"The Internet is Hard. Is Words": Investigating Information Search Difficulties Experienced by People with Aphasia and Strategies for Combatting Them

Vasiliki Kladouchou
Centre for Language and Communication Science Research
City St George's, University of London
London, United Kingdom
vasiliki.kladouchou@city.ac.uk

Stephann Makri
Centre for HCI Design
City St George's, University of London
London, United Kingdom
stephann@city.ac.uk

Sylwia Frankowska-Takhari
Centre for HCI Design
City St George's, University of London
London, United Kingdom
sylwia.frankowska-takhari@city.ac.uk

Timothy Neate
Department of Informatics
King's College London
London, United Kingdom
timothy.neate@kcl.ac.uk

Andrew MacFarlane
Centre for HCI Design
City St George's, University of London
London, United Kingdom
andym@city.ac.uk

Stephanie Wilson
Centre for HCI Design
City St George's, University of London
London, United Kingdom
s.m.wilson@city.ac.uk

Abi Roper
Centre for HCID
City St George's, University of London
London, United Kingdom
abi.roper.1@city.ac.uk

Abstract

People rely on online information for important life tasks such as managing personal finances and understanding medical symptoms. However, due to its intrinsically language-focused nature, online search poses considerable difficulties for people with language impairments. Currently these difficulties are poorly understood. We report findings from an observation of the information search behavior of 12 people with aphasia. We identify a wide range of difficulties and strategies aimed at combating them, spanning the entire information search process. Findings include previously unreported difficulties and strategies that highlight the importance of designing search technologies to better support the complex needs of people who find language challenging, such as by facilitating word finding cueing strategies, error prevention and recovery, browsing, appropriation, text interpretation and and by decreasing reliance on language competency in general. This has the potential not only to benefit searchers with language impairments, but to make information search easier for all.

CHI '25, Yokohama, Japan

ACM ISBN 979-8-4007-1394-1/25/04
https://doi.org/10.1145/3706598.3713808

CCS Concepts

• **Human-centered computing → Empirical studies in accessibility**; *Web-based interaction*; *HCI theory, concepts and models.*

Keywords

Information seeking, information retrieval, disability, aphasia, search, search technologies, communication.

ACM Reference Format:
Vasiliki Kladouchou, Stephann Makri, Sylwia Frankowska-Takhari, Timothy Neate, Andrew MacFarlane, Stephanie Wilson, and Abi Roper. 2025. "The Internet is Hard. Is Words": Investigating Information Search Difficulties Experienced by People with Aphasia and Strategies for Combatting Them. In *CHI Conference on Human Factors in Computing Systems (CHI '25), April 26–May 01, 2025, Yokohama, Japan.* ACM, New York, NY, USA, 20 pages. https://doi.org/10.1145/3706598.3713808

1 Introduction

People rely on search technologies for important life tasks such as finding employment, managing personal finances and understanding medical symptoms. However, information search relies heavily on language use. First, users must formulate queries (usually text-based) to express the information they are looking for (their *information needs*). They must then assess the potential relevance of the search results returned. Next, they must extract important information from the web pages and linked documents to decide how well the information matches what they were looking for. Due to its language-focused nature, online search poses considerable difficulties for people with language impairments. These difficulties remain under-explored and poorly understood. They can negatively impact the quality of information found and, as a consequence, decisions made on the basis of that information. Consider, for example, missing a posting for a highly-relevant job, choosing less suitable personal finance products or misunderstanding health symptoms. Given the ubiquity of search technologies, and their importance for informing key life decisions, it is essential to make search more equitable [39] – to ensure search technologies support access for people with language impairments.

Aphasia is a common and complex language impairment that results from damage to the parts of the brain responsible for language. It usually occurs suddenly, following a stroke or head injury, but can also develop slowly – often as a result of a brain tumour or progressive neurological disease [52]. Although not as well-known as less frequently-occurring conditions such as Parkinson's disease and cerebral palsy [2], around one-third of people who have a stroke go on to experience aphasia – approximately 2 million people in the U.S. alone [2]. Aphasia's high prevalence highlights the importance of providing accessible technologies, including search technologies, to those with language impairments. Despite the ubiquity of search and high prevalence of aphasia, very little research has focused on understanding the difficulties that people with aphasia experience during online search, their impact, and how we can better support people with aphasia by improving the design of search environments.

We report an empirical, observational study of the information search behavior of people with aphasia. This study aimed to identify the difficulties that people with aphasia experience when searching for information online and the strategies they use when attempting to overcome these difficulties. It aimed to identify difficulties and strategies across the entire information search process - from understanding information needs, to formulating queries, assessing results and interpreting webpages and documents to determine how well they address the information needs.

The study addresses three research questions:

- **RQ1** What difficulties do people with aphasia experience across the information search process and why?
- **RQ2** What strategies do people with aphasia use to try to overcome these difficulties and how successful are these strategies?
- **RQ3** How can insight into these difficulties and strategies inform the design of search technologies to better support people with aphasia?

Our key contribution is a wide range of previously unreported difficulties and strategies, spanning the entire information search process. Our study also provides new insight into how these difficulties manifest and the effectiveness of the strategies used. This new insight can inform the design of search environments to make them more accessible to users with complex language needs. Furthermore, it can provide insights for speech and language professionals supporting language rehabilitation and communication access training for people with aphasia. Finally, our study constitutes an example of inclusive research by taking an impairment-sensitive approach to investigating information search behavior.

In the rest of this paper, we first review the background literature on the accessibility of search technologies, technology accessibility for people with aphasia and the limited prior work on aphasia and information search. We then explain and justify our data collection and analysis method. Next, we present our findings – focusing on the aphasia-related search difficulties participants experienced throughout the information search process and the strategies they used aimed at overcoming these difficulties. We then discuss how an understanding of these difficulties and strategies can inform the design of future search environments to make them more suitable for users with language impairments such as aphasia. Finally, we discuss implications for speech and language professionals, conclude and suggest avenues for future work.

2 Background

In this section, we discuss prior research on the *accessibility of search technologies*, *technology accessibility and aphasia*, and the few studies that have been conducted on *aphasia and information search.* In doing so, we highlight the research gaps our study fills.

2.1 Accessibility of Search Technologies

Early search technologies, including library catalog search and the first 1990s Web search engines (e.g. Lycos, Yahoo! Search, Altavista, then Google) were not developed with accessibility in mind, as they primarily focused on efficiency and relevance. This created a design legacy that has resulted in search technologies still being difficult to use for people with a range of impairments; physical [27], cognitive [6] and, most relevant to our study, language-based [29, 30, 43].

Recognition of this lack of accessibility has driven an increasing number of research studies aimed at understanding how the accessibility of search technologies can be improved [4]. These have examined access for a range of impairments including: visual impairments [64], intellectual disabilities [66], motor impairments [32] and dyslexia [36]. However, despite the intrinsic language-focused nature of search technologies, which often require sophisticated language skills to conduct successful searches, there has been relatively little research on how search technologies can be made more accessible for people with language impairments. We review the little existing work later in this section.

2.2 Technology Accessibility and Aphasia

Aphasia is an impairment that affects language but not intellect. It therefore affects some combination of speaking, reading, writing or listening [2], to varying degrees. In the HCI and accessibility communities, there is a growing body of literature focused on understanding the difficulties that people with aphasia experience when interacting with different types of technology and considering how this technology might be designed for improved access.

Prior work has shown how some technologies, and their intrinsically language-focused nature, cause difficulties for people with aphasia [7, 19, 42]. Research in the clinical literature has, for example, highlighted that people with aphasia experience difficulties interacting with mobile phones [7, 19] and the internet in general [43]. HCI researchers have investigated the specific difficulties experienced by people with aphasia when engaging with commonplace technologies, such as social media [20] and videoconferencing platforms [48]. This research has not only highlighted specific challenges related to the language-based aspects of these platforms, but has also prompted critical reflection on the (inherently language-focused) methods used to conduct user studies with people with aphasia [60]. The study reported here follows much of the good practice advocated by this research, such as using a qualified speech and language therapist as a user study facilitator.

Given the extent of the difficulties that people with aphasia experience with technology, prior work has also examined how technologies can be designed to take those difficulties into account. These technologies have often focused on rehabilitation. For example Palmer et al. [53] examined the effectiveness of computer-based speech and language therapy, Marshall et al. [41] evaluated the usefulness of virtual reality to support group-based communication and Roper et al. [61] explored how technology might support the rehabilitation of gesture.

However, there is also an increasing body of HCI research which has not focused on supporting rehabilitation, but instead on designing useful technologies for people with aphasia – often by involving them in the design process through participatory design approaches. Much of this work has focused on providing communication support – a type of design intervention termed as Alternative and Augmentative communication (AAC). Waller et al. [77] for example, designed and evaluated an AAC intervention to support people with aphasia in recognising familiar words to support conversation. AAC interventions have often focused on supporting image-based communication (c.f. [35]), such as through picture-based communication boards. More recently, research has considered how embodied form-factors might enable better communication, providing a stronger focus on the non-verbal [11, 12].

Other HCI research has also considered how additional computer-based activities might be made more accessible to people with aphasia. Examples include: cooking – through the use of visual recipe books [70], e-mail [1] – through the use of a client incorporating pictograms and a mini-dictionary created by speech and language therapists, and social media [46] – through the use of a predominantly visual platform. Participatory research with people with aphasia has also given rise to tools to support engagement in creative activities such as poetry writing [49] and digital content sequencing [50].

Although some research has emphasized the importance of making digital technologies more accessible for people with aphasia [42], users with aphasia are still significantly under-represented in the accessibility literature. This is the case in both the general accessibility literature (see Mack et al. [37]'s review of accessibility literature at ASSETS and CHI) and also in technologies specifically aimed at supporting users with communication (see Curtis et al. [13]'s review of AAC technologies). There is clear evidence of the potential quality of life benefits of access to technology (e.g. access to videoconferencing-based therapy [57]) and communication support technologies (e.g. AAC [24]). It is therefore vital we improve access to technologies that are important to the lives of users with complex language needs. Search technologies are a key component of everyday life. Our study provides insight into how access to search technologies can be improved for people with aphasia.

2.3 Aphasia and Information Search

Prior research has found that people with aphasia make relatively little use of everyday internet technologies, including search engines, due to the language demands they pose [62]. This finding reflects a pressing need to understand the difficulties that underlie this non-use. Although there has been very little research into the impact of aphasia on information search [4, 67], the few existing studies that have examined this impact provide an important foundation that our study builds on, and are discussed here.

A case study of the general internet use of a retired academic with severe aphasia [43] found that, despite finding search extremely challenging, he was strongly motivated to find information on topics of personal interest, such as sports. Although this study did not focus specifically on identifying aphasia-related search difficulties or report the search difficulties it did identify in detail, it found that his search skills were strongly influenced by his language impairment; he found *formulating queries* and *assessing result*s difficult and often became *disoriented* in his search when he clicked on links in error – a known difficulty associated with assessing lists of search results [71]. This study demonstrates that search can be impacted by aphasia and indicates that people with aphasia may experience difficulties throughout the information search process – not just in formulating queries. Motivated by this finding, our study investigates difficulties throughout the search process, and identifies previously unreported difficulties related to assessing results.

Building on the insights from the above case study, a survey-based study of general internet use among people with aphasia [44] found low reported usage. Common perceived barriers to internet use for communication purposes included low self-efficacy, health/physical issues and a lack of support from others – i.e. 'no one to help me.' When they did use the internet to find information, this was often to support their everyday life needs, such as comparing products or finding health or travel information. The authors concluded that people with aphasia are at particular risk of digital exclusion, due to difficulties in using Internet-based communication technologies. Indeed, multiple studies have found people with aphasia have low self-efficacy surrounding their ability to search for information [29, 31, 43, 44] and have identified the associated risk of digital exclusion if they decide not to attempt searching [29, 31]. Our study aims to reduce the risk of digital exclusion among people with aphasia by improving access to search technologies.

A series of studies by Kvikne and Berget, both interview [29, 31] and observation-based [30, 31] provide the most insight so far on the impact of aphasia on information search. These studies focused on understanding the general search behavior of people with aphasia [29, 31] and the impact of aphasia on finding information as a type of life transition [30]. Although these studies did not specifically aim to identify search difficulties and strategies for overcoming them, they identified some nonetheless – mostly around the core search activity of *formulating queries*.

