Reading online in deaf and hearing young people

Reading online in deaf and hearing young people: do differences exist?

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Abstract

This pilot study explored effects of hearing loss on deaf children's reading comprehension in an online context. Eighteen deaf secondary students, ages 13-14 years (11 with British Sign Language as their dominant language, seven with English as their dominant language) engaged in an online research comprehension task. Six age-matched hearing spoken language bilingual students served as a comparison group. All participants were identified as confident readers by their teachers. Participants were asked to 'think aloud' during an online search task to provide insights into their strategies. Additionally, participants completed a battery of assessments related to reading comprehension, vocabulary, non-verbal IQ, and working memory. Overall results showed similar use of strategies across all students. Strategies applied by the most skilled readers involved drawing on prior knowledge sources, e.g., informational websites or search engines, prior knowledge of the topic, and taking the time to read and evaluate website headings before deciding which one to use as source. Participants also made use of working memory skills. Findings highlight the importance of teaching online search and evaluation skills as part of the reading curriculum in schools.

KEYWORDS: Online Reading, Deaf Children, Think Aloud, Online Search, British Sign Language (BSL), Internet, New Literacies, Reading Comprehension

Introduction

The increasing use of the internet as a teaching and learning tool brings the need to better understand the reading patterns and cognitive processes students use to access and comprehend digital texts. This has become even more relevant during the COVID pandemic which forced most schools and universities to adopt an online format for teaching (Alshawabkeh et al., 2021). Online reading comprehension may seem like a straightforward task for students, many of whom use online resources as part of their daily lives. However, day-to-day use may not contribute to online learning skills e.g., students may have difficulties with critically evaluating the authenticity of online texts (Bråten & Braasch, 2017; Leu et al., 2015; Salmerón et al., 2006) and may lack skills specific to web-based reading, e.g., locating information online (Kuiper & Volman, 2008; Hu & Yu, 2021).

Despite similarities between comprehension processes involving printed informational text and internet text (e.g., prior knowledge, inferential reasoning, self-regulation), there are additional complexities linked with the comprehension of internet text. These include prior knowledge of informational website structures and web-based search engines, how to best navigate multi-layered reading processes across internet spaces, and "rapid information-seeking cycles within extremely short text passages" (Coiro & Dobler, 2007). These differences necessitate a re-evaluation of traditional approaches to literacy and development as well as developing new ways of capturing and evaluating online reading comprehension to inform these approaches (Coiro & Dobler, 2007).

The present study investigates online reading comprehension strategies in a unique population – deaf language learners- that we might suspect to read differently due to their different visual processing. Deaf readers are known to struggle when learning to read. The reading age of the average deaf high school graduate is below age-matched hearing peers (Wauters et al., 2006). Despite this, a large degree of variation means that some deaf students

graduate with excellent reading skills. Little is known about what factors promote successful literacy outcomes in deaf students, although we do know that having a solid foundation in a signed language can help (Hoffmeister et al., 2022. Mounty et al., 2014).

Further, there is evidence that deaf individuals rely on visual information in the absence of auditory information (Holmer et al., 2020). An increased sensitivity towards visual input and attention to the periphery (Bavelier et al., 2001; Bavelier et al, 2000) may make this population users of the internet due to the multimodal nature of hypertext documents (Farjardo et al., 2008; Bavelier et al., 2001). Therefore, understanding how deaf pupils approach internet-based reading may inform approaches for reading pedagogy in schools. The present study explores this more closely, drawing on the New Literacies framework by Coiro and Dobler (2007).

To maximise internet-based teaching potential, this pilot study was designed to identify information-seeking and evaluating strategies used during online searches in different groups of school-aged deaf readers, including both those with British Sign Language (BSL) or English as their dominant language. Another population, hearing readers, served as a comparison group. Comparing reading strategies used by hearing and deaf children – who show different visuo-spatial skills – offers a way to provide new insights into the relationship between language and more general cognitive abilities (Holmer et al., 2020). This can help extend knowledge of possible relations among visuospatial skills, language, and related cognitive abilities for reading comprehension of online texts and describe the role of children's visual-spatial abilities in online reading.

Literature Review

New Literacies and online reading strategies

New Literacies is a framework defined by Coiro and Dobler (2007) as the new social practices made possible by changing technologies. It draws on several disparate theoretical viewpoints: The first comes from van Dijk and Kintsch (1983) and is based on the idea that readers organise a new framework for themselves as they read. They condense the meaning, constructing a new 'text' while drawing on long term memory of facts about the topic to make inferences. Secondly, the Cognitive Flexibility Framework (Spiro, 2015) explores how to cope with the overwhelming range of choices which often occur with online reading pathways to understand new, multifaceted and complex ideas. Finally, New Literacies draws on a socio-cultural tradition from the UK (New Literacy Studies), which looks at children's home literacies as social practices important to investigate (Street, 1997). Street shows that literacies are always embedded in relations of power differentials between teacher, pupil and those with different socio-economic backgrounds with resultant social consequences, for example, of different access to new technologies.

