More than Words: The Impact of Memory on how Undergraduates with Dyslexia Interact with Information

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ABSTRACT

Despite the prevalence of dyslexia and the challenges it poses for seeking, assessing and using information, there has been relatively little research on the challenges people with dyslexia face when interacting with information. What existing research there is has mostly focused on the impact on information comprehension and spelling. However, people with dyslexia often face considerable memory impairment that can affect their learning. This paper reports findings from retrospective think-aloud (RTA) observations with 13 undergraduates with dyslexia, focusing on the memory-related barriers they face and the workarounds they use to overcome these barriers. An enhanced understanding of the full range of barriers faced by information-seekers with dyslexia can inform the design of dyslexia-aware digital information environments and information literacy programs. These can 'level the information playing field' by helping to break down barriers to information and, in turn, to knowledge creation.

CCS CONCEPTS

• Information systems • Information retrieval • Users and interactive retrieval

KEYWORDS

Dyslexia, Memory, Human Information Behaviour

1 Introduction

In the UK, 2-3% of undergraduates have the specific learning difficulty dyslexia [1]. While dyslexia often surfaces as challenges in information comprehension and spelling, it can also manifest itself in impaired working memory ability [2], which can cause barriers to processing and remembering information [3]. Although information-seekers vary in their memory-related abilities (i.e. how easy or difficult they find it *"to store, retain, and recall information"*) [4], those with dyslexia can have *"impairment in phonological coding [which] restricts the number of verbal items [they] can retain in memory"* [2].

Impaired working memory can cause challenges following multi-step processes [5], which are an intrinsic aspect of information interaction. However, while memory can be a key challenge for people with dyslexia, it is a relatively under-researched aspect; we do not yet fully understand the impact of dyslexia on Human Information Interaction. Examining the impact of memory on information interaction is important because it is not just people with dyslexia that can be affected by impaired memory (many information-seekers can), and memory impairment can make information interaction less effective and efficient.

This work is part of wider research that aims to gain an in-depth understanding of the barriers faced and workarounds employed by undergraduates with dyslexia when interacting with information to prepare for assignments. This paper reports selected findings from this project, focusing on the memory-related issues faced by students with dyslexia when interacting with information.

While existing information interaction research on dyslexia has focused mostly on information comprehension and spelling difficulties, the challenges that dyslexia can present go beyond these: memory can be a key challenge for people with dyslexia [2]. A greater understanding of the role working memory plays in how people with dyslexia interact with information can inform the design of digital information environments and information literacy programs that go beyond word and reading-focused support.

2 Related Literature

There have been relatively few previous studies that have sought to understand how dyslexia impacts information-seeking [6-16]; only one prior study [12] has considered working memory as a cognitive variable as part of a wider investigation into dyslexia and information retrieval; In their quantitative, logging-based experiment, MacFarlane *et al* [12] concluded there was a link between working memory capacity and the relevance judgement of documents, noting that the higher the working memory capacity, the higher the number of documents that were judged to be irrelevant. Eye-tracking data collected during the MacFarlane *et al* [12] study, but reported later, showed that those with dyslexia back-track more frequently when reading online [14]. They hypothesised this was due to working memory issues; the participants forgot the information read and had to re-read the text [14]. Kvikne and Berget [13] found that memory can make search result evaluation more challenging for users with dyslexia, with one user stating it is 'completely unrealistic' to evaluate several pages of results, because they would forget what they have read.

There have been suggestions of how to improve digital information environments to make them more suitable for people with dyslexia, but these have been based on limited empirical research and none directly assist with memory issues. Berget, Mulvey and Sandnes [15] found differences in the searching behaviours of people with dyslexia related to their peers and suggested that the use of a combination of icons and text may be useful in search tasks for people with dyslexia. Morris *et al* [16] make several (non-memory-specific) design recommendations; these include features to

aid with document triage, such as changes to ranking algorithms, and enhanced text-to-speech options. These studies suggest there are unique barriers experienced by information-seekers with dyslexia. However, the barriers posed by working memory and how information-seekers with dyslexia work around these warrants further exploration. This research identifies these barriers and workarounds.

3 Method

3.1 Data Collection Method

When trying to better understand information interaction behaviour and rationale, researchers often ask participants to think aloud *concurrently* (i.e. when interacting with the information). However, we were concerned this might artificially increase the burden on participants' working memory. Therefore, *retrospective* think aloud (RTA) sessions were conducted, as these do not require participants to talk when interacting with information [17]. Naturalistic data was collected; participants chose information-seeking tasks related to their current assignments.

