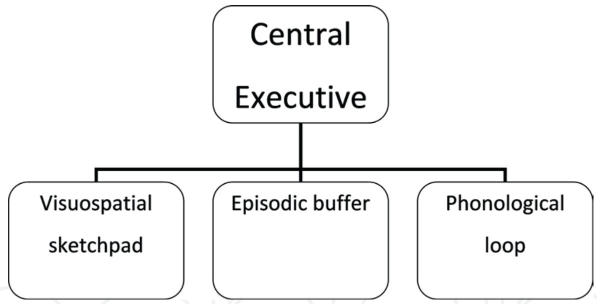

Figure 1.
Model of the working memory (adapted from Ref. [2]).

memory is overloaded, learners experience cognitive load. When this occurs, the working memory becomes less efficient, and students might struggle to process the information that is being received.

The implications of working memory for students with dyslexia need to be considered carefully. When students are being taught new knowledge, that knowledge is being processed in the working memory. The working memory is an active component of the memory. It enables us to complete tasks as we are doing them, and it helps us to remember what we need to do next. New information is processed in the working memory. When a single processing chamber (i.e., the phonological loop or the visuospatial sketchpad) is overloaded, this reduces the capacity of the working memory to process information. However, it is possible for both processing chambers to work concurrently, processing different types of information (auditory, written visual and spatial) without experiencing cognitive load. This is because auditory and written information are processed in the phonological loop and visual and spatial information are processed in the visuospatial sketchpad. The implications of this are important for educators to consider. We know that dyslexic students tend to experience difficulties with working memory. Educators therefore need to reduce the amount of information that enters the working memory at any time. Overloading the phonological loop by introducing too much auditory information will reduce its efficiency and dyslexic students are likely to struggle when they are given too many instructions or lengthy auditory explanations. This is because the auditory information is processed in the phonological loop. It quickly becomes overloaded, and learners experience cognitive load. Introducing dyslexic students to multiple phonemes in a phonics lesson will also result in the same effect. In a similar way, the visuospatial sketchpad quickly becomes overloaded when learners are exposed to too much visual information which is required to process. An example might be introducing students to multiple diagrams in a lesson.

Understanding the limitations of working memory is particularly important for dyslexic students because their working memory capacity is limited. It is important to break new knowledge into smaller, manageable chunks so that the working memory does not become overloaded. This approach is likely to benefit all students but is particularly beneficial for dyslexic students because the capacity of their working memory is reduced.

3. Cognitive load

Cognitive load occurs when the working memory becomes overloaded. This reduces the efficiency of the working memory in relation to information processing.

There are three main types of cognitive load which occur: intrinsic, extraneous and germane. Intrinsic load occurs when too much information enters the working memory, even when new knowledge can easily be assimilated into existing knowledge and existing schemas do not need to be modified. Extraneous load occurs when irrelevant content is introduced in lessons, which is not essential to the core learning taking place. This essentially gives students too many things to think about and reduces the capacity of the working memory to process the intended learning. Germane load occurs when new knowledge is not easily assimilated into existing knowledge. In this case, existing schemas need to be modified to accommodate new knowledge, resulting in more advanced understanding and transformative learning.

There are clear implications of cognitive load for dyslexic students. It is important to reduce intrinsic load by limiting the number of instructions that students need to follow, reducing the amount of auditory information that is transmitted to students in lessons and reducing the number of diagrams or other visual images that students need to visually process at any time. In addition, it is important to keep lessons focused on the core intended learning. This places a responsibility on teachers to focus sharply on the new knowledge that students need to learn rather than introducing additional content that serves as a distraction. In addition, overloading classroom environments with visual information, which requires visual processing, can serve as a distraction and reduce the efficiency of the visuospatial sketchpad.

Germane load occurs when existing schemas require modification. An example of this is in early reading when children progress from learning a simple alphabetic code to a complex code. This is problematic in languages such as English where a grapheme can represent several phonemes and a phoneme can be represented by several graphemes. One example of this is as follows: in the simple alphabetic code, children associate the grapheme 'ch' with the phoneme /ch/ in church, chip and chocolate. In the complex alphabetic code, they subsequently learn that the same grapheme represents the phoneme/k/ in 'chemist' and/sh/in 'chef'. This results in disequilibrium because the original schema that they have formed for the grapheme 'ch' now needs to be extended to incorporate multiple phonemes rather than just one. Given that we know many dyslexic learners struggle to make associations between graphemes and phonemes, as well as experiencing difficulty with phoneme addition (adding a phoneme to a word), phoneme deletion (removing a phoneme from a word and phoneme substitution (substituting one phoneme for another to change the word) due to the affected area of the brain, it is important to consider how to support them through this process of schema modification when they progress from the simple alphabetic code to the complex alphabetic code. Mastery of the alphabetic code is important for all learners because knowledge of sounds becomes a key strategy to aid spelling throughout life, even if they rely on more visual strategies to support reading. In this example, it is important that dyslexic learners can focus on the new knowledge that they are accommodating so that they can focus on the accommodation of one schema at a particular time rather than being exposed to multiple schema modifications. They also need opportunities to overlearn that new knowledge by revisiting it in different ways on multiple occasions.