The features of online reading which New Literacies focuses on are the cycle of planning, predicting, monitoring and evaluating. Online research and comprehension need the same literacy skills as print reading, but many more besides: choosing relevant keywords and persisting with new searches; the ability to skim the output of a search engine, deciding on the most fruitful answers to pursue, using background knowledge (Bråten & Braasch, 2017); the ability to collect multiple views on a topic rather than one answer; the skill of evaluating a source, often found in school subjects like history (Afflerbach & Cho, 2009); efficient navigation and rapid comprehension (Salmerón et al., 2018); and the ability to synthesise findings by communicating their complexity and contradictions (Leu et al., 2015; Coiro, 2017). Overall, online research and comprehension skills as defined by the New Literacies Framework depend on strong semantic knowledge, background knowledge and persistence, or self-

efficacy. We will make use of the New Literacies Framework to evaluate the cognitive strategies which deaf and hearing students use while reading online.

Deaf children's reading skills

The current study investigates online reading patterns for deaf children aged 12-14 years. Many deaf children have a much smaller vocabulary in the spoken language than hearing children (Kyle et al., 2016; Connor et al., 2006). Both their development of vocabulary and world knowledge may be impacted by their reduced access to language, particularly in their early developmental years (Lederberg, Prezbindowski, & Spencer, 2000). This is likely to affect their reading comprehension (Qi & Mitchell, 2012). Studying both deaf and hearing children Alasim (2020) tested reading of text-explicit details, text-implicit details, which drew on particular pieces of world knowledge, and script-implicit details, which ask the reader to make inferences based on general knowledge of how the world works, (e.g., what usually happens after a burglary). While all participants struggled more when implicit knowledge was needed to access meaning, deaf children were the poorest at making implicit inferences. This reduced world knowledge is likely driven by language deprivation in the family and at school (Garrison et al., 1997; Jackson et al., 1997) as well as less ambient language input from hearing people talk in everyday situations.

Teachers of children in many parts of the world tend to focus on phonics in the early stages of learning to read (Torgerson et al., 2019). Deaf mainstream children in Ireland have benefited from this approach, as demonstrated in a recent study by Mathews and O'Donnell (2020). In this study, reading comprehension skills were in the low average range for 38 deaf mainstreamed children aged 7–14 years (standardised score mean of 92) whereas their phonic decoding was better than average (standardised score mean of 111). The gap indicates that reading comprehension needs to be the priority for teachers.

Visual processing and deaf readers

There is evidence that visual processing may differ in deaf people and in particular deaf signers. Bélanger and Rayner (2015) used a forward masking task where words in the periphery become visible at certain times, and found that deaf readers have a wider perceptual span. Other research has explored the benefits of visual learning techniques and strategies for deaf children within an education setting, given their full access to visual information regardless of degree of deafness or type of amplification (Cannon et al., 2011; Easterbrooks & Baker, 2002; Luckner et al. 2001; Paul, 2009; Schirmer, 2003). This included studies focusing on the role of visual resources, e.g., pictures, sign language, in deaf students' reading comprehension (Wilson & Hyde, 1997; Walker et al., 1998) and, more recently, on the use of multimedia applications, e.g., captioning, hypertext stories (Blom et al., 2017; Loeterman et al., 2002; Lang & Steely, 2003; Wang & Paul, 2011, Nikolaraizi et al., 2013). While there seems to be an overall consensus of the potential benefits that multimedia resources may hold for deaf learners, much depends on learners' ability to use such resources independently.

However, using resources independently requires cognitive strategies for appropriately processing different resources, something that many deaf children struggle with, specifically poor readers, who may not know which visual information to attend to and how to integrate text and picture information (Holmer et al., 2020). Some studies have described deaf children as inattentive and easily distracted by visual information, particularly motion at the periphery (Stevens & Neville, 2006). Dye and colleagues (2008) argue that this may be due to a difference in allocation of attentional resources between deaf and hearing individuals in that deaf children have greater attentional resources in the periphery compared to hearing individuals who have these resources located more centrally. As a consequence, peripherally located distractors may be more distracting for deaf compared to hearing individuals.

In a classroom situation, this means that a deaf pupil may struggle to concentrate on the teacher or sign language interpreter in front of her because her attention is being drawn to

things that happen in the periphery, e.g., other pupils interacting with each other, a teaching assistant moving around in the class (Ladd, 2022). Deafness can also have an impact on deaf children's executive functioning, specifically their organizational and self-regulatory skills required for goal-directed behavior such as controlling attention and impulses and inhibiting irrelevant responses (Beer et al., 2009; Figueras et al., 2008). While the review by Dye et al. (2008) does not mention online reading, it is possible that deaf children face a similar situation when visiting websites where they are exposed to multiple visual stimuli, e.g., news banners, flashing ads, etc. Based on their research, one would expect deaf individuals to be more distracted by irrelevant peripheral information, whereas hearing individuals may be more distracted by irrelevant central information.