During query formulation, searchers with aphasia struggled in particular with *word finding*: retrieving sought words from memory to use as query terms [29–31]. To address this difficulty they used a variety of strategies including using *query support tools* such as autocomplete and autocorrect [29–31], *searching for synonyms* to words they struggled finding [29–31] and *conducting image searches* to find possible query terms [29–31]. Another key difficulty during query formulation was *spelling* query terms. Autocomplete and autocorrect were found to help with spelling [29–31], although not always for the types of spelling error people with aphasia commonly make (e.g. omission of letters in a word) [30]. Using text-to-speech to support spelling was also reported [29, 31]. To circumvent difficulties in formulating queries, some searchers with aphasia browsed rather than searched, to avoid having to formulate queries in the first place [30, 31].

In summary, previous research has started to paint a picture of some of the difficulties people with aphasia experience when searching for information and the strategies aimed at overcoming them. However, as prior studies have identified these difficulties and strategies as a by-product rather than specific focus of their research, this picture is currently patchy. In particular, we lack a detailed understanding of difficulties and strategies post-query formulation – when assessing search results and interpreting web pages and documents. Our study provides this detail.

3 Study Method

This study involved an observation of the interactive search behavior of people with aphasia, comprising one *prescribed* and one *self-directed* (participant-chosen) task. Our method followed good practice guidance for conducting user studies with impairments [3]. For instance, all materials presented to participants (e.g. the information sheet and consent form) were designed to be communicatively accessible and therefore aphasia-friendly [55, 63]. Each was presented both verbally and in written form. We also took care not to overburden participants, by having a separate preparation session aimed at making sure the participants understood what they had to do and by giving them lots of time to perform each task (discussed further later). The study received approval from our university's Research Ethics Committee.

3.1 Participants

We recruited a purposive sample of 12 participants by e-mail. All were over the age of 18, with a clinical diagnosis of mild or moderate aphasia due to a stroke and fluent English use before the stroke. We excluded users with visual impairments and with severe aphasia to the extent where they might not fully understand the study or be able to provide informed consent. All participants had taken part in a previous speech and language study on aphasia and had given permission to be invited to participate in future aphasia research. However, none, to our knowledge, had previously participated in technology-related aphasia research. Their average age was 46.8 (min=28, max=63). Six identified as male, six female. The time since having their stroke was 10 years on average (min=1, max=34). During the observation, they used various device types to search: tablet (4 participants), laptop (5), desktop (1) and smartphone (2) and all chose to use Google as their search tool. This aligns with the general population; 94% of the UK population uses Google [69]. All self-reported to search online 'several times a day', apart from P8 ('once a day') and P11 ('once a month'). The researcher e-mailed information about the study, including a participant information sheet, to those who expressed interest. If people were interested in participating, a consent meeting was arranged. During this meeting, information about the project was re-iterated by the researcher reading out key points from the informed consent form. Participants each received a £30 Amazon voucher for their time and expertise.

3.2 Study Process

Following the consent meeting, the study involved two sessions: 1) a *preparation session* and 2) an *information search session*. Both lasted around an hour and took place separately. The sessions were conducted remotely using Zoom, with participants sharing their screen from the personal device they were most comfortable with (desktop, laptop, tablet or smartphone). Their screen, audio and face were recorded. Use of familiar devices, in participants' homes, facilitated a naturalistic (i.e. as natural as possible) observation approach.

3.2.1 Preparation Session. In the preparation session, consent was confirmed verbally to ensure that participants fully understood the study and their role. We also conducted a short interview to gather demographic information as well as participants' self-reported search frequency.

3.2.2 Information Search Session. Participants were asked to undertake two search tasks; one prescribed and one self-directed.

(1) The **prescribed task** involved participants searching for information about heroes and heroic acts; specifically we asked them to "*find stories about people who have done something heroic, and what they did*." This is a standard task from the TREC (Text REtrieval Conference) topic set[1], but was tailored to ensure appropriateness for users with aphasia (by using more accessible language). This task was broad enough to elicit a wide range of search behavior (and therefore potential difficulties and strategies for addressing the difficulties) but specific enough to provide participants with a concrete goal. They were asked to find as much information as they could in 20 minutes, but told they should not rush and it did not matter how much and what information they found during that time. We provided some examples of heroes – 'Nelson Mandela' and 'Florence Nightingale' to aid task comprehension.
(2) The **self-directed task** involved participants searching for information on a topic of their choice. They were told it should be a real topic they wanted to find information on and that they should not have looked for information on the topic before. This was to prevent any previous information search behavior from influencing their observed behavior. They were given 25 minutes for this task, but were told it did not matter if they completed it during that time.
(3) A **post-study questionnaire** was used to elicit participants' perceptions of their overall search success, including questions on: how happy they were with the information they found; how difficult it was to find the information overall; and how difficult it was to undertake specific aspects of the information search process – 'decide what to type,' 'change the search,' 'decide which results to choose' and 'decide if the

[1]TREC: https://trec.nist.gov/data.html

ID	Age	Sex	Time since stroke	Study device	Study search engine	Search frequency
P1	39	Male	9 years	Desktop	Google	5/5
P2	30	Female	11 years	Smartphone	Google	5/5
P3	28	Female	11 years	Tablet	Google	5/5
P4	42	Male	11 years	Laptop	Google	5/5
P5	41	Male	7 years	Laptop	Google	5/5
P6	63	Male	1 year	Laptop	Google	5/5
P7	55	Female	34 years	Tablet	Google	5/5
P8	54	Female	20 years	Tablet	Google	4/5
P9	56	Female	5 years	Smartphone	Google	5/5
P10	54	Female	3 years	Tablet	Google	3/5
P11	61	Male	11 years	Laptop	Google	1/5
P12	74	Male	1 year	Laptop	Google	5/5

Table 1: Participant demographics showing ID, sex, time since stroke and device/search engine used in study. ’Search frequency’ is participants’ self-reported search frequency on a 1-5 Likert scale, where 1="less than once a month", 2="once a month", 3="once a week", 4 ="once a day" and 5="several times a day."

search results were useful.’ These questions were presented with a Likert scale for responses (1="Very," 5="Not at all").

The information search sessions were specifically tailored to the needs of people with aphasia. For example, we presented specific tasks rather than open-ended scenarios, introduced the tasks verbally (as well as in writing), one-at-a-time, and ensured sessions were not rushed to give participants enough time to retrieve words, using alternative communication approaches such as gesture if they wished to.

Traditional approaches to observing information search often involve participants thinking aloud – verbalizing their thoughts and actions to provide insight into their search rationale [38]. However, this requires the use of the very language skills that aphasia can impair and can result in cognitive overload, even among people without language difficulties [56]. Therefore to ensure we did not place additional speech and language burden, thinking aloud was not mandatory. Instead, we followed aphasia-specific guidance to ask probing questions during natural pauses in the tasks [60]. We did this only when the facilitator considered it unlikely that asking questions would cause participants difficulty or distress. We adopted this key variation from a traditional think-aloud approach to emphasise empathy for our participants’ language difficulties above all else. However, it was also the case that all participants spontaneously verbalized some of their thoughts and feelings without prompting. Ensuring the tasks were not rushed may have facilitated this verbalization [67].

The sessions were facilitated by a qualified speech and language therapist (first author, referred to here as the "facilitator"), who provided technical support and facilitated communication where required. For example, she did this by verbally prompting participants, inviting them to use other communication strategies (e.g. gesture) when verbal expression became difficult and aiding spelling where participants had exhausted all other options (e.g. autocomplete or autocorrect). Crucially, the facilitator did *not actively support participants in their search tasks.* For example, they did not suggest search queries or make participants aware of search engine functionality. This was to ensure that participants followed their own search strategies while receiving support to aid language expression when, in the facilitator’s professional judgement, this was becoming difficult or frustrating. If it became clear that a participant was struggling to complete a task, they were reminded that they could stop at any time. The first four sessions were also observed by HCI researchers with experience in information search and accessibility to ensure research quality, without them playing a role in the facilitation.

3.3 Data Analysis

A qualitative approach was used to analyze the observational data. The qualitative data addressed both RQ1 (which focused on identifying and understanding the difficulties people with aphasia experienced when searching online) and RQ2 (which focused on identifying strategies for combating the difficulties identified and their effectiveness). RQ3 is addressed through reflection on the design implications of the observation data. Data analysis involved three phases: 1) *transcribing* the screen recordings of each observation, 2) conducting an *inductive qualitative Thematic Analysis* [76] of the transcripts and 3) conducting a *descriptive quantitative analysis* of the post-study questionnaire.

3.3.1 Transcription Approach. Transcription was completed manually by the study facilitator due to the need to decode complex speech patterns. This required the expertise of a professional speech therapist and was therefore not suitable for automated transcription. A transcript was created for each information search session, incorporating verbatim comments, interpretations of non-verbal communication and time-stamped screenshots of key interactions. Each interaction was described in square brackets on the transcripts (e.g., [P5 clicks on search result link entitled ‘*7 real life heroes’*]). This helped to create ‘interaction narratives’ of each observation, which detailed what participants said and did (their thoughts and actions) while searching.

3.3.2 Thematic Analysis Approach. To identify participants’ aphasia-related search difficulties and strategies, we followed an inductive Thematic Analysis approach [76] to code the transcripts, supported by NVivo. Five of the authors conducted a first-pass inductive coding of the transcripts from two participants (P1 and P5) and discussed the nature of the difficulties and strategies we identified. This was to ensure we gained as rich an insight as possible. This first-pass coding informed a detailed coding conducted by one of the authors.

Detailed coding involved identifying 1) key stages in the information search process; *understanding information needs*, *formulating queries*, *assessing results* and *interpreting* web pages and documents, 2) the *aphasia-related search difficulties* experienced at each stage, along with *how* and *why* they manifested and 3) what *strategies* participants used to try to overcome them and their effectiveness. For example we noted that, when formulating queries, a common aphasia-related search difficulty was *word finding* and strategies aimed at overcoming this difficulty included using *generic* or *semantically-related word*s and using *autocomplete*. These difficulties and strategies should not technically be regarded as themes, but capture causality in a similar way by providing an explanatory account of participants' interactions.

4 Findings

We begin by briefly reporting findings from the post-study questionnaire, to provide an indication of participants' perceptions of the success and difficulty of their searches. We then report the findings from the Thematic Analysis, focusing on providing a detailed account of the aphasia-related search difficulties participants experienced and the strategies they used to try to overcome them. See Appendix 1 for a list of the queries submitted for the prescribed search task on 'heroes and heroic acts' (Task 1) and Appendix 2 for those submitted for the self-directed task (Task 2). Participant-chosen topics for Task 2 included: family cars (P1); Natasha Preston and trainer size (P2); pet supplies (P3); parallel/concurrent computing (P4); music (P5); Eurovision (P6); sport (P7); knitting (P8); gardening (P9); travel (P10), British army regiments (P11) and British motorcycles (P12).

4.1 Perceived Search Success and Search Difficulty

The post-study questionnaire results (Figure 1) showed that participants were generally happy with the information they found for both tasks (Q1, median=4), but they also reported they found it difficult to find information during both tasks (Q2, median=4). This may reflect a sense of achievement experienced from persevering through a difficult search process to find information that was generally relevant to their task. Narrowing in on the specific stages of the search process, *deciding on what to type* (Q3, median=3) was regarded as somewhat difficult, but less so than the other stages, especially *changing the search* (Q4, median=4) and *choosing results* (Q5, median=4). Participants considered *deciding if search results were useful* to be particularly difficult (Q6, median=5).

4.2 Search Difficulties and Strategies Aimed at Combating Them

The Thematic Analysis identified a wide range of *difficulties* and *strategies aimed at overcoming them* across all stages of information search, which are presented in the following subsections:

(1) *Understanding information needs* – Difficulties with conceptualizing what information they were looking for.
(2) *Formulating queries* – Difficulties with word finding, query formulation, and spelling.
(3) *Assessing search results* – Difficulties interpreting search results and keeping track of their place in the search.
(4) *Interpreting web pages and documents* – Difficulties reading and interpreting the text of the web pages and documents found during the search.

Although we frame our findings as per these stages, search is not a linear process; searchers often move back and forth between stages [40]. Therefore although an oversimplification of a complex process, these stages provide a practical framework for segmenting the search difficulties people with aphasia experienced and the strategies used to try to overcome them. It is notable that our participants experienced difficulties across all of these stages, not just when formulating queries (a stage that requires particularly strong language skills when representing the information need in written form).

