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REVIEW

Data visualization and decision making in adults with acquired and developmental language disabilities: A scoping review

Niamh Devane[1] | Nicola Botting[1] | Madeline Cruice[1] | Abi Roper[1] | Danielle Szafir[2] | Jo Wood[3] | Stephanie Wilson[4]

[1]Department of Language and Communication Science, School of Health and Psychological Sciences, City St George's, University of London, London, UK

[2]Department of Computer Science, University of North Carolina, Chapel Hill, North Carolina, USA

[3]giCentre, Department of Computer Science, City St George's, University of London, London, UK

[4]Centre for Human-Computer Interaction Design, Department of Computer Science, City St George's, University of London, London, UK

Correspondence
Niamh Devane, Department of Language and Communication Science, School of Health and Psychological Sciences, City St George's, University of London, London, EC1V 0HB, UK.
Email: Niamh.devane.2@city.ac.uk

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Abstract

Background: Accessibility of data visualization has been explored for users with visual disabilities but the needs of users with language disabilities have seldom been considered.

Aim: This scoping review synthesised what is known about data visualization for adults with language disabilities, specifically the acquired language disability, aphasia and Developmental Language Disorder. It sought to extract key findings and identify what practices support effective visualization for decision making for people with language disabilities.

Method: Papers were included if they investigated visualization of data, and the consumers of the data visualization were people with aphasia or developmental language disability. Seven databases were searched: CINAHL, Academic Search, Medline, PsychINFO, Ovid, ACM Digital Library and IEEE Xplore. Included studies were charted to extract title, author(s), year, country, paper type, scientific field, participant number(s), participant group(s), main topic, subtopic, method, task description, task category, data visualization, summary, key findings relevant to the review question, and guidelines or recommendations. Narrative synthesis was used to describe how people with language disability have interacted with data visualization from a range of literature.

Main Contribution: Six studies (seven publications) were included in the review. One study came from the field of health, one from a disability rights collaboration and four studies from computer science. No studies satisfying the review criteria explored data visualization for Developmental Language Disorder; however, five studies explored participants with cognitive disabilities that included impairments of language, so these were included. A range of visualization designs were found. Studies predominantly explored *understanding* of visualization (4/6). One study explored how to *express* data visually, and one explored the *use* of the visualization that is, for an action, choice, or decision. Cognitively accessible data visualization practices were described in four papers and synthesized. Supportive practices reported were reducing the cognitive load associated with processing a visualization and increasing personal relevance of data visualization.

Conclusion: Accessible data visualization for adults with aphasia and Developmental Language Disorder has only minimally been explored. Practices to specifically support users with language disability are not yet apparent. As data use in making everyday decisions is widespread, future research should explore how people with language disabilities make use of data visualization.

KEYWORDS

accessibility, adults, aphasia, data visualization, developmental language disorder, scoping review

WHAT THIS PAPER ADDS

What is already known on this subject

- Visual resources are used widely to support people with language disabilities in understanding of language. That is, icons, maps timelines and so forth, are used to support auditory processing. However, data visualization is used routinely by people without a language disability to support everyday decisions for example, visualization of live traffic data is used to provide users with the best route to their destination. It is unclear whether any work has explored data visualization for people with language disabilities.

What this paper adds to existing knowledge

- This paper brings together research on the use of data visualization by adults with either Developmental Language Disorder or aphasia, collectively people with language disabilities. It highlights a gap in the design of inclusive data visualization for language disabilities and the minimal research exploring the use of data visualization for decision making in these populations.

What are the clinical implications of this work?

- Access to data can be empowering. It has potential to enable agency in decisions and increase social participation. The existing gap in knowledge about how to design inclusive data visualization for people with language disabilities thus poses a risk of exclusion and threats to informed decision making. Highlighting the current field of literature may drive research and clinical activity.

INTRODUCTION

Acquired and developmental language disabilities

Language disabilities[1] occur when a disordered or damaged language system affects everyday communication. The focus in this review was two diagnoses where language processing difficulties occur in adults in the absence of other cognitive or speech diagnoses: adults with Developmental Language Disorder (DLD) and adults with the acquired language disability, aphasia. The exact number of adults living with language disability in the UK is not known; current estimates however suggest that approximately 7% of the population have DLD (extrapolated from child data given that it is a lifelong condition (Norbury et al., 2016), and 350 000 people are living with aphasia after stroke (Stroke Association, 2018). The number of adults with communication needs is higher, likely in the millions (Communication Access, n.d.), as language disabilities additionally occur with other developmental and acquired conditions such as autism, brain injuries beyond stroke, dementia (i.e., primary progressive aphasia) and progressive neurological conditions. Although aphasia and DLD arise from different causes, the language profiles and subsequent language disabilities experienced are similar (Kladouchou et al., under review). Language disabilities are negatively associated with well-being (Lam & Wodchis, 2010) and people can become isolated (Arts et al., 2022; Hilari & Northcott, 2017). The rates of anxiety and depression are often high in these populations (Baker et al., 2018; Morris et al., 2017; Wadman et al., 2011). Access to information and services is reduced due to the resulting communication barriers, impacting equal rights (Berg et al., 2020). There is currently little support for adults with DLD despite it being a lifelong disorder (RCSLT, 2023), so it is important to consider this underserved group alongside those with aphasia. There is a need for wider public awareness (Code, 2020; Thordardottir et al., 2021), and more inclusive practice and inclusive design to overcome these barriers.