Comparing deaf, hearing and bilingual children's reading online

Comparing deaf and hearing children's online reading comprehension is interesting for a number of reasons: firstly, it offers a way of comparing across different contexts of modality, signed vs. spoken language. Research has shown that deaf children who are exposed to native or near-native signers from birth reach developmental milestones in their signed language at a pace comparable to that of hearing children learning a spoken language (Corina & Singleton, 2009; Woll & Morgan, 2002; Schick, 2003). At the same time, deaf children's ability to perceive and acquire spoken language has increased over the last decades due to earlier identification of deafness and improved digital hearing aids or cochlear implants (Knoors & Marschark, 2012). Comparing signing deaf children to non-signers who have been raised orally allows us to explore the role of sign language exposure in reading patterns. Signed languages are the only fully accessible languages for deaf children. Further, some differences in visual-spatial processing have been linked to sign language skills and not deafness (see for example Cordina et al., 2017). It is possible, therefore, that deaf signers may demonstrate different patterns of reading compared to their non-signing counterparts. In this context, investigations

into deaf children's online reading comprehension can help researchers and educators understand the strategies applied during online searches and guide teachers' efforts to help students develop the necessary skills.

Aims of the study

What little research is available related to online reading comprehension indicates deaf students experience difficulties with using search engines (Smith, 2006). This may be for various reasons, including limited vocabulary knowledge, poor connections between words, weak strategy use, restricted executive functioning, or poor monitoring of performance. The current study investigates these possible reasons more closely by examining deaf students' online reading comprehension strategies during information-gathering tasks on the internet and identifying how these strategies differ in comparison to printed reading. In addition, the study compares deaf readers' use of on/offline reading comprehension strategies to those of hearing readers, which sets it apart from previous research. It extends prior research on the New Literacies and online research comprehension framework by contributing information on reading comprehension strategies in an under-researched target population, i.e., deaf children.

This study was motivated by the following research questions:

- What strategies do confident readers use to search for online information within a school context, i.e., carrying out an online search?

- How do these strategies differ between the groups of deaf readers (signers vs. speakers) and between deaf and hearing readers?

- Is there any relationship between participants' at-home internet use and their choice of strategies during online searching?

Methodology

Study design

To address our research questions, we adapted a theoretical framework from Coiro & Dobler (2007), which combines three perspectives: 1. reading as an active, constructive, meaning-making process), which uses a range of strategic, cognitive processes (e.g., asking questions, developing connections, making inferences) to select, organise, connect, and evaluate what is read, 2. the rapidly changing nature of literacy as new technologies emerge (Lankshear & Knobel, 2003) which requires new comprehension skills, strategies, and dispositions as traditional reading skills may no longer be sufficient to read and learn from information on the internet, and 3. the need for cognitive flexibility (which is positively affected by children growing up bilingually, e.g., Crowe & Guiberson, 2021, 2022) to reassemble existing knowledge with new knowledge applications, e.g., hyperlinks, icons, interactive diagrams.

Participants

Ethical agreement for this study was gained from the first, third and fourth authors' universities. The parents of all the participants gave their consent for their children to take part and the young people gave consent on the day. Information about the study and consent forms are available on the project website in both English and BSL. A total of twenty-four students aged 12-14 years participated (see Table 1 for demographic information): six bilingual hearing children (Age M: 13;5); eleven BSL-dominant deaf children (Age M: 13;7) and seven English-dominant deaf children (Age M: 13;5). Both languages were available in the test sessions; the participants completed a questionnaire about language use at home and school, and which language they preferred to use for the tasks. This was done, where possible, in advance or at the testing facility. Deaf participants (i.e., deafness levels of moderate to severe) were recruited from across the UK through personal contacts with heads of school services for deaf children and the National Deaf Children's Society. Bilingual hearing participants with English as their second language were recruited from a nearby

school. Spoken language bilinguals were chosen because the deaf signing students were bilingual in BSL and English. Other inclusion criteria for this study -aside from age - were that a child had to be identified as a confident reader by their teacher. Results from our reading assessment showed that students' comprehension was weak in all three groups, despite them being recommended as confident readers (see Table 2).