4. Worked examples

Providing dyslexic students with worked examples reduces cognitive load because the worked examples serve to remind students of the steps that they need to complete to solve a problem and remind them what the expected standards are in a particular task.

5. Dual coding

The EEF [1] states:

Dual coding theory is based on the theory that working memory has two distinct components, one that deals with visual and spatial information and another that deals with auditory information. By presenting content in multiple formats, it is possible that teachers can appeal to both subsystems of the working memory, which subsequently strengthens learning (p. 37).

Dual coding is essentially the practice of providing students with information in different formats. One example of this is when teachers support a verbal explanation with a diagram. This is particularly effective when the diagram helps students to understand the information that is being presented in an auditory form. This pedagogical approach should not be confused with learning style theory, which has now been largely discredited. In the example provided here, the auditory information that the teacher is providing is processed in the phonological loop. Students will process the diagram in the visuospatial sketchpad. Both slave systems of the working memory can work concurrently to process different types of information, resulting in no cognitive load. The dual coding is beneficial to dyslexic students because knowledge that is being transmitted in one form is then reinforced using a different mode of communication. In practice, teachers could support their verbal explanations with different types of visual information including diagrams, photographs and objects at different times. However, it is important to limit the amount of information that a single slave system is required to process. Therefore, introducing many different types of visual information in a lesson alongside verbal explanations could result in cognitive load because the visuospatial sketchpad would become overloaded. In addition, if information in one form does not support understanding of the subject content, which has been introduced using a different mode, this can become distracting and result in cognitive load.

6. Concept mapping

Concept maps are essentially visual representations of subject-specific concepts. They are commonly used in science and mathematics, but they can also be used in other subjects. Subject-specific concepts (for example, states of matter in science) can be represented through pictures, diagrams, cartoons and other forms of presentation. Concept maps are helpful to dyslexic students because they may struggle to process lengthy teacher explanations.

7. Spaced/distributed learning

According to the EEF [1], 'Spaced practice (also referred to as spaced learning, distributed practice, distributed learning, and the spacing effect) applies the principle that material is more easily learnt when broken apart by intervals of time. Spaced practice is often contrasted with 'massed' or 'clustered' practice, whereby material is covered within a single lesson or a linear and sequential succession of learning' (p. 15).

This approach is particularly beneficial to dyslexic students because it provides them with opportunities to revisit (and overlearn) key components of knowledge before deepening their understanding. It involves retrieval of knowledge from the long-term memory after a period of time has elapsed. The knowledge that is stored in the long-term memory can then be re-processed in the working memory before being channelled back into the long-term memory. This retrieval of knowledge supports long-term knowledge retention.

8. Interleaving

The EEF [1] states that:

Interleaving involves sequencing tasks so that learning material is interspersed with slightly (but not completely) different content or activities, as opposed to undertaking tasks through a blocked and consecutive approach. While similar to spaced practice, interleaving involves sequencing tasks or learning content that share some likeness whereas a spaced practice approach uses intervals that are filled with unrelated activities (p. 19).

Interleaving forces students to think hard in lessons because they must switch between different types of tasks. Additionally, tasks might be interleaved across a sequence of lessons. There is a need for further research to explore the benefits of interleaving for students with dyslexia.

9. Retrieval practice

The EEF [1] states that 'Retrieval practice describes the process of recalling information from memory with little or minimal prompting' (p. 21). Students with dyslexia (and other types of disabilities) are likely to benefit from regular retrieval activities. Regular visiting of knowledge supports the development of automaticity. When learning becomes automatic, students do not need to think as much about it. This frees up the working memory. Regular retrieval tasks support dyslexic students to master foundational knowledge. Low-stakes quizzes, sorting and matching activities, talking to a partner, making lists, labelling diagrams and drawing a diagram are examples of useful retrieval activities.

10. Conclusion

This chapter has briefly introduced several pedagogical approaches that potentially could benefit dyslexic students. The application of cognitive science into the classroom has not been fully researched across a range of subjects and age phases and therefore there is a need for further research in this field. However, the potential of these strategies for dyslexic students is worthy of further consideration and further research.

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References

[1] Education Endowment Foundation (EEF). Cognitive Science Approaches in the Classroom: A Review of the Evidence. London: EEF; 2021. Available from: https://d2tic4wvo1iusb.cloudfront.net/production/documents/guidance/Cognitive_science_approaches_in_the_classroom_-_A_review_of_the_evidence.pdf?v=1699496157

[2] Baddeley AD, Hitch GJ. Working memory. In: Bower GA, editor. Recent Advances in Learning and Motivation. Vol. 8. New York: Academic Press; 1974. pp. 47-89. DOI: 10.1016/s0079-7421(08)60452-1