Accessibility for language disability

The accessibility of 'communication' spaces can be conceptualised in similar ways to the accessibility of physical spaces. In the same way that buildings have ramps and lifts to allow people with physical disabilities to access the activities of a space, so signs, maps and conversations can use simplified language, written keywords and symbols with text to allow people with communication disabilities to interact within a space (Solarsh & Johnson, 2017). Communication access has been described in terms of documents, interactions and environments (Parr et al., 2006), and efforts have been made to improve access for people with communication disability (Bigby et al., 2019; Kim et al., 2023; Parr et al., 2006; Solarsh & Johnson, 2017; Taylor et al., 2021). Guidelines exist for inclusive design of digital technologies for aphasia (languagelightux.org). The guidelines include simplifying language, minimising distractions and training for key stakeholders. Importantly, access to information is linked to knowledge and empowerment (Cruice, 2007). Access to information allows for informed decision making and can help counteract the loss of equal rights and access to services (Berg et al., 2020).

Data visualization

Processing data and other forms of information can be challenging for people with language disabilities. Data visualization[2] presents data in a visual format, usually graphical or pictorial, to make data easier to understand (Sadiku et al., 2016). An information containing unit, or *mark*, is presented visually and is most often used to make sense of relationships between data points or dimensions, see patterns over time, or summarise information. The resulting output has been described as a visual idiom (Munzner, 2014). Data visualizations in everyday life include weather maps, news summaries such as polls during elections or COVID rates during the pandemic (see, Figure 1 as an example), health apps that track personal data such as weight or steps, and route mapping software. It has been argued that reading a visualization is easier than reading data that are not presented visually because the visualization allows an 'offload' of cognitive processing to a more instinctive perceptual response—our sense of sight (Arias-Hernandez et al., 2012). This ability of visualization to support processing has been called different things by different researchers; a 'cognitive prosthesis' because it supports cognitive processing (Arias-Hernandez et al., 2012; Arnott et al., 1999); 'amplifying cognition' (Card et al., 1999); or 'cognitive mediator' because it can influence action by changing how people make decisions with data. For these reasons, data visualization may well support communication access to data for adults with language disabilities by supporting language processing and thereby supporting everyday decision-making.

Accessible data visualization

Current accessibility guidance for data visualization predominantly addresses the needs of users with visual impairments (see, Marriott et al., 2021 for a summary).