Table 1: Demographic information of participants

	Deaf / Hearing	*Age at test date*	*SES (decile)*	*Home Languages*	*Preferred language for these assessments*	*Available to participant / total internet devices at home*
	H	13;8	1	Somali English	English	3/5
	H	13;8	1	Urdu English	English	2/5
	H	13;1	1	English Urdu	English	3/6
	H	13;2	1	English Pushto	English	3/4
	H	13;9	1	English Pushto	English	Not answered
	H	13;5	1	English Somali	English	4/9
Means		*13;5*	*1*			*2.5*
	D	13;9	5	English	English	6/11
	D	13;3	10	English	English	4/7
	D	14,5	7	English	English	2/2
	D	13;9	9	English Urdu	English	5/13
	D	13;6	1	English	English or BSL – chose English	2/5
	D	13;1	8	English	English	4/8
	D	14;4	5	English	English	3/4
Means		*13;5*	*6.4*			*3.7*
	D	14;9	1	PSL Polish	BSL	5/12
	D	13;1	8	BSL SSE	BSL	3/5
	D	13;11	7	English	BSL	4/7

				BSL		
	D	14;11	9	BSL	BSL	3/9
	D	12;9	9	BSL SSE	BSL	5/12
	D	14;5	7	BSL English	BSL	3/4
	D	13;11	8	Nigerian English BSL	BSL	10/13
	D	13;4	Not given	Latvian SL Latvian	BSL	3/9
	D	13;10	8	English SSE	BSL	10/13
	D	14;6	Not given	Latvian SL Latvian	BSL	3/9
	D	14;0	4	English SSE	BSL	3/9
Means		*13;7*	*6.8*			*4.7*

H=hearing, O=English dominant deaf children, S=BSL dominant deaf children

Materials

In addition to their verbal responses while completing the online research comprehension task (described further below), participants' cognitive and language skills were measured using the following assessments (see Table 2 for overview):

Descriptive Measures:

Kaufman Brief Intelligence Test 2 Matrices subtest (KBIT-2):

In order to measure nonverbal IQ, we used the Matrices subtest of the KBIT-2 (Kaufman & Kaufman, 2004), which assesses the ability to perceive relationships and complete visual analogies (e.g., pick which picture best completes the set).

Expressive One Word Picture Vocabulary Test (EOWPVT):

The EOWPVT (Martin & Brownell, 2010) was used to measure participants' expressive vocabulary knowledge. This test is a picture-naming task that assesses an individual's ability to name objects, actions, and concepts.

Peabody Individual Achievement Test (PIAT)

The Reading Comprehension subtest of the PIAT (Markvardt, 1997) was used to assess participants' ability to derive meaning from single sentences. It measures written sentence comprehension by requiring participants to read a sentence and then select the corresponding picture that best matches the meaning of the sentence.

Corsi block task

The Corsi block task (Mueller, 2013) task was used to measure participants' visual-spatial working memory (WM). It is a non-verbal task, which requires the participant to remember block sequences of different length. The total score is the number of sequences correctly reproduced by the test taker. This test lacks age-based norms, although Burggraaf et al. (2018) with hearing 13 – 14-year-olds found a 95% confidence level scores of 5.8 - 6.1. Visual-spatial working memory using Corsi tasks has been shown to be affected by varying socioeconomic status (Lima et al., 2020).

Table 2: Mean Scores from Standardised Assessments (standard deviation in brackets)

Tests	Hearing	Deaf Speech	Deaf Sign
n	6	7	11
PIAT – RC	83.1 (4.1)	87.7 (7.8)	88.0 (12.7)
EOWPVT	90.1 (5.5)	90.3 (11.8)	84.0 (23.2)
K-BIT	81.3 (16.9)	100.9 (15.7)	111.0 (11.5)
CORSI	4.5^ (1.0)	5.0^ (0.7)	5.5^ (0.9)

^=test score missing from one group member

PIAT-RC: Peabody Reading Comprehension; EOWPVT: Expressive One Word Picture Vocabulary Test; K-BIT: Non-verbal IQ; These first three tests are standardised with a mean score of 100. CORSI: visual-spatial Working Memory.

It is notable that the hearing participants were not, on average, skilled readers based on their PIAT (offline) reading scores. In fact, both of the deaf groups had an average reading comprehension score just within one Standard Deviation below the mean, whereas the hearing group was slightly below 1SD. That is, across all groups in our study, over 80% of children the same age and without special needs would have better reading comprehension. The group of hearing participants were all from an inner-city school in an area of socio-economic deprivation. In all cases for these six hearing participants, English was not the language of the home.

Procedures:

Most of the testing took place in the research lab at university or at participants' own schools. All children were tested individually during one morning or afternoon session. Testing was carried out by two research assistants (RAs; one deaf, one hearing) and the second and fourth author. All were fluent BSL signers and also fluent in English, enabling free communication with all participant groups.

Think Aloud Task

Participants were presented with two questions in a Word document on their computer screen and asked to use a search engine of their choosing to find the answers. The first question, "What makes a hurricane lose its power?" was adapted from Coiro and Dobler (2007). Participants typed their responses in the same Word document and included the websites that they had used. The second question was "How do you add subtitles to a video?" Participants were asked to locate relevant information from no less than three different websites to answer

this question. The answer required synthesis of different information and could not be answered by simply copying/pasting the question into the search bar.