The researcher met with each participant for about an hour; the study comprised an information-seeking session and a RTA session. In the information-seeking session, participants were asked to find information for about 20 minutes on a topic of their choice: for example, P15 sought information on *periodization* for a sports science essay and P12 sought information relating to the theorist *Vygotsky* for a presentation on children's communication and language. The variety of tasks chosen served to facilitate the observation of a range of behaviours and, hence, a variety of barriers. The information-seeking sessions lasted no more than 20 minutes, so as to avoid participants becoming over-tired. Participants were informed they could take breaks and stop whenever they wished, but only one participant asked to stop before the researcher ended the session. Screen and audio recordings were made of the information-seeking sessions.

During the RTA, the screen recording of the information-seeking session was played and participants were asked what their thoughts, feelings and actions had been and specifically to discuss any barriers faced and workarounds used.

Undergraduates were recruited from two universities and an Independent Higher Education (IHE) provider via email. 17 RTA sessions were conducted with 13 participants: where possible in the early stages, participants were asked to a follow-up session after a cyclic process of data analysis and reflection to probe interesting findings more deeply. All were female and 10 were studying for an Early Years Development and Learning degree at the lead author's institution. Over 95% of the student body are female at the IHE provider, which accounts for the all-female participation. Permission was obtained from the universities' ethics committees and care was taken to ensure participants at the IHE provider were informed their participation would have no impact upon their grades.

3.2 Data Analysis Method

A narrative document showing and explaining what happened during the information interaction sessions was created: alongside a description of the actions taken by the participant, each time an action happened, such as clicking a link or highlighting text, a screenshot of this action was added to the document. Each RTA session was transcribed and analysed in relation to the description of the session. This allowed the thoughts, feelings and actions participants referred to during their RTA to be recorded alongside their associated actions. For example, if a participant commented they found a document difficult to read, which made them frustrated, a screenshot of this document along with a narrative of actions, such as, 'scrolled up and down rapidly' was added next to this comment in the transcript.

An inductive Thematic Analysis [18] of the data was conducted using NVivo. Barriers and workarounds relating to dyslexia were identified: this paper reports only those related to memory. Once these were identified, they were grouped (part-inductively, part-deductively) into traditional information behaviours such as 'browsing' and 'extracting' and into the broader categories of *seeking*, *assessing* and *using* information. This provided a structured framework for discussing the barriers and workarounds.

3.3 Limitations

Although retrospective rather than concurrent think-aloud sessions were conducted, it was still possible that working memory issues could impact participants' ability to recall their behaviours and motivations in the RTA. However, there was little evidence of this; participants used the screen recordings as reminders. While we would have preferred a gender-balanced sample, no difference in challenges between males and females with dyslexia has been identified in the literature [2]. This provides confidence that an all-female sample has not biased the findings. The sample size of 13 is relatively small, but in-line with exploratory studies of information interaction (e.g. [12,14, 20]). As many were on the same degree, it is possible the barriers demonstrated could be domain-specific. However, the information interaction behaviour demonstrated conforms to the existing literature (e.g. [20]), suggesting this risk did not materialize. It is also possible barriers could have been (perhaps unwittingly) over or under-emphasized in the RTA sessions, but we did not note any evidence of this when comparing the RTA and observation data. While this study does not provide direct causal evidence that specific information interaction barriers (such as losing one's place within text) were a result of working memory issues, the RTA data does provide evidence that memory issues contributed to these barriers.

5 Findings

Memory contributed to several barriers for undergraduates with dyslexia when interacting with information. Sometimes the students demonstrated or discussed *workarounds* they put in place in an attempt to overcome these challenges. Barriers and workarounds related to the key information interaction activities of *seeking*, *assessing* and *using* information are discussed in this section.

5.1 Seeking Information

Barriers and workarounds related to two observed information-seeking behaviours, *browsing* and *chaining*, were identified. Browsing, defined as opportunistic *"navigating, scanning and scrolling"* [19] was, as might be expected, a common behaviour observed. Chaining (*"following chains of citations or other forms of referential connection"* [20]) was

only observed minimally. The focus here is not on how participants undertook these information-seeking behaviours, but the specific barriers that memory posed during these activities, and the workarounds used to try and mitigate for these difficulties.