4.3 Understanding Information Needs

As Task 1 was a prescribed task, it required participants to conceptualize details about what they were looking for. For several participants, a receptive language impairment made it difficult to conceptualize what the search topic 'heroes and heroic acts' meant. For example P1 asked "*is something about good people or not good people?*". For many participants, an expressive language impairment led to difficulty expressing their information needs; P10 stated "*I am going to look at emm? Ohh I can't say these words; In in (=incredible) acts of of ok ok I am going to look what is so who is the bravest history in in who are the gravest [sic] people in history.*" In the self-directed task (Task 2), participants had already planned what they would be searching for, which might explain why difficulties conceptualizing their information needs were not observed in this task.

Strategies aimed at overcoming difficulties conceptualizing information needs included 1) *repeating words or phrases from the task brief* and 2) *paraphrasing*. Three participants (P2, P6, P10) *repeated keywords and phrases*, such as from the 'heroes and heroic acts' written task brief. For example, to help her make sense of the task, P10 repeated to the researcher 'heroes and their acts?'. Three participants (P1, P2, P6) also *paraphrased the task* by using words more familiar to them than those in the brief. For example, P6 said "*yes, I can find, which people are looking for, yes, people who save the world for example.*"

Difficulties in conceptualizing information needs negatively impacted on the quality of queries produced and, in two cases, on the entire search. For example, P2 began the prescribed task by copying words from the task instructions. After asking the researcher "*what's it called.. heroes?*" and the researcher confirming the task was to search for information about 'heroic acts,' P2 typed 'hero acts' into the Google search box and said "*Wikipedia? Heroes, acts, I Googled*". She was surprised when the results contained a thumbnail linking to Marvel Studio's charitable initiative 'Hero Acts' (see Figure 2): "*oh what? Right? mmm...mmm... Marvels?*" P2 then looked through the thumbnails and continued to scroll down the results page, selecting a result that pointed to another non-relevant use of

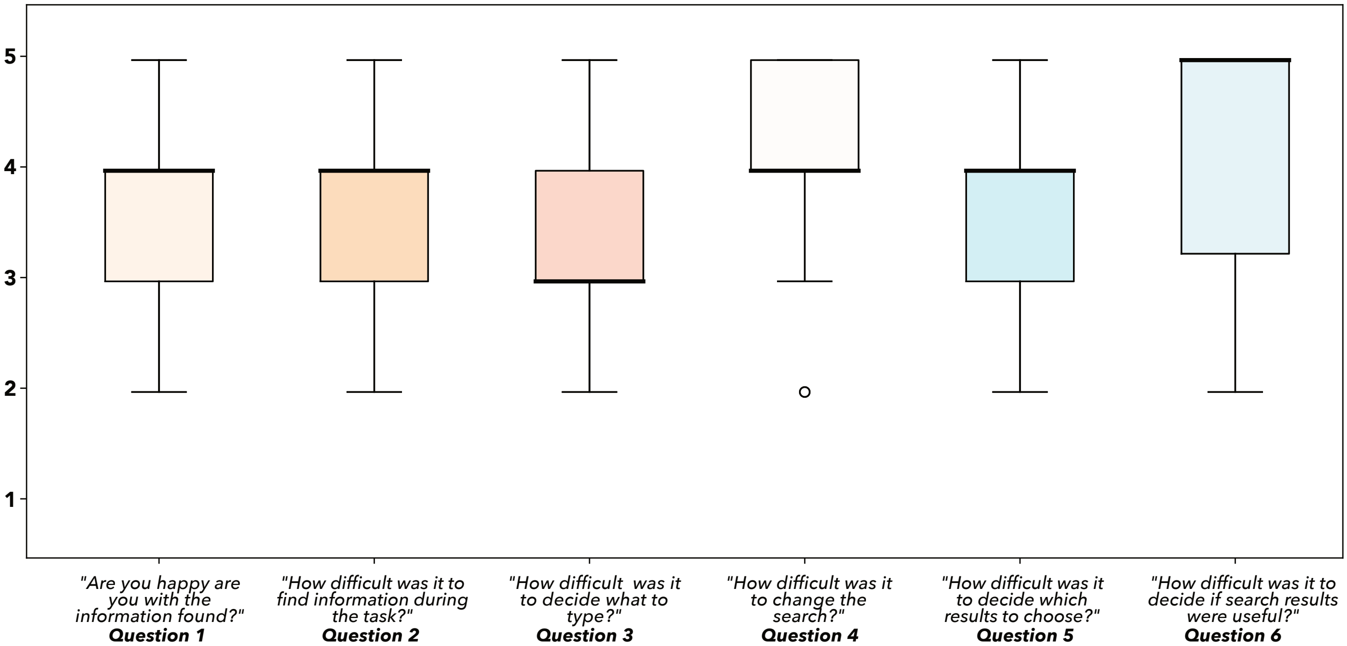

Figure 1: Post-Study Likert. Participants rated their agreement with given statements when reflecting on their search – 1 being ‘Not at all’, 5 being ‘Very’. The thick bar indicates the median value.

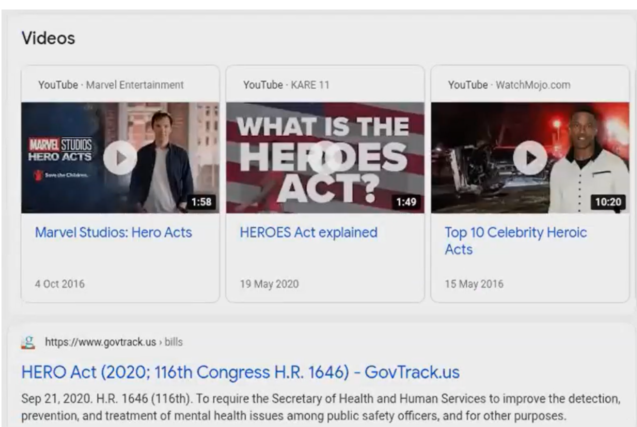

Figure 2: Non-relevant search results for the query ‘hero act’ – Marvel’s ‘Hero Acts’ charitable initiative, and the U.S. HEROES Act (2020)

the word ‘heroes’; the 2020 U.S. Congress HEROES Act; legislation aimed at stimulating COVID recovery in the U.S. P2’s difficulty conceptualizing the information task resulted in her finding non-relevant information and stated, after viewing the HEROES Act, “*I do not think it’s, it’s...mmm... (...) I do not think it’s coming up with much*".

These difficulties in conceptualizing information needs and the identified strategies aimed at combatting them (*repeating words and phrases from the task brief* and *paraphrasing the task*) have not been previously reported in the aphasia and search literature. This may be because Task 1 was a prescribed search task, which required participants to understand what they were required to search for on-the-fly. It was likely easier for them to conceptualize their information needs for the self-directed task because it was self-chosen and therefore grounded in their existing knowledge and interests.

4.4 Formulating Search Queries

Once participants had understood their information need, they needed to express that need in the form of search queries. Almost all participants who experienced difficulties conceptualizing their information need also experienced challenges with formulating successful queries. This was due to difficulties with *word finding*, *formulating the query itself* and *spelling query terms.*

4.4.1 Word Finding. When formulating search queries, five participants experienced difficulties with *word finding* – recalling a word and incorporating it into their query. This is known as *anomia* and has been noted as a key language difficulty for people with aphasia when retrieving words from memory [9, 22].

While attempting to formulate an initial query to find heroes in the prescribed task, P1 said “*some names of people...is hard from nothing here*". Similarly, in the self-directed task, P12 was trying to look for information about a specific motorbike brand he used to own. He intended to use the name of the bike as a query term, but had word-finding difficulties. He explained, “*it’s irritating. I cannot think of a particular motorbike that I had eee...can’t? with names so I can’t name search for it*". Some of the strategies participants used to circumvent word finding difficulties included: a) using *domain* *knowledge* to think of semantically-related words, b) using *generic words*, c) using *autocomplete*.

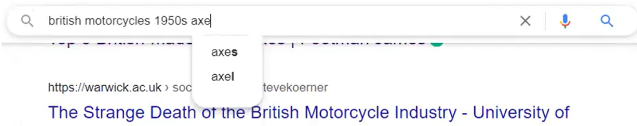

Figure 3: P12 added the term 'axel' to his query as he remembered the motorbike he was looking for ran with an axle rather than a chain

Participants *used domain knowledge to think of semantically-related words.* Unable to recall the name of the motorbike brand he previously owned, P12 searched for 'British motorbikes', adding '1950' from the autocomplete list. While scrolling through the search result pages, he voiced his hope of the results triggering his memory; "*ah is one particular bike I'd like to see (...) ooh what is the other one I thought; ahhh, yes (...) was aaa; what's it called*". He clicked through to one of the websites and saw an image of a similar motorbike, commenting "*but has a different name*". Struggling with word finding, he decided to modify his query, "*I would try British Motorcycle ride… was not (...) it wasss (...) axle? axle? driven*". He explained to the researcher that this particular motorbike, unlike others, did not run with a chain, but with an axle "*so I put in 'axle British motorcycle' and they came up with this one it is there... it was great fun to ride*" (Figure 3). By using his existing domain knowledge about the motorbike he previously owned, P12 modified the search query and eventually located the information he needed.

Despite using their pre-existing domain knowledge, participants could not always retrieve adequate information to formulate successful search queries, and this sometimes led to them abandoning the search altogether. For example, P3 wanted to search for information about a specific dog hero. She added 'dog' to the terms 'top heroic heroes' already in the Google search box, and commented, "*like two weeks ago emmm do not remember, which hospital in the hospital in the UK there is a aaa like a medal? for mental health training*". She could not recall more details about the specific assistance dog she had heard about to formulate an effective query and decided to end the search.

Another strategy for tackling word finding difficulties when formulating queries was *using generic words* in place of the target words participants were unable to recall from memory. To start searching for 'heroes and heroic acts,' P1 entered a generic word – 'person,' then noticed the phrase 'famous people' in the search results. This to led him refining his query to 'person helping famous.' In the self-directed task, when searching for family cars, he typed 'car' into the search box. In both tasks, this staged search strategy helped P1 construct more specific queries using words encountered on search result pages and in autocomplete suggestions (Figure 4). Most participants (P1, P3, P4, P5, P8, P9, P12) *used autocomplete* to address word finding difficulties. For example, when searching for the motorcycle brand he previously owned, P12 searched for 'British motorcycles.' He said, "*b*" and typed '*britishe motorbikes*' into the search box (Figure 5). While moving the cursor down the list of autocompleted search query suggestions, he said "*oh!*" and clicked

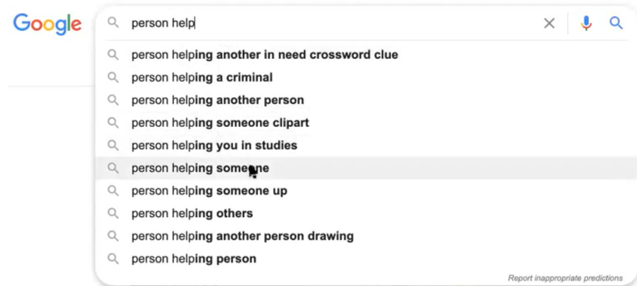

Figure 4: P1 used autocomplete to create a more specific search query from the initial seed term 'person'

on 'British motorcycles 1950s.' P12 wanted to find a motorcycle from this specific era, so the autocomplete suggestions were useful in adding this additional dimension to his initial query.

Autocomplete typically adds more detail to a search query and, in this case, this detail happened to be what the participant wanted. However, autocomplete was not always helpful; when searching for family cars, P1 tried to make use of autocomplete, hoping that the list of suggestions would bring up the word he needed – 'MPV'. After opening a new tab, he said, "*so I start again new word (...) Google*". He then typed 'car' in the address bar. Referring to his word finding difficulties, P1 said, "*that's difficult sorry, a car or*"; pressed space and pasted 'SUV.' He typed 'or', while saying, "*is it p? is it p?*" then typed 'p' whilst commenting "*there is another word to make bigger car*". P1 then deleted 'or p' and added 'vs.' By including 'or' and 'vs.' in query terms, P1 wanted to use autocomplete to help him find the target word 'MPV'. He anticipated the search engine might recognise his search intent and suggest various car types (including MPVs) for comparison. However, this rather advanced strategy was not successful (Figure 6). There were also instances where use of autocomplete resulted in participants selecting an unsuitable search query.

In summary, word finding difficulties were a search obstacle for the majority of participants. Participants used several strategies to address this. These included using *domain knowledge* to come up with words semantically related to those they could not find, using *generic words* as a starting point for search then refining the search and using *autocomplete*. While these strategies often aided progress in search, they were not always successful and, in those instances, sometimes resulted in participants experiencing further search difficulties or abandoning the searches.