For both tasks, participants were asked to 'think out loud' while they were looking for information to answer the question, using speech or BSL as desired. To familiarise students with the Think Aloud procedure, verbal reporting was modelled for the participants by the researcher and students were encouraged to make verbal/signed utterances as frequently as possible during the task. This type of instruction is commonly used in Think Aloud studies on text-processing due to the importance of introducing and clarifying the task for participants (Afflerbach, 2000). All participant data (signed and spoken) was video-taped. Synchronised with their verbal/signed reports, we recorded participants' screen movements using the screen-capture software Camtasia *(www.techsmith.com/video-editor.html).* These data were used to complement participants' verbal responses and provide detailed information on search terms used, links clicked on, the order in which webpages were read, etc. Camtasia also allows audio recording of the participant at the computer which was most useful for observing the hearing and deaf speaking groups.

Drawing on these data we made inferences about participants' use of strategies during online reading. In addition, information on participants' previous internet knowledge was collected by means of a survey to enhance our interpretation of participants' performance on the online research comprehension task along with their verbal reports (see supplementary materials).

Data analysis

All Think Aloud utterances recorded during the online research comprehension task were transcribed by the two RAs and the BSL translated to written English. The translations from BSL captured with Camtasia and/or video were checked before coding. We adapted the

coding scheme by Coiro and Dobler (2007), which focuses on three types of reading strategies that participants may draw on (see Table 3).

To prepare for analysis, the first and second author each reviewed one of the transcripts separately, working with the video and screen capture concurrently. Each author annotated the transcript to show the timing of physical actions which were part of the search in relation to participants' signed or spoken utterances. This was followed by a discussion of the coded reading strategies. Due to the pilot character of this study and the unfamiliarity of both deaf and hearing participants with the Think Aloud protocol, we decided that both authors would co-code data from all participants. This gave us the opportunity to study the coding scheme more closely with particular regard to its potential for use with deaf readers. Any disagreements were discussed and resolved. A number of issues arose from these conversations which will be pointed out in the discussion. One slight amendment was made to coding of the Think Aloud responses for the following reasons: As most of our participants were deaf this often made it difficult to interrupt them before they carried out an action, e.g., clicking a link on the search results page; for this reason, if a participant did not comment automatically while they were conducting their search, we would prompt them with a question each time just after they had carried out an action. Hearing participants could be prompted as they carried out an action, but most deaf participants would turn to the researcher to listen, lipread or watch their question. Consequently, some of the things participants are reporting refer to very recent actions rather than future actions, or actions while they are being carried out

Table 3: Comparison of reading comprehension of printed text and on the internet (adapted from Coiro & Dobler, 2007, p. 229)

Reading comprehension strategies	Similarities between comprehension of printed informational text and internet text	Additional complexities associated with comprehension of internet text
Prior knowledge Sources	Skilled readers draw upon their a. prior knowledge of the topic b. prior knowledge of printed informational text structures	Skills readers also draw upon their a. prior knowledge of informational website structure b. prior knowledge of Web-based search engines
Inferential reasoning strategies	Informed by a reader's conventional use of a. Literal matching skills b. Structural cues c. Context clues	Inferential reasoning strategies are also informed by a. a high incidence of forward inferential reasoning b. multi-layered reading processes across three-dimensional internet spaces
Self-regulated reading processes	Occur as a. independent fix-up strategies for comprehension monitoring and repair b. connected components of a larger	Self-regulated reading processes also occur as a. cognitive reading strategies intertwined with physical reading actions b. rapid information-seeking cycles within extremely short text passages

Results

To address our three research questions, we used a mixed-methods approach that included comparing frequency counts of strategies from the Think Aloud protocols, observing actions that are unique to the process of online reading, identifying strategies used by four skilled readers (based on their PIAT scores) while completing the search task, and responses from a brief survey on all participants' access to and use of the internet at home.

1. *Differences in strategies used by deaf and hearing readers during online reading*

We compared the frequency of deaf and hearing readers' use of strategies during the online research comprehension task. Table 4 shows the results from all participants. The lack of inferential predictions from participants may have been due to the task design, which did not require asking participants what they would do next before an action (in which case they might have been more likely to tell us about inferences).

Table 4: Observed frequency of deaf and hearing readers' use of strategies during the online research comprehension task

Frequency	Sub-skill	Average Hearing	Average Deaf Speaking	Average Deaf Sign
Statements		4.7	9.3	10.1
Reading/signing aloud		1.7	5.6	2.4
Inferential predictions	Inferential predictions	1.0	1.0	0
	Literal matching	0	2.0	0
	Using structural cues	0	0	0
	Using context cues	0	0	1.0
	Anticipation across multiple levels	0	0	0
Use of prior knowledge	Of topic	0	1.3	2.3
	Of informational text structures	1.5	1.0	1.0

	Of informational websites	2.3	1.0	2.8
	Of search engines	1.0	1.7	1.7
Self-regulated reading	Plan	2.2	6.3	3.0
	Predict	3.5		1.0
	Monitor	2.6	7.8	3.0
	Evaluate	3.2	6.8	3.6
Physical actions while searching	Keystroke	3.3	3.7	3.0
	Click	13.7	11.9	19.0
	Scroll	14.6	12.6	12.6
Time on tasks		12:49	16:32	15:32

The signing deaf group made good use of prior knowledge when searching, while the speaking deaf group used self-regulation as a frequent strategy. The hearing group used prediction as a self-regulation strategy, used less by the deaf groups.