5.1.1 Browsing: Barriers

A barrier to browsing that can be attributed to memory were occasions where participants were engrossed in the browsing activity, and its associated reading, to the point they forgot the original purpose of the search. If it is accepted that browsing documents involves working memory (remembering the structure of documents, aspects of the content read etc.), then it is conceivable that this may sometimes leave too little working memory capacity to hold the original information need in memory. While browsing, P9, P12, P14, P16 and P21 reported they had difficulty remembering the purpose of their search. This resulted in P9 reporting she was, *"internally panicking that I don't' know what I'm doing"*. P21 described this as an issue as her information-seeking progressed, stating that "*after a while I have to, like, remember what I was trying to do*" and sometimes she realised that she had "*forgotten what I'm actually looking for*". She noted this happened when she looked away from the screen or got distracted.

5.1.2 Browsing; Workarounds

Workarounds were observed to help negate the impact of impaired memory when browsing. These included reference back to physical notes or to previous searches. For example, P21 had a post-it-note which she stuck to the side of the laptop screen. The note stated one of her assignment's assessment criteria and she referred back to this throughout her information-seeking. P21 reported she was "*just trying to look what I was actually trying to find again*". Similarly, P12 had her assignment visible on an iPad that she brought with her to remind her of her assignment title. Another way that participants helped themselves to remember their information need was to refer back to searches previously conducted: P9 did this by looking at her previous searches in Google, while P14 and P16 referred back to open tabs from previous searches to remind themselves of their search focus.

5.1.3 Chaining: Barriers

There were three examples of unsuccessful chaining observed (P13, P19, P21) that could potentially be attributed to memory, and memory was explicitly mentioned by P19. P19 considered memory to be a barrier to chaining when she experienced difficulties in remembering how to spell an unfamiliar author's surname. During her information-seeking session, P19 read about a researcher (Karmiloff-Smith) and, during her RTA session, expressed that she had wished to learn more about this researcher's work. P19 attempted to copy the researcher's name but the copy function did not work. As she was not familiar with the name, she was unable to perform a successful new search for related work by formulating a new search query. She attempted a few workarounds to typing, detailed below, but ultimately P19's inability to remember how to spell the name meant she abandoned her search for further work by this author.

5.1.4 Chaining: Workarounds

P19 attempted several (unsuccessful) workarounds to deal with memory difficulties while chaining: while attempting to find further work by researcher Karmiloff-Smith, she tried to remember the surname by memory, and typed '*karm*i' before selecting *Karmiloff-Smith* from a drop-down list of suggestions. She selected a source and tried to 'search within' the source for *Karmiloff-Smith*. She reported she had forgotten how to spell the name by this point. To try and work around this she searched only for '*Smith*' and looked in the index to see if she could recognise the name there. Finally, she retraced her steps to the original source, but could not re-find the page she had been reading.

5.2 Assessing Information

Participants preferred to look for information on familiar and trusted online platforms. When asked why she used the library catalog 'Discovery', P12 stated, "*I just do everything from there*". Like other participants (P10, P13, P15, P17), she reported she was wary of using the Web in its entirety as she did not trust her ability to judge the reliability of information she found. As assessing information has the potential to place considerable load on working memory, this might explain participants' concerns about their ability to successfully remember their information need, read and interpret documents, then judge the relevance to their information need, while also assessing reliability.

Only if a document has been successfully read and interpreted can its relevance in relation to the information-seeker's need be judged. Dyslexia was found to create barriers to accurate reading and interpretation and hence, as will be shown below, impacts on the information-seeker's ability to judge document relevance.

5.2.1 Reading Documents: Barriers

Barriers related to memory were also identified when participants were reading documents. This often resulted in the unsuccessful navigation of documents - both within the text of a single document and between documents. While reading, most participants reported losing their place due to eye-tracking difficulties. Working memory issues then meant they were unable to recall either the word or line of text they had read last. This caused them to re-read portions of text, echoing the findings of [14]. Even if they eventually read the desired text, participants often forgot the information they had read, resulting in more re-reading. For example, when P15 and P21 navigated away from the page of text they were reading accidentally, they were unable to remember which page they were on or what text they had just read and could not return to the text.

5.2.2 Reading Documents: Workarounds

One workaround observed to aid reading was using the cursor or a physical object to follow along the line of text. Another was highlighting the text in some way - either on screen or by printing and physically highlighting the hardcopy. Nine participants were observed to use the cursor and 3 their finger or a ruler to follow along lines of text. Seven participants highlighted portions of text. They reported this helped them "*focus*" (P19) and stop "*getting lost*" (P13). In addition to highlighting, P17 copied and pasted information into a Word document, stating that "*if I forget*

what I've just been reading I look at what I've last copied just to refresh what I've done". While workarounds to losing their place *within* a single page were observed, no workarounds to losing the *page* being read were observed.