4.4.2 *Formulating the Query Itself.*

Even when participants could find the words to use in a query, they often had difficulties *formulating the query itself* using those words. To overcome these difficulties, participants used a) *external words*, b) *autocomplete* and c) *facets/categories* to help narrow down searches.

All participants experienced difficulties with query formulation. Some, notably P4 and P10, *used external words*, such as those from the task brief in the prescribed task as a strategy aimed at making query formulation easier. For example, when being introduced to the prescribed task, P10 repeated "*heroes and their acts?*" from the task instructions and used these exact words as her query, typing them into the search box with difficulty: P10 types 'he' deletes 'e'

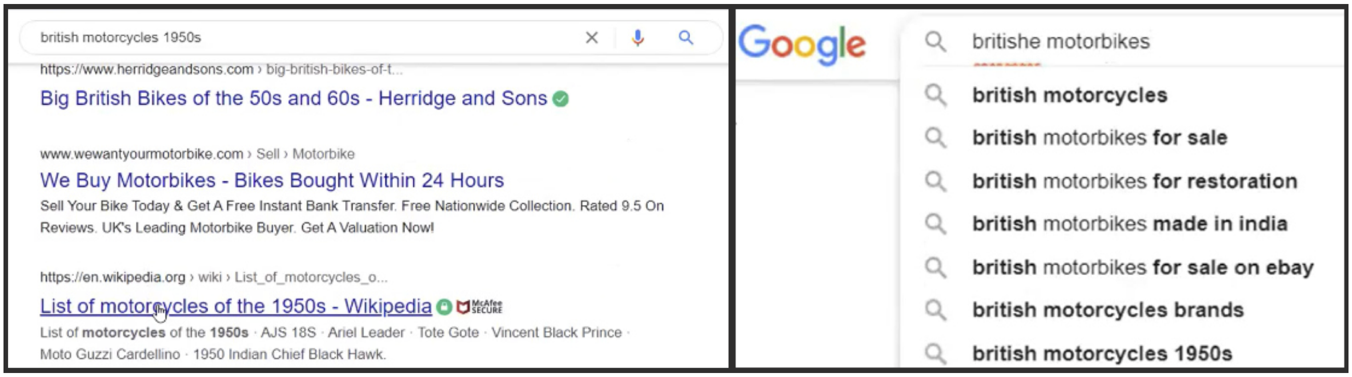

Figure 5: P12 used autocomplete to refine his search for British motorbikes to the 1950s era.

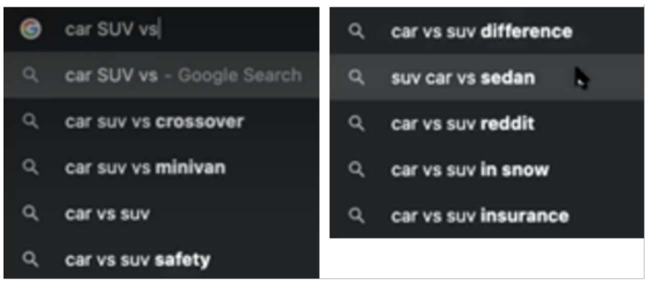

Figure 6: These autocomplete suggestions were not useful for P1, as none included 'MPV'

types 'ers' deletes 's' types 'o,' then says "*hero, ic?*" types 'ic and their acts.' P3 and P7 searched for the example hero from the task brief – Nelson Mandela, yet still experienced difficulties.

Most participants *used Google's autocomplete* feature to support formulating queries. For example, in the prescribed task, P9 typed 'heroic' in the search box and selected 'heroic movie' from the autocomplete list. When this search did not bring back useful results, she selected 'heroic age' from the suggestions, then refined her query to 'heroic age history.'

On Amazon, one participant (P3) *used categories and facets* to find grooming products for her dog so as not to spend time on the difficult task of formulating queries. With an empty search box, she selected 'Pet Supplies' from the list of Amazon department categories. She then narrowed down her search by selecting 'Dog Supplies' and 'Grooming' (Figure 7). While using categories and facets is usually associated with browsing rather than searching, P3 relied on category labels for recognition and used them to support a browse-based alternative to search without the need to formulate textual queries – which all our participants found difficult. When people browse rather than search for information, this removes the need to remember words to use as query terms [67].

4.4.3 Difficulties Spelling Query Terms. Almost all participants experienced *difficulties spelling query terms*. Typically, search engines require users' verbal input and an ability to spell words correctly, or almost correctly. People with aphasia often have difficulties with word production, including spelling [16]. Some participants noticed spelling mistakes and corrected them, while others encountered difficulties with the spelling of most words and were assisted by the facilitator. For example, P1 said that he would not be able to carry out some of the searches that he did in the session without help. When asked what he would do if the researcher was not be there to help him spell the word 'carrier', he said, "*I can't*". Strategies for tackling spelling difficulties included: a) *self-cueing*, b) *using autocomplete*, c) *using external words*, and d) *using speech-to-text*.

Three participants (P1, P2 and P10) *'self-cued'* by sounding words out loud before typing them. For example, in the self-directed task, P10 was searching for holiday destinations and wanted to use the word 'vacation' in her search, which she found difficult both to pronounce and spell. She first tried to say the word out loud, "*cation, va ca va ca vavaca vacation, hold on*", and then she started typing, 'va'. P10 typed 'v' => space => deleted space and => typed 'action' (='vaction'). She then commented, "*Because I struggle to get words I have to use I use it to help me to vac va c..*" and then in the current

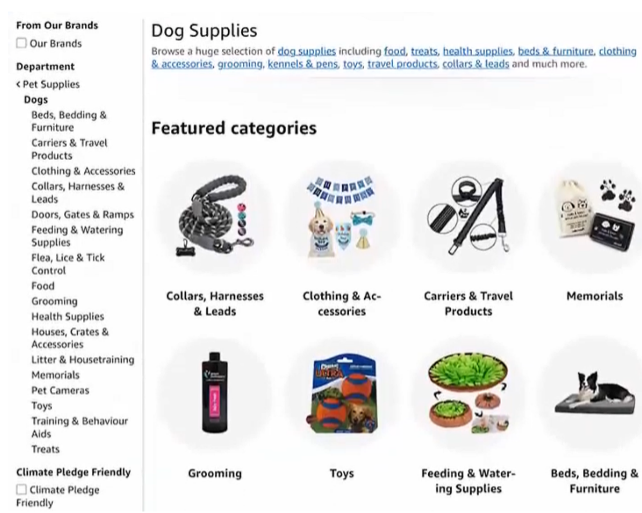

Figure 7: P3 found grooming products on Amazon by browsing through 'Pet Supplies' 'Dog Supplies' 'Grooming' product categories.

search P10 typed ‘ vaction.’ => put cursor before full stop and deleted ‘tion’ and typed ‘ation’.

As well as *using autocomplete to aid word finding*, P4, P8 and P12 also used it to aid spelling. For example, P8 typed ‘capet tom’. The autocomplete showed, ‘Captain Tom’ and she said “*Yes, there we go*". Two participants (P1, P4) used *external words* as a workaround for challenges with spelling and to minimize typing. For example, P4 constructed his search by copying and pasting words from search results and from autocomplete suggestions. In his self-directed task that aimed to understand the difference between concurrent and parallel computing, P4 typed ‘concurrency is not parallelism’, and copied ‘parallelism’ to the clipboard. He then opened a new tab and pasted ‘parallelism’ to search for the term. In the original tab, he added ‘examples’ to ‘concurrency’ and carried out another search.

Three participants (P1, P4, P7) made *extensive use of the speech-to-text feature* in the Google search bar. However, this strategy was not always effective; it would often misinterpret words. For example, P7 said "*Horatio Nelson*" but the speech-to-text feature picked up “*Where is your Nelson?*" requiring her to recognize and recover from the error.

In summary, novel (previously unreported) strategies we identified that aimed to overcome difficulties in formulating queries included using *self-cuing* to tackle difficulties in word finding, using *external words* (e.g. from the task brief) to combat difficulties in formulating the query itself and spelling query terms and using *categories and facets* to narrow down searches instead of reformulating queries. We also identified difficulties and strategies related to formulating queries that validate findings from prior research. These include difficulties in word finding, formulating queries and spelling query terms and strategies aimed at overcoming them, such as searching for semantically-related words, searching by image, using autocomplete, autocorrect and text-to-speech and browsing rather than searching [29–31].

4.5 Assessing Search Results

After participants had understood their information need and formulated their searches, they assessed the results – deciding which were likely to be useful and therefore whether to click on them. When assessing results, participants demonstrated difficulties *interpreting search results* and *keeping track of visited pages*.

4.5.1 Interpreting Search Results. Participants *experienced difficulties interpreting search results*, often due to the inconsistent and complex nature of the result presentation. Two participants (P2, P7) used Google’s ‘instant answers’ feature – which provides extracted or AI-synthesised content from web pages in the search results – to avoid having to assess multiple search results. Sometimes this made search result assessment easier. For example, instant answers helped P7 “*confirm*" what she already knew about people whom she considered as heroes, such as Mary Seacole. Other times, using instant answers introduced new difficulties. For example, when looking for “*ancient heroes*" for the prescribed task, P7 engaged with an instant answer listing names of “*Top 10 Heroes of Greek Mythology*" from ‘teachervision.com’. P7 tried to click on “*Jason*", but the instant answer did not preserve the hyperlinks from the source web page. Although P7 was able to identify a hero that she wanted to know more about in the instant answer, the feature did not offer an easy way for P7 to access the information she needed.

A common strategy for addressing difficulties with interpreting search results on search pages was *reading summaries of text* – e.g. titles, snippets or lists. For example, in the self-directed task, P1 searched for “*new big family car*" and read many of the web page titles in the search results aloud. Another strategy was to engage less extensively with the search result text and, instead, *use non-text media* such as images and video to aid their understanding of the search results. Unprompted, P6 expressed his preference for non-text media: “*you can find also eee there how I, which I, because this information I can forget, but for me is better for example if you find something on YouTube*". He explained that images helped him with word retrieval, “*yes, for example, yes, because I remember the picture of it.*"

Several participants skipped much of the text in Google’s search result snippets and instead *made use of images* to help assess search result relevance – often by examining the web pages and documents in the results. P9, who particularly struggled with reading and interpreting text, conducted a Google image search rather than a conventional Google search to avoid having to assess heavily text-based search results. When asked why, she said “*pictures*". After the researcher’s probe “*only pictures?*", P9 said, “*Yeah...the internet is hard. Is words.*" When asked if she ever tried to find text-based information on the internet, she said, “*no. The pictures"*. Despite making extensive use of image-based results, P9 struggled to find information on heroic acts.

When probed about the usefulness of images, P6 explained “*why is helping me (...) because I have got one problem, my working short memory is cut, but there sometimes I’ve got fantastic picture memory. If for example, if you show me something you talk and the same time you showing me this one [shows a pen to the camera], I’ll remember because picture is talking to me, but word is disappeared*". This explanation highlights that images enabled P6 to access the semantic information required for oral naming, which is necessary to facilitate reading and therefore search result assessment.

4.5.2 Keeping Track of Visited Pages. Whilst assessing search results, some participants had *difficulty keeping track of visited pages*. For example, to his surprise, P12 unintentionally re-opened the same web page multiple times when searching for heroic people. On the first occasion, P12 commented, “*seven great social justice heroes; yeah, see what is got*" and clicked on the link, unaware that the purple underline meant he had already visited that page. On opening, he immediately remembered he had already seen it.

Three participants (P1, P4 and P12) *used the affordances of tabs* to support their working memory and language difficulties when assessing search results. For example, P1 had difficulty in keeping track of which pages in the search results he had visited and which he had not. To combat this difficulty, he right-clicked on search results of interest and opened them in new browser tabs. By doing so, he kept the search result page open so he could easily get back to it. He demonstrated this when he viewed a Wikipedia page on heroes and said, “*it’s probably not right*". He then closed the tab and went back to the search results page to continue assessing the results. However, this strategy was not without its drawbacks;

when he accidentally closed a tab containing a page he still wanted to read, he stated “*oops I lost one*".

Although a previously reported observation of a retired academic with aphasia becoming disorientated hinted at difficulties in *assessing search results* [43], our findings add to this and unpack some of the difficulties experienced and strategies used to try to overcome those difficulties when assessing results. As well as difficulties in *interpreting search results*, our participants also experienced difficulties in *keeping track of visited pages* - a difficulty not previously reported. Newly-identified strategies for tackling these difficulties included using *instant answers*, *reading textual summaries* and *using images* to support result assessment, and making use of the *affordances of tabs* to keep track of web pages and documents visited.