Next, we searched our data for examples of self-regulated, cognitive reading processes that were intertwined with an associated set of physical reading actions, e.g., clicking, scrolling, typing, which are unique to the process of online reading (Coiro & Dobler, 2007). These actions add to the complexity of the reading process as they require readers to go beyond the two dimensions of the printed text and navigate their way through the three-dimensional space of the internet. The following example is an excerpt from the search process for our first task ('What makes a hurricane lose its power?') from a hearing participant (Table 5). While this student had not been identified as a skilled reader based on their PIAT score, they were one of the few participants who connected different self-regulated reading strategies during their search. Coiro and Dobler (2007, p235) refer to this as "a recursive cycle of choice-making behaviors".

Table 5: Transcript of one hearing participant's self-regulated comprehension process

	T	So I'm going to Google search 'what makes a hurricane lose its power'.
P		Types 'what makes a hurricane lose its power' into Google search bar, clicks 'enter'
C	PLAN.	INFER MAIN KEYWORDS FROM QUESTION
	T	And then you see an answer to the question.
P		Scans the text
C		MONITOR
	T	This site's saying that they lose strength because of cool temperatures…
P		
C	EVALUATE	

T: Think Aloud comment; P: physical action; C: cognitive reading strategy

The second example (Table 6) is an excerpt from one of the skilled readers from the deaf signing group, related to the second task. Drawing on Rowe (2004) and Coiro and Dobler (2007), students' Think Aloud comments ('T') are matched with their associated physical actions ('P') and cognitive reading strategies ('C') to demonstrate the intricate nature of the online reading process. In an effort to display their temporal relationship to each other, the participants' speech/translated sign and actions both appear horizontally. The verbal protocol shows a skilled reader employing a self-regulated Internet comprehension process that integrates multiple dimensions of complex thinking through an interplay between web-based physical reading actions (e.g., scrolling, clicking) and conventional printed text strategies (e.g., monitoring, evaluating).

Table 6: Transcript of one deaf signing participant's self-regulated comprehension process

T	I'm looking for something that tells me how to put it on the app...		
P			*Scroll down/up results page*
C	PLAN		MONITOR
T	… and how to use that app to put text onto the video		
P		*Clicks on first link*	
C	PLAN		
T		This doesn't say where the video is on the app, it only says where the app is	
P	*scans the page*		*scrolls left/right to see all text*
C	MONITOR	EVALUATE	

The third example (Table 7) is also from the second search task ('How do you add text to a video?') from a participant in the deaf speaking group. Similarly to the hearing student, this participant had not been identified as a skilled reader based on their PIAT score. However, they stood out from all participants due to their consistent use of self-regulated strategies, specifically planning, monitoring and evaluating.

Table 7: Transcript of one deaf signing participant's self-regulated comprehension process

T	I'll just find a different link.		
P		*scrolls down the Google results page*	*clicks on link*
C	PLAN	MONITOR	FIX-UP STRATEGY
Researcher: What made you pick that one?			
T		Because it said 8 different ways you can do it. So I'm just gonna find one.	
P	*scans the page*		
C	MONITOR	EVALUATE	PLAN
T		So the first is Adobe After Effects	
P	*scans the page*		
C	MONITOR	EVALUATE	

2. Strategies used by skilled readers

As part of this study, we observed participants during the online search task and also asked them -as part of the Think Aloud activity- to comment on their actions while they were engaging in the search. Our analysis is restricted to participants who had been identified as skilled readers based on their performance on the reading assessment.

This left us with four participants overall, three from the Deaf Sign group and one participant from the Deaf Speaking group (see Table 8).

Table 8: Characteristics of the skilled readers

ID	Age	Gender	School	IQ	Vocab	Reading	WM	Time for search
1021	13;1	F	SB	129	107	109	*	7:40
1041	14;11	F	MS	110	102	100	6.0	9:44
1081	13;11	M	MS	104	96	102	5.0	21:57
1032	13;3	F	MS	127	112	104	5.5	15:33

SB = Sign bilingual; MS = Mainstream; *= Task was interrupted / stopped early

The strategies of these four skilled readers are displayed in Table 9.