5.2.3 Interpreting Documents: Barriers

When much of an information-seeker's working memory is engaged in reading a document, this can potentially limit the capacity available for text interpretation. As P10 notes, "*I'm so concentrating on what I'm reading that I don't take it in*". This barrier was compounded by the type of texts accessed for academic assignment preparation, where the vocabulary level was judged by the participants to be too high to engage with. Eight participants reported difficulties in interpreting the documents they accessed: P13, for example, stated she did not "*like journals*" because of the "*wording*". The inability to interpret documents is a significant barrier, as if interpretation does not take place, relevance evaluation is not possible.

5.2.4 Interpreting Documents: Workarounds

Most participants stated they had to re-read text several times to interpret meaning. This is not a *workaround* as such, but a method reported in the RTA session as often being a necessary part of information interaction for them. P18 noted that by "*the fourth time I could probably tell you what it actually meant*". The layout of the documents sometimes aided participants' ability to interpret meaning; bullet points (P11), short sentences (P12) and the use of tables (P15) were reported as helping interpretation. When unknown vocabulary was encountered, definitions were sought by 4 participants – either by inserting the unknown word or phrases into Google or by asking Apple's voice assistant Siri for a definition. P12 reported she relied heavily on Siri, using it "*all the time*". This workaround was not wholly satisfactory though, as she could not use it while interacting with information in certain situations, such as during lectures. P20 used Google ineffectively to find a definition: she wanted to define '*passive abstract experiences*', a phrase she had read while searching. However, she found a definition related to Kolb's theory of reflection [21], rather than a definition related to her assignment context of children's childcare experiences.

5.3 Using Information

When participants found information they considered relevant to their information needs, two key information behaviours observed were *extracting* and *storing* information. Both behaviours are arguably on the border between 'assessing' and 'use'. But for the purpose of this paper, they are discussed as information use behaviours.

5.3.1 Extracting Information: Barriers and Workarounds

Memory issues meant P12's process of extracting information was disrupted; she reported that, "*I copied the link but then forgot to write any notes*". P12 had a Word document open during her session, where she copied and pasted the link to relevant documents and text relevant to her assignment. However, for one of the information sources she accessed, she only copied the link and had to return to the source later to copy and paste the information she wanted to extract. When extracting information from eBooks, P15 reported that she had to '*write it all down really quickly*" as she feared she would "*not remember that I read it*" if she became automatically logged-out of the eBook platform. P16 explained her memory-related difficulties extracting information: "*you have to scroll all the way back up to the beginning to find their name…then scroll back down the page that you were on to then find the bit of text that you were trying to talk about….It's a lot of scrolling up and down and trying to remember which part you were on.*"

5.3.2 Storing Information: Barriers and Workarounds

Several participants kept browser tabs open as reminders to re-visit certain pages. This is a common behaviour among information-seekers in general [22], but the students in our study heavily relied on it to mitigate memory-related information-seeking challenges. P14, for example, kept open tabs for all the potentially relevant sources she wanted to read, to avoid forgetting to read some of them. She stated *"there's a tab and I'll be like, yeah, I need to look at that"* (P14). Keeping tabs open reassured P16, who commented she felt "*better knowing it's there*". However, she also stated open tabs could cause frustration later, as she often remembered that she read something interesting, but not which document it was in. This meant she had to spend time switching through the tabs to try to recall which open tab the information she wanted to re-visit was in.

6 Conclusions and Future Work

This study found memory issues cause barriers to undergraduates with dyslexia when seeking information for their assignments. While many workarounds were observed, participants regarded many of these as ineffective. This highlights the need to provide dyslexia-aware digital information environments and information literacy programs. These have the potential to 'level the information playing field' by helping to break down barriers to information and, in turn, to knowledge creation.

To continue this research, a validation study will be conducted involving two focus groups; one comprised of undergraduates with dyslexia and the other without. This will serve to consider the generalisability of the findings, by feeding them back to students with dyslexia and determining whether and to what extent those who do not have dyslexia identify with the barriers and workarounds discussed above. Creating a framework of barriers and workarounds will support discussion and reasoning about how best to mitigate for key barriers identified in this study through system or training design.

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