4.6 Interpreting Web Pages and Documents

As well as difficulties assessing search results, participants experienced difficulties interpreting the web pages and documents linked from the results. These included *difficulties reading at word level* and *difficulties with broader comprehension* of text. Some participants demonstrated difficulties when reading, which prevented them from comprehending individual words. For example, when searching for information about heroic people, P12 misread “*adventuring*” for “*advertising*” and asked himself “*adventuring – what’s that?*" Strategies for combating these reading difficulties included a) *skipping text* and b) *using text-to-speech*.

4.6.1 Difficulties Reading at Word Level. Seven participants (P1, P3, P4, P5, P8, P9 and P12) *skipped larger chunks of text* in web pages and documents, by scrolling over them. Instead, they only read single words, headings, titles or short textual snippets (such as synopses). During the self-directed task, P1 opened a page and read out the title, “*ohh best best large family car*". While scrolling down the page, he said, “*some words yeahh some words some words*", referring to the text that he skipped. To support reading at word level, participants often read unfamiliar words (e.g. proper names of people or locations) aloud, or sounded them out phonetically. For example, when P5 was reading a web page entitled “*5 unsung heroes who shaped history*", he came across a difficult name (Tenzig Norgay), which he read aloud before returning to silent reading. Three participants (P1, P2 and P4) also used their browser to read words aloud for them. While speech-to-text (as a form of input) was used to aid spelling, *text-to-speech* (as a form of output) was used to aid reading – especially individual words. The formatting of text was also a key factor in dictating how participants approached their word level reading difficulties; P6 opened a web page entitled ‘*7 real-life heroes’* and appeared to pay attention only to text formatted in bold and larger font, whilst ignoring the paragraphs of body text. He commented “*this for example, because I have a lot of information, Donnie Navida, but next one is William Ayotte*", while still scrolling and reading out the headings.

4.6.2 Difficulties with Broader Comprehension. Beyond word level, to aid broader comprehension of text in web pages and documents, four participants (P1, P6, P9 and P12) relied on images (P9 only used image search) and three participants (P1, P2 and P4) used text-to-speech to avoid having to read the text independently. Other

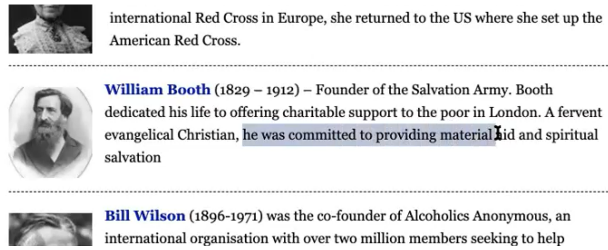

Figure 8: Highlighted text from a web page on famous charity workers that P1 found difficult to understand.

strategies included a) *"anchoring" to familiar words*, b) *reading aloud* (which is not discussed further here, as it was discussed at word level) and c) *reading visually distinctive text*. Participants *‘anchored’ to familiar words* to aid their broader reading comprehension. When P7 found a web page about Mary Seacole during the prescribed task, she did not read the entire text but identified some words that reassured her that she had found the hero she was thinking of. She stated *"yes, she is a nurse*" and “*red cross*". In contrast, P1 anchored to familiar words but still struggled to interpret the meaning of the text he was trying to read. He highlighted parts of a web page (Figure 8) on famous charity workers and commented “*nothing, nothing, nothing, nothing*". He decoded some single words that appeared relevant to his search for heroes, anchored to them and substituted them with other words with a similar meaning. For example, he read out the word “*aid*" and said, “*help, not help*". This approach, however, did not enable him to understand the full meaning of the text.

These search difficulties related to interpreting web pages and documents (*difficulties reading at word level* and *difficulties with broader comprehension*) have not been previously reported in the aphasia and search literature, even though many people with aphasia demonstrate difficulty reading outside of a search context [78]. New strategies for supporting reading and comprehension of web pages and documents revealed by our findings included *“anchoring” to familiar words*, *relying on images* and *reading visually distinctive text.*

4.7 Findings Summary

People with aphasia experienced a wide range of difficulties across all stages of the information search process; at the start of their search, most participants found it difficult to *conceptualize their information needs* (during the prescribed task). When formulating queries, most found difficulty in recalling appropriate words from memory (*word finding*), *spelling* individual words and *formulating the query itself.* When assessing search results, most participants had difficulties *interpreting search results* and *keeping track of visited pages.* Finally, when interpreting web pages and documents, most participants had difficulties *reading at word level* and with *broader textual comprehension.*

Participants combatted the language difficulties they experienced by employing their strengths, which they had likely honed as compensatory strategies in the years since they acquired aphasia. Some participants demonstrated ingenuity in technology use when aiming to overcome their aphasia-related difficulties. For example, some used the text-to-speech feature of their browsers to aid search result and document comprehension. Some also leveraged search engine features (e.g. autocomplete, autocorrect) to support query formulation and refinement. Others used browser functionality (e.g. tabs, the address bar) to help form an overall search strategy. Some participants also used their visual recognition skills (which P6 termed as his *"picture memory"*) to assess the relevance of web pages and documents, reducing the need to interpret large chunks of text.

Overall, while aphasia clearly had a profound impact on participants' search behavior, their desire to find useful information, the strategies they developed to compensate for the difficulties they experienced and the sheer determination they demonstrated in persisting with often difficult searches enabled them to complete their search tasks and feel reasonably happy with the information they found. While this does not detract from the substantial difficulties they experienced, and highlights that the highly linguistic demands of search significantly disadvantage people with aphasia, it also demonstrates that even in the face of difficulty, our participants persevered and, as a result, found information that was at least to some extent useful.

Table 2 summarizes the previously reported and new search difficulties and strategies we identified. It illustrates a *wide range* of not previously reported difficulties and strategies. These *span the information search process*, beyond the core search activity of 'formulating queries' that existing research has mostly focused on. They provide a fuller, more detailed picture of the impact of aphasia on the information search process. Although the range of difficulties and strategies we identified is unlikely to be comprehensive, together they provide a much richer understanding of a variety of challenges people with aphasia experience when searching and their approaches aimed at overcoming those challenges.

Most of the search difficulties we identified have been noted among the broader population of internet searchers [21, 79]. However, these difficulties were particularly prevalent and acute in our study of searchers with aphasia. Although our study did not seek to quantify the extent of the difficulties they experienced (e.g. through comparison with the broader population of all searchers), future research might compare the difficulties experienced (and strategies used to try to overcome them) between searchers with different types of language impairment (e.g. expressive or receptive language disorder) or between those with aphasia and the broader population of searchers.

In summary, these findings represent a wide range of novel, previously unreported difficulties and strategies as well as new insight into how these difficulties manifest and on the effectiveness of the strategies. While almost all previously-reported difficulties and strategies arose during the core search activity of query formulation, we identified difficulties and strategies *throughout* the information search process, including when assessing search results and interpreting web pages and documents. These findings help paint a richer and more holistic picture of the impact of aphasia on information search.

5 Discussion

This study identified a range of search difficulties experienced by people with aphasia spanning the entire information search process – from understanding the information need, to formulating queries and assessing results, to interpreting web pages and documents. Although these difficulties were wide-ranging and impactful, we also observed a range of strategies, some of them creative, aimed at tackling them. Many of these difficulties and strategies have not been previously reported. In particular, while previous research has mostly identified difficulties associated with the core activity of search (formulating queries), we identify difficulties and strategies at *all* stages of information search, including assessing results and interpreting web pages and documents. This provides a more detailed and more holistic understanding of the impact of aphasia on search.

Participants generally reported satisfaction with their search outcomes (Figure 1), despite the substantial search difficulties they experienced. This tension is interesting as it suggests that, in many cases, the utility of the search outweighed the access barriers it imposed. This can be understood as a form of cost-benefit analysis framework for usability [58], where users are willing to tolerate poor (or even 'broken' [8]) interfaces if their need to accomplish a goal is high enough. A striking example is how users navigate poor usability in high-risk medical applications to achieve their goals [51]. It is noteworthy, therefore, that despite experiencing search difficulties, our participants persisted using Google rather than switching search engines and only a few used complementary assistive technologies such as text-to-speech or speech-to-text. This could be because 'Googling' has become a cultural norm [73] and therefore may have been participants' most familiar and trusted information-seeking tool. However, as HCI researchers, we must recognize that it is naive to assume that just because users *can* tolerate the barriers of search interfaces, they should.

Despite innovative strategies aimed at combatting them, the substantial impact of some of the difficulties participants experienced cannot be understated. This highlights a pressing need for search technologies to better support users with language impairments. In the rest of this section, we discuss specific ways this might be achieved – by supporting *word finding cueing strategies, error prevention and recovery, browsing, appropriation* and *interpretation*. It has also been suggested that it may be possible to adapt approaches for supporting neurodiverse searchers (e.g. people with dyslexia or autism) to support people with aphasia (which is a language impairment rather than a form of neurodiversity) [67]. This should be considered alongside the specific suggestions below.

Several of the design suggestions below leverage opportunities presented by LLMs (Large Language Models). LLMs are a potentially transformative technology for search and have the potential to support people in formulating and editing queries, as well as in simplifying text – such as in search result snippets or in web pages and documents. This noted, significant challenges remain. For example, while LLMs might support users with complex language needs in generating verbal output, they might also reduce users' autonomy by producing information which does not align with their communication style [74]. LLMs also flag issues of concern as they can introduce significant biases in search [65]. These biases risk further disempowering users with access needs. It is therefore vital to consider users with diverse language needs as we begin to shape these nascent search technologies. This is likely to be best achieved by directly involving end users.

Stage of information search process	*Search difficulties at this stage of information search*	*Previously reported strategies for overcoming difficulties*	*Novel strategies we identified for overcoming difficulties*
Understanding information needs	Conceptualizing information needs	None	**• Repeating words/phrases from task brief** **• Paraphrasing from task brief**
Formulating queries	Word finding, formulating the query itself and spelling query terms	• Using semantically-related words to support word finding [29–31] • Searching by image to support word finding [29–31] • Using autocomplete to support word finding, query formulation and spelling [29, 31] • Browsing rather than searching to avoid query formulation [29–31] • Using autocorrect to support spelling [29, 31] • Using text-to-speech to support spelling [29, 31]	**• Self-cueing to support word finding** **• Using external words to support word finding and query formulation** **• Using facets/categories to narrow down search, avoiding query formulation**
Assessing search results	**Interpreting search results**	None	**• Using instant answers** **• Reading textual summaries** **• Using images to support result interpretation**
	Keeping track of visited pages	None	**• Using affordances of tabs**
Interpreting web pages and documents	**Reading at word level and broader text comprehension**	• Using text-to-speech [29, 31] (reported as a strategy to support search comprehension in general)	**• Skipping larger chunks of text** **• "Anchoring" to familiar words** **• Reading visually distinctive text** **• Relying on images**

Table 2: Summary of the search difficulties and strategies we identified across the information search process. New (not previously reported) difficulties/strategies are in bold text.

5.1 Supporting Word Finding Cueing Strategies

Participants made frequent use of word finding cueing strategies to support spelling individual query terms and overall query formulation. Phonological cueing [23] is a common approach that people with aphasia use to recall words from memory. Indeed, it has been found that training in cueing can improve word recall among people with aphasia [34]. Designers of search technologies might gain inspiration from AAC approaches, for instance, apps which allow users to search for words they want to recall from the first sound – e.g. Spoken AAC [68] and Curtis and Neate [12]'s 'Watch In' smartwatch app.

Future search technologies might offer autocomplete-style suggestions of 'tip-of-the-tongue' words or phrases after users say or type initial phonemes, using the search context to guide the suggestions. For example, knowing that someone previously searched for 'dog food' might enable more accurate autocomplete of queries (e.g. 'nice place to walk [...my dog]'). Existing AAC approaches have successfully extracted word suggestions from the context of a conversation. For example, [75] generates starter phrases related to an ongoing conversation in a video call. These approaches, which leverage LLMs (Large Language Models) to produce speech, could be adapted to an information search context.

5.2 Supporting Error Prevention and Recovery

Errors during search were often caused by misreading a word or reliance on images that did not always best represent participants' intended searches. The principle of error prevention suggests an opportunity to support users of search technologies in assessing results *before* they interact (e.g. click on a link). Previous research has investigated providing previews of web pages and documents from search result pages, so users can get an idea of what is on the next page before they interact [28, 80]. However, there is a risk that current preview-based approaches might be overwhelming for people who struggle with language. Considering novel preview approaches, such as providing successive AI-generated summaries of search results and key points of documents, providing text-to-speech preview of autocomplete suggestions on mouseover, or providing previews of the images and video contained within a web page on search results might aid rather than overwhelm people with language impairments.