Table 9: Strategies of good readers observed during online searches

- Draws on prior knowledge sources, e.g. informational websites or search engines, prior knowledge of the topic
- Good working memory (remembers the task question)
- Takes time to read/evaluate website headings before deciding
- Searches beyond first page of results on Google
- Good decision making about what to put in search bar
- Frequent use of self-regulated reading processes, e.g., plan, monitor, evaluate

Many of these strategies draw on more elaborate cognitive processes, e.g., activating prior knowledge, planning, monitoring the text for important parts, and directed attention. It is worthwhile pointing out that the skilled deaf readers did not identify all of the strategies in Table 8 during the Think Aloud activity. This suggests that they may not always choose them consciously, or perhaps struggled with describing some of their strategies while engaged in the task because they were not used to Think Aloud. For instance, when one of the skilled readers was asked why they had edited their search terms, the participant responded, as follows:

R: How do you know what to type into the search bar?
P: The question looks long, so I just took the important parts.
R: How did you decide what is important?
P: "Explore" that is what I am doing so I don't need to type it, "different ways", I'm looking for different ways so I need to type that. So that's why I chose it.

3. Participants' online strategies and internet experience

In our demographics questionnaire, respondents were asked to indicate the number of devices they could use at home which had internet access (Table 10). The hearing group had access to fewer devices; this may be as a result of living in an area of deprivation.

Table 10: A comparison of the number of devices with internet access

Number of devices	Hearing	Deaf Speaking	Deaf Sign
1-5	67%	43%	18%
6-10	33%	29%	55%
11-15	0%	29%	27%

Participants were asked to choose their top two internet activities they enjoyed outside school time from eight categories (Table 11). Interestingly, the group of hearing students reported no communication on social media. This may be because they had limited access to devices or less internet access (see final column in Table 1). In comparison, communicating on social media was important for both deaf groups, though the signing group preferred streaming more while the oral deaf group preferred gaming.

Table 11: The top two uses of the internet at home by group

	Hearing N=6		Deaf Speaking N=8		Deaf Sign N=11	
Top two internet activities (%)	1st	2nd	1st	2nd	1st	2nd
Searching	33	17				18
Communicating on social media			43	14	45	27
Streaming music/movies	50			14	9	27
Gaming		17	57	14	9	
Shopping						
Reading		17			9	9
Homework		17		43	9	18
Browsing		33		14		
Multiple	17				18	
Total %	100	100	100	100	100	100

We asked participants how long they spent on these two top internet-based activities outside of school (Table 12).

Table 12: Time per week spent on each group's two most favourite online activities

Group	Activity	< 1 hour	1-3 hours	> 3 hours
Deaf Signers	Communicating	-	36%	64%
	Streaming	27%	36%	27%
Deaf Speakers	Gaming	14%	-	86%
	Homework	29%	29%	29%
Hearing Group	Streaming	-	67%	33%
	Browsing	67%	-	33%

The hearing group reported spending the most time streaming and browsing, while the signing deaf group reported spending the most time communicating with others, and the speaking deaf group spent most time on gaming and homework. These choices reflect the cultural and physical limitations and opportunities the internet provides to the three particular groups in our study.

Discussion

This pilot study employed a mixed-methods approach to investigate strategies used by two deaf and one hearing group of readers, within the context of an online research comprehension task. We adapted a methodology from Coiro and Dobler (2007) for use with two populations of deaf readers, one BSL-dominant and the other English-dominant. Our key findings suggest that skilled deaf readers tend to make use of strategies but do not always choose them consciously, or perhaps do not find it easy to report on their reading intentions while engaged in a cognitively challenging reading task. Furthermore, all of the profiled skilled readers in our study had high working memory (apart from one student who did not complete the working memory task).

One interesting observation we made was that some students seemed to be less familiar with using a web browser on a PC/Apple computer rather than, perhaps, on a mobile when carrying out online searches. While our observation needs to be validated in a future study, this trend is concerning given schools' growing use of the internet as a research- and learning tool. More detailed information is needed from schools on the frequency of internet use and, more specifically, on how online search skills are taught. Finally, since part of our aim was to explore a new methodology for investigating deaf children's use of cognitive strategies during online reading, our findings indicate a need for adjusting the Think Aloud protocol for use with deaf children. We address each finding individually below.

Other key findings

Across all groups, our readers rarely made use of inferential reading strategies, regardless of type. This is different from previous studies with hearing readers (Coiro & Dobler, 2007), where readers made inferences about information which was hidden from their current location on the web or in the text. One possible explanation for this could be an effect

of the way we had set up our task, which did not require the task administrator to stop participants before they carried out an action, e.g., pressing the return key. This could be addressed in the future by providing participants with a training session during which they are told that they will be asked to talk about their actions before/while they are carrying them out. To make the task more deaf-friendly, the task administrator could just sit directly opposite the participant on another PC mirroring the participants' screen, plus streaming a camera view of the participant from behind.

In comparison, all three groups made consistent use of self-regulated strategies of reading, especially the deaf speaking group and, to a lesser extent, use of previous knowledge. The deaf signing group used previous knowledge most frequently, in particular knowledge related to topic and to informational websites. This is perhaps not surprising since the second search task had to do with subtitles, a topic which is of high relevance to both deaf groups.

With regard to search task duration, both deaf groups took a similar amount of time (average 15-16 minutes), whereas the hearing group took an average of 13 minutes. Given their overall lower-than-expected performance, the results from the hearing group where English was an additional language need to be interpreted with caution.