Another search query formulation error involved speech-to-text. Current speech-to-text tools do not cater well for people with language impairments as they are not trained on diverse speech patterns, such as aphasia or apraxia of speech. This can result in errors when words are mistaken for others or speech is not detected as speech in the first place [31]. Prior research in a videoconferencing context has also highlighted preventing speech-to-text errors as an important challenge for people with aphasia [48]. Future speech input technologies might be designed to incorporate a greater diversity of voices, resulting in the creation of datasets that include people with speech impairments (c.f. [47]). It is also possible to allow end users, including those with impairments, to provide data to train the underlying deep learning models (c.f [72]). Initiatives such as Google's Euphonia project [18] are taking important steps towards crowdsourcing non-standard speech from a diverse range of speakers and using it to refine speech-to-text functionality. However, given the speech-related difficulties many people with aphasia experience, enhanced speech recognition is not enough on its own to adequately support the information-seeking needs of people with aphasia; it should be incorporated as part of a broader package that supports communication in a variety of different ways, e.g. both verbally and non-verbally. Future search technologies might provide more holistic communication support, such as where gestures can be used alongside speech and images as a form of input.

Misplaced trust in the search technology was another source of error among our participants; sometimes they trusted functionality such as autocorrect and autocomplete to provide them with useful search query suggestions but struggled to detect when this functionality had taken them in an undesirable direction in their search. This resulted in them getting lost in their search task and struggling to recover (e.g., by returning to a familiar point in their search). This reflects a similar disorientation to that reported in [43]. We therefore need to reconsider how we design automated forms of search suggestion. For example, we may provide users with control over the relevance and/or diversity of these suggestions, or provide suggestions that are written in accessible language. It is also possible to provide personalized suggestions based on searchers' specific language-related query formulation difficulties (e.g., identified through machine learning approaches) or tailored suggestions based on generalized difficulties (e.g. common spelling difficulties for people with aphasia, such as omission of letters in a word).

5.3 Supporting Browsing

P3 browsed facets and categories of dog grooming products to avoid query formulation and other participants actively reduced their need to formulate queries in other ways – such as by using search suggestions. This highlights the potential for search environments to integrate additional browsing support to reduce the need for searching. Browsing rather than searching for information supports 'recognition over recall' – a key HCI design principle [54]. Browsing can also allow people to navigate (and narrow-down) information in an incremental manner that can encourage learning [59]. Rather than replace search entirely, browsing support can complement existing search functionality to allow people to narrow down their searches without necessarily having to refine their initial queries. It is also possible to organize categories in information environments in ways that better support people with language impairments. Such category-based search might borrow findings from grid-based AAC, where strategically using spatial cues and clustering UI elements might support navigation and comprehension of concepts (c.f. [33]).

5.4 Supporting Appropriation

Participants regularly appropriated features of the search engine or browser by adopting them in "*ways the designers never envisaged*" [15]. An example of this was the way P1 used multiple browser tabs. The intended design of tabs is to manage multiple documents and concepts (see [10]) and several participants used them to keep track of their place in their search, as is common when searching [26]. However, P1 used tabs for a particularly creative (and novel) purpose – spelling support. He used them as a 'parking area' for words that might be useful as future query terms but which he found difficult to spell. This can be considered a form of distributed cognition [25], where remembering (and in this case *writing*) is distributed across the brain, body, environment, technology and other people [45]. It is likely that, in P1's case, this form of tab use was enabled by the browser being designed 'ambiguously' (i.e. with flexibility of use in mind; see [17]), which afforded appropriation. Providing ambiguous functionality such as this, aimed at encouraging creative appropriation, may be a useful approach for making search more flexible for people with language impairments. In the case of the Google Chrome Search bar, for example, when a new tab is opened, the interface is not prescriptive about what can be entered. This ambiguity may encourage users to appropriate the search bar for their own needs – e.g., as a temporary storage area for words to use in future search queries.

Ambiguity is, however, a tension. We have seen in prior work that constrained interface design can also encourage creativity in people with language impairments [49, 50]. How to strike an appropriate balance between providing functionality that, on the one hand, constrains thinking and action when appropriate and, on the other, is flexible enough to encourage creative appropriation when needed is an interesting tension that future search technologies should consider when aiming to better support users with complex language needs.

5.5 Supporting Interpretation

Participants struggled to interpret text-heavy web pages. They skipped reading large chunks of text in favour of textual summaries and relied on images to support interpreting search result snippets and document text. Generative AI could support text interpretation by offering successive layers of simplification, tailored to specific language impairments such as aphasia – e.g akin to GenAI (re)simplification approaches explored by Bircanin et al. [5] when making audio content more accessible to listeners with aphasia. As well as simplifying text, generative AI could be leveraged to reformat text in line with good practice guidelines for communicating information to people with language impairments – for instance via the Language Light UX Guidelines or the 'Dos and Don'ts of Designing for Aphasia' poster [2]. It could also explain text that someone finds difficult to understand in an alternative way. This may be through use of aphasia-friendly text principles, pairing text with highly contextualized pictures [14]. Generative AI could also highlight those parts of the text it considers most relevant to the search query submitted (an extension of traditional 'hit highlighting'), or to the information need inferred from the queries submitted throughout the search session. It is also possible to personalize text based on a person's language difficulties and abilities (e.g. 'Steve understands text better when it contains concrete nouns and words with as few syllables as possible'). This could potentially incorporate a user feedback loop to facilitate a degree of text customization. To aid search result interpretation, it is possible to augment textual result snippets with images (e.g. a carousel of images from the linked web page or document or images related

[2]Language Light UX Guidelines and Dos and Don'ts of Designing for Aphasia resources: blogs.city.ac.uk/inca/design-resources/

to the text within it). Image-based AI tools could identify nouns within text and generate images for those nouns.

In summary, novel insight into the search difficulties experienced by people with aphasia can inform the design of search environments that try to better support these difficulties, or support a wider range of them. This is likely to result, overall, in stronger search support for people with aphasia. Furthermore, novel insight into the strategies people with aphasia use to combat particular difficulties can be generative for design – by encouraging designers and developers to consider how to support or better support useful strategies, or even how to reduce the need for them by easing the difficulties that necessitate using them in the first place.

5.6 Implications for Speech and Language Rehabilitation

As well as providing implications for the design of search technologies to better support people with language impairments, our findings also have implications for speech and language rehabilitation. They provide speech and language professionals with a tool to proactively support people with language impairments in conducting successful searches and in tackling search difficulties they experience. Our findings identify a range of strategies used by participants with aphasia to navigate obstacles to search, including those that were often successful – such as appropriation and word finding cueing.

Not everyone with a language impairment will be aware of possible strategies or how to enact them effectively. This represents an opportunity for speech and language professionals to train people with language impairments in the successful application of these strategies. For example, they could be supported to creatively appropriate browser functionality such as tabs to support a range of activities – from keeping track of which queries they have already submitted or plan to submit, to which result pages they have viewed or web pages/documents they want to examine later. They might even be supported to use browser tabs as a 'parking space' for searches to follow-up on, as demonstrated by P1.

Teaching approaches for catalyzing word finding may also be useful for supporting people with language impairments such as aphasia. For example, searching for similar words or phrases to those they are currently unable to recall, browsing, or conducting image searches to find web pages containing text that may be useful as possible query terms. Speech and language professionals could also support the use of generative AI tools to support word cueing; for example, when one of the authors submitted the Bing Co-Pilot prompt 'I want to find a small, furry animal on the Internet but can't find the word,' they received suggestions and photos of a hamster, gerbil, mouse and chinchilla.

Search could also be included in therapy curricula as an important everyday life context where self-cueing is important (e.g. alongside social interaction, travelling, shopping etc.). Speech and language professionals could, mirroring our study, encourage people with aphasia to think of and express real information needs (including through gesture). When they struggle to recall a word from memory, the professional could support them using the word recall approaches discussed above in order to develop their word cueing skills.

6 Conclusion and Future Work

Search is a fundamental way we engage with the world and must be accessible to everyone. In this study, we identified a wide range of difficulties that people with aphasia experience when searching online and strategies aimed at overcoming them. This study identified several aphasia-related search difficulties and strategies that have not been previously reported – particularly those observed post-query formulation (i.e. when assessing results and interpreting web pages and documents). Together these novel insights, combined with a deeper understanding of how the difficulties manifest and the effectiveness of the strategies, provide a much richer picture of the impact of aphasia on search.

While participants valued their ability to search, the difficulties they experienced were extensive and impactful. These difficulties often resulted, on the one hand, in information needs that were only partly-addressed and, on the other, in the use of creative strategies aimed at combating them. While these strategies helped to a certain extent, they were no panacea and it was clear that, despite useful workarounds, search technologies do not adequately support people with aphasia in finding information.

As well as the specific design suggestions we have discussed, a broader opportunity is for designers of search technologies to re-think their reliance on language skills for, in particular, formulating queries and assessing results. For example, they could simplify formulating queries by providing visual query formulation support and iterative query building and refinement functionality. They could also make it easier for people with language impairments to interpret results, web pages and documents, for example by providing successive layers of AI-generated summaries and providing additional visuals to support interpretation.

Future research could investigate the search difficulties and strategies experienced by people with aphasia or other language impairments using a broader range of search tasks (e.g. additional prescribed tasks), different types of task (e.g. known-item retrieval as well as exploratory), multi-session searches and non-individual searches (i.e. collaborative searches, such as deciding on a family vacation destination). It could also examine non-search-based approaches to information-seeking, such as browsing and scrolling news or social media feeds, in more detail. Finally, future research might investigate the barriers and strategies people with aphasia use when interacting with generative AI tools such as ChatGPT, Microsoft Bing Co-Pilot or Google Gemini to find and interpret information from the Web. By designing search technologies to be less reliant on language competencies, we can make search more accessible to people with diverse language needs.

7 Authorship Statement

AM, SM, SW and TN initiated the research and designed the initial study. VK refined the study protocol and facilitated all the observations. Analysis was conducted by SF-T, with support from VK, SM, AM, TN and SW. Paper writing and editing was led by SM and TN, with input from all authors. Accessible captions created by TN and AR. Video presentation designed by AR, with support from VK and AM.

Acknowledgments

This research was funded through the HCID Pump Priming Scheme. We would like to thank the CHI 2025 reviewers for their constructive and useful feedback and our participants for their time and valuable insights.

References

[1] Abdullah Al-Mahmud and Jean-Bernard Martens. 2015. Iterative design and field trial of an aphasia-friendly email tool. *ACM Transactions on Accessible Computing* 4, 7 (2015), 1–36.

[2] Aphasia.org. 2021. National Aphasia Organization. https://www.aphasia.org/aphasia-resources/aphasia-statistics/

[3] Gerd Berget and Andrew MacFarlane. 2019. Experimental methods in IIR: The tension between rigour and ethics in studies involving users with dyslexia. In *Proceedings of the 2019 Conference on Human Information Interaction and Retrieval.* ACM, Glasgow, 93–101.

[4] Gerd Berget and Andrew MacFarlane. 2020. What is known about the impact of impairments on information seeking and searching? *Journal of the Association for Information Science and Technology* 71, 5 (2020), 596–611.

[5] Filip Bircanin, Alexandre Nevsky, Himaya Perera, Vaasvi Agarwal, Eunyeol Song, Madeline Cruice, and Timothy Neate. 2025. Sounds Accessible: Envisioning Accessible Audio Media Futures with People with Aphasia. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '25)*. Association for Computing Machinery, New York, NY, USA.

[6] Mateo Borina, Edi Kalister, and Tihomir Orehovački. 2022. Web Accessibility for People with Cognitive Disabilities: A Systematic Literature Review from 2015 to 2021. In *HCI International 2022 – Late Breaking Papers: HCI for Health, Well-being, Universal Access and Healthy Aging*, Vincent G. Duffy, Qin Gao, Jia Zhou, Margherita Antona, and Constantine Stephanidis (Eds.). Springer Nature Switzerland, Cham, 261–276.

[7] Caitlin Brandenburg, Linda Worrall, Amy D Rodriguez, and David Copland. 2013. Mobile computing technology and aphasia: An integrated review of accessibility and potential uses. *Aphasiology* 27, 4 (2013), 444–461.

[8] Veli Budak, Emre Akadal, and Sevinç Gülseçen. 2020. Research on User Behaviours and Tolerance of Faulty Web Interactions. *Acta Informatica Pragensia* 9, 2 (2020), 108–131.