Implications

The findings from this study have a number of theoretical and practical implications: from a theoretical point of view, the analysis of deaf students' comprehension strategies for online reading provides new insights into the possible relations among various visuo-spatial skills, language, and associated cognitive abilities about reading comprehension of online texts. Moreover, it adds to our understanding of reading competence required in internet contexts, including the question of whether online learning environments are less or more likely to distract deaf children. One possible concern is that webpages, specifically those that are busy

with visual prompts, will negatively affect a deaf child's attention. At the same time, an increased alertness to peripheral information may hold certain benefits within an online learning context, including the increased ability to skim, scan, and/or browse internet content.

Observations from this study complement findings from previous investigations into strengths and weaknesses of hearing adolescent readers within digital contexts: that only a third of 14-year olds could detect the relevance of a text from a search, or notice that some outputs were too complex to use (Macedo-Rouet et al.; 2019); that teenagers did not often confirm or question the credibility of a website (Kiili et al., 2018); that teenagers need more practice in synthesising meanings across online texts (Kannianen et al., 2019); and that they need more support in summarising their findings from online reading (Lazender et al., 2020). Taken with our findings, this could open the door for future studies to compare reading, summarising and evaluation of online texts by (skilled) deaf and hearing young people.

On the practical side, the findings could guide teachers in general in explaining search techniques by drawing on the strategies used by skilled readers and informing the construction of online learning materials. Moreover, our findings could be applied to inform work with other (hearing) groups, including those from non-mainstream backgrounds where English is an additional language and/or neurodivergent children, e.g., children with attention-deficit/hyperactivity disorder. One of our findings showed that the hearing participants in our study used prediction as a self-regulation strategy less than the deaf groups (see the supplementary material online for ideas for teachers on reading with comprehension and searching online).

Limitations and suggestions for future research

This study provided valuable preliminary data on deaf and hearing children's use of strategies during online reading which needs to be replicated with a larger sample to substantiate any conclusive statements. Such a sample will also allow us to review our selection

criteria and replicate the study with a wider range of hearing readers. In light of the limited data that is available on deaf children's online reading performance, none of which has been collected using a Think Aloud approach, we believe that our data nonetheless makes a significant contribution. With such small groups we cannot make generalisations from these data, although we have piloted a method which may prove useful in comparing larger groups of online readers.

Second, although we feel that the Think Aloud format has potential for use with deaf participants, we found it at times quite challenging to keep the students engaged in reporting their thoughts. One reason for this may be that deaf readers have to constantly divide their attention between the information on the screen and the researcher talking or signing. This additional requirement does not exist for their hearing peers, who can focus on the screen while listening to the researcher at the same time. However, we observed that our hearing group struggled with the format, as well, and needed to be reminded to think aloud, which suggests that it could be due to their unfamiliarity with this approach. One way to address this in future studies could be by assigning participants to work in pairs. Findings from research with hearing children that examined peer collaboration within an online reading context (Castek et al., 2012; Coiro et al., 2014) are promising and describe this approach as "a tangible means of visualising the interchanges (of students) which helps to target areas where students need support during collaborative online reading of informational texts" (Castek et al., 2012, p.494).

Finally, two areas where we noticed limitations in both deaf and hearing participants' Think Aloud responses related to responding while using the search engine and remembering the question they had to answer. Both deaf and hearing participants often struggled with explaining their actions on the computer and a considerable number of them required several reminders about what they were supposed to do. Follow-up studies need to examine more closely how

online reading and inquiry is taught in the classroom and identify techniques that help students to maximise their use of working memory while navigating resources and negotiating meaning of online texts. With regard to the second area, we noticed that some participants forgot the aim of the search while they were carrying it out. One possible solution would be for students to post a visual reminder of the question that remains on screen during the search or using a split-window/tab approach.

Conclusion

In our study we explored a new methodology to investigate deaf children's use of strategies during online reading. Although the study's original plan was to investigate confident readers, we ended up comparing three groups of participants that all face challenges with reading. This was a pilot study, and pupils with English as an Additional Language would make an interesting group to explore further (see Cates et al., 2022). In future studies we would want to find a more typical and larger group of hearing participants. Limitations aside, our findings show evidence that skilled deaf readers make use of online reading strategies, but may not always be aware of them or possibly lack the vocabulary or processing power to express them. The strategies themselves are similar to those that have been reported for hearing children. More research is needed on this topic, specifically on the role of children's visual-spatial abilities in online reading to inform teachers' efforts to help students develop the skills necessary for this task. All students need to know how to use digital resources appropriately (Burnett, 2017; Polizzi, 2020); this includes carrying out online searches. Therefore, there is a need for systematic instruction in visual or digital literacy skills so that students can learn how to process visual aids and extract more and better information from them, so as to increase their reading comprehension (Nikolaraizi & Vekiri, 2012). Our findings suggest that this need is not limited to deaf students but also exists for hearing readers, including bilingual ones.

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