[9] Cecil Guang Shiung Chang, Fred CC Peng, and Jeng-Yih Yü. 1986. Patterns of information retrieval from LTM in the process of verbalization by a fluent (conduction) aphasic: A Chinese case. *Journal of Neurolinguistics* 2, 1-2 (1986), 277–296.

[10] Joseph Chee Chang, Nathan Hahn, Yongsung Kim, Julina Coupland, Bradley Breneisen, Hannah S Kim, John Hwong, and Aniket Kittur. 2021. When the tab comes due: challenges in the cost structure of browser tab usage. In *Proceedings of the CHI conference on human factors in computing systems.* ACM, [Online], 1–15.

[11] Humphrey Curtis. 2023. Zihao You, William Deary, Miruna-Ioana Tudoreanu, and Timothy Neate. 2023. Envisioning the (In) Visibility of Discreet and Wearable AAC Devices. In *Proceedings of the CHI Conference on Human Factors in Computing Systems. ACM Press, New York, USA*. ACM, New Orleans, 1–19.

[12] Humphrey Curtis and Timothy Neate. 2023. Watch Your Language: Using Smartwatches to Support Communication. In *Proceedings of the 25th International ACM SIGACCESS Conference on Computers and Accessibility* (New York, NY, USA) *(ASSETS '23)*. Association for Computing Machinery, New York, NY, USA, Article 51, 21 pages. doi:10.1145/3597638.3608379

[13] Humphrey Curtis, Timothy Neate, and Carlota Vazquez Gonzalez. 2022. State of the Art in AAC: A Systematic Review and Taxonomy. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility* (Athens, Greece) *(ASSETS '22)*. Association for Computing Machinery, New York, NY, USA, Article 22, 22 pages. doi:10.1145/3517428.3544810

[14] A. Dietz, A. Ball, and J. Griffith. 2011. Reading and writing with aphasia in the 21st century: technological applications of supported reading comprehension and written expression. *Top Stroke Rehabil* 18 (2011), 758–69. Issue 6. doi:10.1310/tsr1806-758

[15] Alan Dix. 2007. Designing for appropriation. In *Proceedings of the 21st British HCI Group Annual Conference on People and Computers* (University of Lancaster, United Kingdom) *(BCS-HCI '07)*. BCS Learning & Development Ltd., Swindon, UK, 27–30.

[16] N.F. Dronkers and J.V. Baldo. 2009. Language: Aphasia. In *Encyclopedia of Neuroscience*, Larry R. Squire (Ed.). Academic Press, Oxford, 343–348. doi:10.1016/B978-008045046-9.01876-3

[17] William W Gaver, Jacob Beaver, and Steve Benford. 2003. Ambiguity as a resource for design. In *Proceedings of the SIGCHI conference on Human factors in computing systems.* ACM, Fort Lauderdale, 233–240.

[18] Google Research. 2024. Project Euphonia. https://sites.research.google/euphonia/about Accessed: 2024-12-02.

[19] Carole-Ann Greig, Renée Harper, Tanya Hirst, Tami Howe, and Bronwyn Davidson. 2008. Barriers and facilitators to mobile phone use for people with aphasia. *Topics on Stroke Rehabilitation* 4, 15 (2008), 307–324.

[20] Brian Grellmann, Timothy Neate, Abi Roper, Stephanie Wilson, and Jane Marshall. 2018. Investigating Mobile Accessibility Guidance for People with Aphasia. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility* (Galway, Ireland) *(ASSETS '18)*. Association for Computing Machinery, New York, NY, USA, 410–413. doi:10.1145/3234695.3241011

[21] Marti A. Hearst. 2009. *Search User Interfaces* (1st ed.). Cambridge University Press, USA.

[22] Marja-Liisa Helasvuo, Minna Laakso, and Marja-Leena Sorjonen. 2004. Searching for words: Syntactic and sequential construction of word search in conversations of Finnish speakers with aphasia. *Research on language and social interaction* 37, 1 (2004), 1–37.

[23] Ruth Herbert, Wendy Best, Julie Hickin, David Howard, and Felicity Osborne. 2001. Phonological and orthographic approaches to the treatment of word retrieval in aphasia. *International journal of language & communication disorders* 36, S1 (2001), 7–12.

[24] Katya Hill. 2010. Advances in augmentative and alternative communication as quality-of-life technology. *Physical Medicine and Rehabilitation Clinics* 21, 1 (2010), 43–58.

[25] James Hollan, Edwin Hutchins, and David Kirsh. 2000. Distributed cognition: toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction (TOCHI)* 7, 2 (2000), 174–196.

[26] Jeff Huang, Thomas Lin, and Ryen W. White. 2012. No search result left behind: branching behavior with browser tabs. In *Proceedings of the Fifth ACM International Conference on Web Search and Data Mining* (Seattle, Washington, USA) *(WSDM '12)*. Association for Computing Machinery, New York, NY, USA, 203–212. doi:10.1145/2124295.2124322

[27] Friederike Kerkmann and Dirk Lewandowski. 2012. Accessibility of web search engines: Towards a deeper understanding of barriers for people with disabilities. *Library review* 61, 8/9 (2012), 608–621.

[28] Theodorich Kopetzky and Max Mühlhäuser. 1999. Visual preview for link traversal on the World Wide Web. *Computer Networks* 31, 11-16 (1999), 1525–1532.

[29] Birgit Kvikne and Gerd Berget. 2022. My words were completely gone. A qualitative study of the information seeking behaviour of people with aphasia. *Info. Res., 27, 1, paper 916. http://InformationR.net/ir/27-1/paper916.html* (2022).

[30] Birgit Kvikne and Gerd Berget. 2024. 'Everything is different': the impact of acquiring aphasia on information seeking. *Information Research an International Electronic Journal* 29(3) (2024).

[31] Birgit Kvikne and Gerd Berget. 2024. "I cannot find the words, it's broken": The impact of aphasia on information searching. In *Proceedings of the 17th International Conference on PErvasive Technologies Related to Assistive Environments* (Crete, Greece) *(PETRA '24)*. Association for Computing Machinery, New York, NY, USA, 118–124. doi:10.1145/3652037.3652044

[32] Huigang Liang, Yajiong Xue, and Susan K Chase. 2011. Online health information seeking by people with physical disabilities due to neurological conditions. *International Journal of Medical Informatics* 80, 11 (2011), 745–753.

[33] Janice Light, Krista M. Wilkinson, Amber Thiessen, David R. Beukelman, and Susan Koch Fager. 2019. Designing effective AAC displays for individuals with developmental or acquired disabilities: State of the science and future research directions. *Augmentative and Alternative Communication* 35, 1 (2019), 42–55. doi:10.1080/07434618.2018.1558283 PMID: 30648896.

[34] Craig W Linebaugh, Rebecca J Shisler, and Leslie Lehner. 2005. CAC classics: Cueing hierarchies and word retrieval: A therapy program. *Aphasiology* 19, 1 (2005), 77–92.

[35] Xiaojuan Ma, Jordan Boyd-Graber, Sonya Nikolova, and Perry R. Cook. 2009. Speaking through pictures: images vs. icons. In *Proceedings of the 11th International ACM SIGACCESS Conference on Computers and Accessibility* (Pittsburgh, Pennsylvania, USA) *(Assets '09)*. Association for Computing Machinery, New York, NY, USA, 163–170. doi:10.1145/1639642.1639672

[36] Andrew MacFarlane, Asaad Albrair, Chloe R Marshall, and George Buchanan. 2012. Phonological working memory impacts on information searching: An investigation of dyslexia. In *Proceedings of the 4th Information Interaction in Context Symposium.* ACM, Nijmegen, 27–34.

[37] Kelly Mack, Emma McDonnell, Dhruv Jain, Lucy Lu Wang, Jon E. Froehlich, and Leah Findlater. 2021. What Do We Mean by "Accessibility Research"? A Literature Survey of Accessibility Papers in CHI and ASSETS from 1994 to 2019. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 371, 18 pages. doi:10.1145/3411764.3445412

[38] Stephann Makri, Ann Blandford, and Anna L Cox. 2011. This is what I'm doing and why: Methodological reflections on a naturalistic think-aloud study of interactive information behaviour. *Information Processing & Management* 47, 3 (2011), 336–348.

[39] Stephann Makri, Dana McKay, George Buchanan, Shanton Chang, Dirk Lewandowski, Andy MacFarlane, Lynne Cole, Sanne Vrijenhoek, and Andrés

Ferraro. 2021. Search a great leveler? Ensuring more equitable information acquisition. *Proceedings of the Association for Information Science and Technology* 58, 1 (2021), 613–618.

[40] Gary Marchionini. 1997. *Information seeking in electronic environments*. Cambridge University Press, USA.

[41] Jane Marshall, Niamh Devane, Richard Talbot, Anna Caute, Madeline Cruice, Katerina Hilari, Gillian MacKenzie, Kimberley Maguire, Anita Patel, Abi Roper, et al. 2020. A randomised trial of social support group intervention for people with aphasia: A Novel application of virtual reality. *PloS one* 15, 9 (2020), e0239715.

[42] Fiona Menger, Julie Morris, and Christos Salis. 2016. Aphasia in an Internet age: wider perspectives on digital inclusion. *Aphasiology* 30, 2-3 (2016), 112–132.

[43] Fiona Menger, Julie Morris, and Christos Salis. 2017. Internet use in aphasia: a case study viewed through the international classification of functioning, disability, and health. *Topics in Language Disorders* 37, 1 (2017), 6–24.

[44] Fiona Menger, Julie Morris, and Christos Salis. 2019. The impact of aphasia on Internet and technology use. *Disability and Rehabilitation* 42, 21 (2019), 2986–2996. doi:10.1080/09638288.2019.1580320 PMID: 30982360.

[45] Kourken Michaelian and John Sutton. 2013. Distributed cognition and memory research: History and current directions. *Review of philosophy and psychology* 4 (2013), 1–24.

[46] Hannah Miller, Heather Buhr, Chris Johnson, and Jerry Hoepner. 2013. AphasiaWeb: a social network for individuals with aphasia. In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility* (Bellevue, Washington) *(ASSETS ’13)*. Association for Computing Machinery, New York, NY, USA, Article 4, 8 pages. doi:10.1145/2513383.2513439

[47] Davide Mulfari, Gabriele Meoni, Marco Marini, and Luca Fanucci. 2021. Machine learning assistive application for users with speech disorders. *Applied Soft Computing* 103 (2021), 107147.

[48] Timothy Neate, Vasiliki Kladouchou, Stephanie Wilson, and Shehzmani Shams. 2022. “Just Not Together”: The Experience of Videoconferencing for People with Aphasia during the Covid-19 Pandemic. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI ’22)*. Association for Computing Machinery, New York, NY, USA, Article 606, 16 pages. doi:10.1145/3491102.3502017

[49] Timothy Neate, Abi Roper, Stephanie Wilson, and Jane Marshall. 2019. Empowering Expression for Users with Aphasia through Constrained Creativity. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI ’19)*. Association for Computing Machinery, New York, NY, USA, 1–12. doi:10.1145/3290605.3300615

[50] Timothy Neate, Abi Roper, Stephanie Wilson, Jane Marshall, and Madeline Cruice. 2020. CreaTable Content and Tangible Interaction in Aphasia. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI ’20)*. Association for Computing Machinery, New York, NY, USA, 1–14. doi:10.1145/3313831.3376490

[51] Jodi Heintz Obradovich and David D Woods. 1996. Users as designers: how people cope with poor HCI design in computer-based medical devices. *Human factors* 38, 4 (1996), 574–592.

[52] National Institute on Deafness and Other Communication Disorders. 2017. What is Aphasia? www.nidcd.nih.gov/health/aphasia [Accessed 22/11/23].

[53] Rebecca Palmer, Pam Enderby, Cindy Cooper, Nick Latimer, Steven Julious, Gail Paterson, Munyaradzi Dimairo, Simon Dixon, Jane Mortley, Rose Hilton, et al. 2012. Computer therapy compared with usual care for people with long-standing aphasia poststroke: a pilot randomized controlled trial. *Stroke* 43, 7 (2012), 1904–1911.

[54] Anunaya Pandey, Sanjeeb Prasad Panday, and Basanta Joshi. 2023. Design and development of applications using human-computer interaction. In *Innovations in Artificial Intelligence and Human-Computer Interaction in the Digital Era*. Elsevier, 255–293.

[55] Gill Pearl and Madeline Cruice. 2017. Facilitating the involvement of people with aphasia in stroke research by developing communicatively accessible research resources. *Topics in Language Disorders* 37, 1 (2017), 67–84.

[56] Matthew F. Pike, Horia A. Maior, Martin Porcheron, Sarah C. Sharples, and Max L. Wilson. 2014. Measuring the effect of think aloud protocols on workload using fNIRS. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI ’14)*. Association for Computing Machinery, New York, NY, USA, 3807–3816. doi:10.1145/2556288.2556974

[57] Rachelle Pitt, Deborah Theodoros, Anne J Hill, and Trevor Russell. 2019. The impact of the telerehabilitation group aphasia intervention and networking programme on communication, participation, and quality of life in people with aphasia. *International journal of speech-language pathology* 21, 5 (2019), 513–523.

[58] Mikko Rajanen and Netta Iivari. 2007. Usability cost-benefit analysis: How usability became a curse word?. In *IFIP Conference on Human-Computer Interaction*. Springer, Rio de Janeiro, 511–524.

[59] Ronald E Rice, Maureen McCreadie, and Shan-Ju L Chang. 2001. *Accessing and browsing information and communication*. Mit Press.

[60] Abi Roper, Ian Davey, Stephanie Wilson, Timothy Neate, Jane Marshall, and Brian Grellmann. 2018. Usability Testing - An Aphasia Perspective. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility* (Galway, Ireland) *(ASSETS ’18)*. Association for Computing Machinery, New York, NY, USA, 102–106. doi:10.1145/3234695.3241481

[61] Abi Roper, Jane Marshall, and Stephanie Wilson. 2016. Benefits and limitations of computer gesture therapy for the rehabilitation of severe aphasia. *Frontiers in human neuroscience* 10 (2016), 595.

[62] Abi Roper, Jane Marshall, and Stephanie M. Wilson. 2014. Assessing technology use in aphasia. In *Proceedings of the 16th International ACM SIGACCESS Conference on Computers & Accessibility* (Rochester, New York, USA) *(ASSETS ’14)*. Association for Computing Machinery, New York, NY, USA, 239–240. doi:10.1145/2661334.2661397

[63] T. A. Rose, L.E. Worrall, L.M. Hickson, Hoffmann, and T.C. 2011. Aphasia friendly written health information: Content and design characteristics. *International Journal of Speech-Language Pathology* 13 (2011), 335–347. Issue 4. doi:10.3109/17549507.2011.560396

[64] Nuzhah Gooda Sahib, Anastasios Tombros, and Tony Stockman. 2012. A comparative analysis of the information-seeking behavior of visually impaired and sighted searchers. *Journal of the American Society for Information Science and Technology* 63, 2 (2012), 377–391.

[65] Nikhil Sharma, Q. Vera Liao, and Ziang Xiao. 2024. Generative Echo Chamber? Effect of LLM-Powered Search Systems on Diverse Information Seeking. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI ’24)*. Association for Computing Machinery, New York, NY, USA, Article 1033, 17 pages. doi:10.1145/3613904.3642459

[66] Laurianne Sitbon, Andrew Bayor, Filip Bircanin, Stewart Koplick, and Margot Brereton. 2018. An Exploration of How People with Intellectual Disability Engage with Online Information Retrieval. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI EA ’18)*. Association for Computing Machinery, New York, NY, USA, 1–6. doi:10.1145/3170427.3188599

[67] Laurianne Sitbon, Gerd Berget, and Margot Brereton. 2023. Perspectives of Neurodiverse Participants in Interactive Information Retrieval. *Found. Trends Inf. Retr.* 17, 2 (2023), 124–243. doi:10.1561/1500000086

[68] Spoken AAC. 2024. Spoken AAC: Bridging Communication Gaps. https://spokenaac.com/ Accessed: 2024-09-09.

[69] StatCounter. 2024. Search Engine Market Share: United Kingdom. https://gs.statcounter.com/search-engine-market-share/all/united-kingdom Accessed: 2024-12-02.

[70] Kimberly Tee, Karyn Moffatt, Leah Findlater, Eve MacGregor, Joanna McGrenere, Barbara Purves, and Sidney S. Fels. 2005. A visual recipe book for persons with language impairments. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Portland, Oregon, USA) *(CHI ’05)*. Association for Computing Machinery, New York, NY, USA, 501–510. doi:10.1145/1054972.1055042

[71] Jaime Teevan, Christine Alvarado, Mark S Ackerman, and David R Karger. 2004. The perfect search engine is not enough: a study of orienteering behavior in directed search. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. ACM, Vienna, 415–422.

[72] Lida Theodorou, Daniela Massiceti, Luisa Zintgraf, Simone Stumpf, Cecily Morrison, Edward Cutrell, Matthew Tobias Harris, and Katja Hofmann. 2021. Disability-first Dataset Creation: Lessons from Constructing a Dataset for Teachable Object Recognition with Blind and Low Vision Data Collectors. In *Proceedings of the 23rd International ACM SIGACCESS Conference on Computers and Accessibility* (Virtual Event, USA) *(ASSETS ’21)*. Association for Computing Machinery, New York, NY, USA, Article 27, 12 pages. doi:10.1145/3441852.3471225

[73] Siva Vaidhyanathan. 2012. *The Googlization of everything:(and why we should worry)*. University of California Press, USA.

[74] Stephanie Valencia, Richard Cave, Krystal Kallarackal, Katie Seaver, Michael Terry, and Shaun K. Kane. 2023. “The less I type, the better”: How AI Language Models can Enhance or Impede Communication for AAC Users. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI ’23)*. Association for Computing Machinery, New York, NY, USA, Article 830, 14 pages. doi:10.1145/3544548.3581560

[75] Stephanie Valencia, Jessica Huynh, Emma Y Jiang, Yufei Wu, Teresa Wan, Zixuan Zheng, Henny Admoni, Jeffrey P Bigham, and Amy Pavel. 2024. COMPA: Using Conversation Context to Achieve Common Ground in AAC. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI ’24)*. Association for Computing Machinery, New York, NY, USA, Article 915, 18 pages. doi:10.1145/3613904.3642762

[76] Braun Virginia and Clarke Victoria. 2022. Thematic analysis: a practical guide.

[77] Annalu Waller, Fiona Dennis, Janet Brodie, and Alistair Y Cairns. 1998. Evaluating the use of TalksBac, a predictive communication device for nonfluent adults with aphasia. *International Journal of Language & Communication Disorders* 33, 1 (1998), 45–70.

[78] Janet Webster, Julie Morris, Jenny Malone, and David Howard. 2021. Reading comprehension difficulties in people with aphasia: Investigating personal perception of reading ability, practice, and difficulties. *Aphasiology* 35, 6 (2021), 805–823.

[79] Ryen W White and Resa A Roth. 2009. *Exploratory search: Beyond the query-response paradigm.* Number 3. Morgan & Claypool Publishers.
[80] Allison Woodruff, Andrew Faulring, Ruth Rosenholtz, Julie Morrsion, and Peter Pirolli. 2001. *Using thumbnails to search the Web.* Association for Computing Machinery, New York, NY, USA, 198–205. https://doi.org/10.1145/365024.365098

8 Appendix 1: Queries submitted during Task 1 (prescribed search task on 'Heroes and Heroic Acts')

Participant	No. of Queries Submitted	Query terms submitted
P1	8	*person*; *person*; *person icon*; *person helping someone*; *person helping famous*; *mother teressa*; *heroic people*; *heroic stories*; *heroic people in history*; *clara barton*
P2	5	Hero Acts *HEROS Act 2020 update today*; *heroes women*; *Health and Economic Recovery Omnibus Emergency Act*; *heroes*; *heroes in history*
P3	14	*top heroic heroes*; *top heroic heroes dog*; *top heroic political heroes dog*; *top heroic political heroes* ; *top heroic sport heroes* ; *sports heroes and legends list*; *top 10 sports legends*; *heros now*; *heroes greta campaign*
P4	7	*Alan Turing Wiki*; *Turning machine*; *Linus Thorvalds wiki*; *heroic people*; *Real Life Heros*; *internet hall of fame wiki*; *unix wiki*; *wiki*; *elon musk wiki*; *penicillin* ; *penicillin wiki*
P5	7	*heroic people in history*; *heroic people in history and their acts*; *heroic people in history and their acts who have helped others*
P6	7	*heroic people*; *real life heros 2020*; *books about real life heros*; *heroic people in medicine 2020*; *Mandela*; *zidzi mandela*; *Walesa*
P7	10	*Mary Seacole*; *Nelson Mandela*; *where's your nelson*; *horatio nelson facts*; *Emma, Lady Hamilton*; *Neston*; *ancient*; *ancient ho*; *ancient heroes*; *ancient heroes jason*;
P8	9	*Winston Churchill*; *captain tom*; *Anne Frank*; *heros*; *what is the definition of a hero*; *Hero examples*; *Tragic Hero examples*; *Romeo Montague tragic heroes*; *hero in community*; *heroes that help the community*
P9	6	*heroic*; *heroic movie*; *hero movie*; *heroic death*; *heroic age*; *heroic age history*
P10	3	*heroic and their acts*; *heroic acts in history*; *who are the bravest people in history*
P11	3	*heroic women*; *heroic men*; *heroic men of ww2 in europ*
P12	4	*social heros*; *social heroes isle of wight*; *examples of social heroes*; *polticial heroes*

Table 3: Queries submitted for prescribed search task on 'heroes and heroic acts.' This table lists all queries submitted to Google during Task 1, including edits to previously-submitted queries. Some spelling errors were automatically corrected by Google autocomplete.

9 Appendix 2: Queries submitted during Task 2 (self-directed search task)

Participant	Chosen search topic	No. of Queries Submitted	Query terms submitted
P1	Family cars	8	*new car*; *new Family car*; *new big Family car*; *car SUV vs carrier*; *best MVP*; *Volkswagon Touran*; *citroen berlingo*; *Ford S-Max*
P2	Natasha Preston and trainer size	5	*https://www.natashapreston.com/*; *natasha preston books*; *trainers size 8*; *natasha preston books*; *natasha preston*
P3	Pet supplies	14	*dog bowls*; *dog bowls amazon*; *pet supplies*; *Dogs*; *dog supplies*; *Grooming Products for Dogs*; *Shampoos & Conditioners for Dogs*; *pets at home*; *puppy treats*; *spring dog bed offers*; *puppy harness*; *collars, harnesses & leads for dogs*; *ID tags for dogs*; *puppy kong*;
P4	Parallel/concurrent computing	7	golang concurency vs parallelism *concurrency wiki*; *parallelism wikipedia*; *concurrency is not parallelism*; *concurrency is not parallelism examples*; *golang concurency example*; *golang channel example*
P5	Music	7	anderson .paak bruno mars album *anderson paak bruno mars album release date*; *anderson paak bruno mars album release date silk sonic*; *prince when is new album out 2021*; *"prince" when is his new album out 2021*; *upcoming prince releases*; *Next Prince release 2021*
P6	Eurovision	3	*Eurovison Song Contest 2021*; *Graham Norton and Eurovision 2021*; *Singers in Eurovision 2021*
P7	Sport	8	*all inda tennis tournament*; *all english tennis tournament*; *tennis tournaments uk 2020*; *tennis tournaments uk 2021*; *tennis tournaments uk 2021 dates*; *frank lampard how many games did he play for chelsea*; *Usain Bolt how many medals*; *Usain Bolt how many olympic gold medals*;
P8	Knitting	9	*knitt a summer top in double knit*; *Easy Summer Knitting Patterns*; *summer top knitting patterns free*; *I would like to knit a summer top*; *knitted summer tops*; *I would like to knot a summer top*; *free knitting patterns for ladies summer tops uk*; *knitting kits with summer tops*; *free summer knitting patterns 2020*
P9	Gardening	5	*garden triangle*; *garden designs for triangular gardens*; *triangular plot triangle*; *triangular landscape design plan*; *plants*
P10	Travel	3	*vacation*; *vacation in europe*; *vacation in carribean*
P11	British army regiments	4	*regiments that serviced in the crimean war*; *regiments that serviced in the crimean war and their divisions*; *regiments that serviced in the crimean war and the battles that they took part*; *crimean war battles and the regiments that served in them*
P12	British motorcycles	3	*british motorcylces 1950s*; *british motorcylces 1950s axcel*; *axcel driven british motorcyle*

Table 4: Queries submitted for self-directed search task. This table lists all queries submitted to Google during Task 2, including edits to previously submitted queries. Some spelling errors were automatically corrected by Google autocomplete.