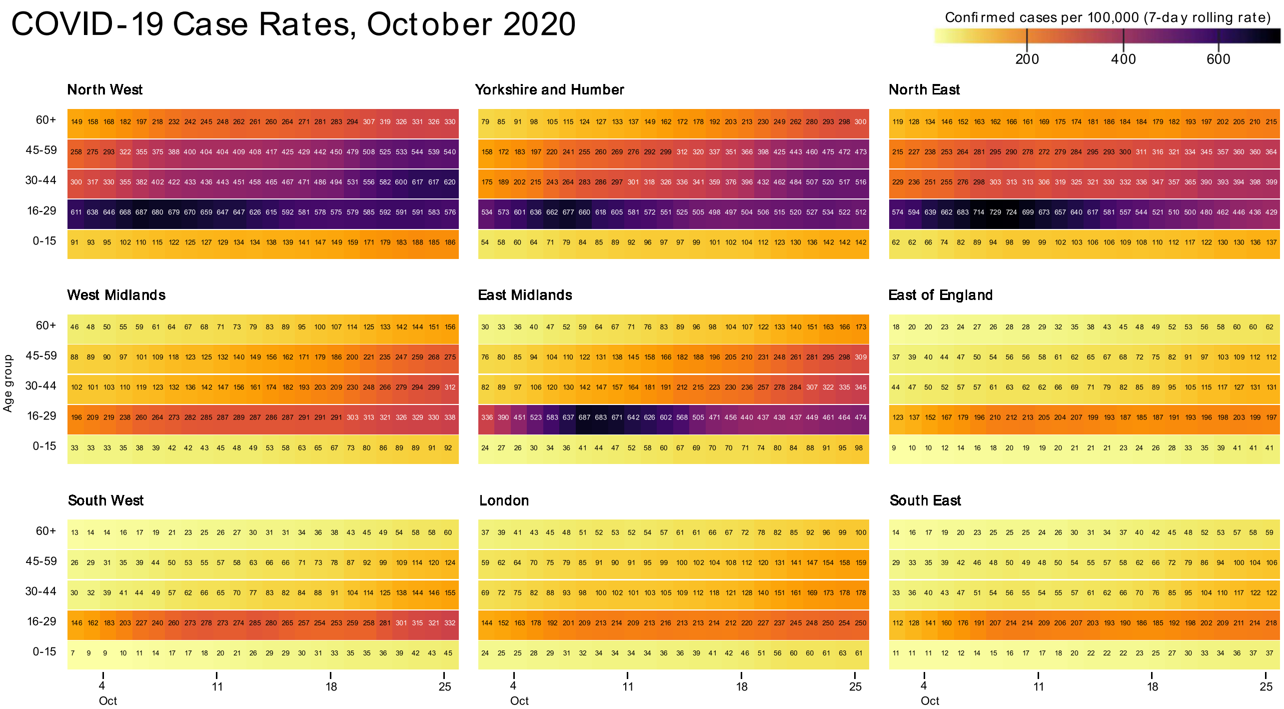

FIGURE 1 COVID-19 case rate data visualization of the type shown on national government broadcasts during the hight of the COVID pandemic. It shows typical characteristics of data visualization: graphical encoding of multiple data values (case rates by date, region and age cohort); multiple encoding types (colour, position, grid rectangles, number text); supporting information (titles, axis labels, legend). Together they support the visualization processes of searching data (data foraging), linking with our mental models (schema instantiation) and problem solving leading ultimately to possible decision making (Card et al., 1999). Note the significant reliance on language to interpret the visualization fully.

For example, guidance from the World Wide Web Consortium, an international body which develops standards to promote digital accessibility, recommends alternative text descriptions for images for read aloud software (Caldwell et al., 2008). Additionally, sonification can transform data to an auditory modality to reduce a reliance on the visual modality. However, using the auditory modality will not support users with language processing difficulties where auditory comprehension difficulties are a key feature (Lwi et al., 2021). Accessibility guidance for language disability is needed.

Data visualization for decision making

A primary driver behind the need for accessible visualization is the growth in data-driven decision making. Decision making is defined as a choice between two or more actions (Padilla et al., 2018). Data visualization can support decisions that have important consequences, such as whether to evacuate a town in the path of a storm (e.g., dynamic weather maps), or everyday decisions, such as which film to watch this evening (e.g., visualised data of film ratings such as stars or rotten tomatoes). Decision making in language disabilities has been explored in the context of health decisions (Jayes et al., 2021). The United Nations Convention on the Rights of Persons with Disabilities highlights the right to decision making for people with disability in general (United Nations, 2006). There is literature exploring the use of the Mental Capacity Act guidance in practice (Jayes et al., 2022): that people should be supported to make decisions if there is reason to believe they will have difficulty. A recent review explored literature on decisions made with people with aphasia and the supports provided (Stipinovich et al., 2023). Many of the papers in the review were theoretical (10/16): they described the impact of aphasia and ethical issues around exclusion. Decisions reported in the sample related to discharge planning, participation in research, consent for treatment, financial decisions and therapy decisions (goals) (Stipinovich et al., 2023). The review outlined language support strategies for decision making, organising them by general strategies, and then specific strategies for presenting verbal and written information, checking comprehension, supporting the weighing up of pros and cons, supporting the person to express their choice and checking understanding of that choice. All strategies aligned with 'Supported Conversation for Adults with Aphasia' (Kagan, 1998). However, these decisions related to healthcare, where decisions often have clear outcomes and factors such as risk play a core role and data visualization was not explored. Support for everyday decisions such as which route to take to avoid traffic are, to our knowledge, unexplored in the literature. The literature on use of data visualization by people *without* disability has reported improved decision making with data visualization (Park et al., 2022). These improvements were thought to be the result of a reduced cognitive and intellectual burden to interpret information.

Summary

In brief, decision making for healthcare has been explored in aphasia, and the benefit of data visualization for decision making has been established in a population without disability, but there has been no synthesis of the literature on the use of data visualizations in people with either acquired or developmental language disabilities to support decision-making. The review reported here aimed to uncover what is known about data visualization for people with language disabilities, specifically aphasia and DLD, and to identify what practices have been used to make data visualization accessible for this group. Access to information and data, particularly personal data, can be empowering and support social participation. Visual resources support conversations in people with language disabilities so visual data may be used and useful in this population, however, this has not been investigated. It is possible that new guidance is needed.

Review questions

RQ1: What is known about data visualization for adults with acquired or developmental language disabilities?

RQ2: What practices support effective visualization for decision making for people with language disabilities?

METHODS

A scoping review was chosen to map the current literature and identify gaps. A template from the Joanna Briggs Institute (JBI) scoping review guidance was used to support conducting and reporting the review (JBI Scoping Review Network). The research is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews; see Appendix 1. A preliminary search of the International Prospective Register of Systematic Reviews was conducted and no current reviews on the topic were identified. The review protocol was not registered.

Box 1. Population, Exposure and Outcome (PEO) framework

Population: Adults with acquired and developmental language disabilities (aphasia, developmental language disorder)
Exposure: Data visualization
Outcome*: Decision making

*removed after the pilot search

Box 2: Language disabilities defined

Aphasia is a language impairment occurring as a result of brain injury, most commonly stroke. It affects a person's ability to read, write, speak and process language, with far reaching negative consequences for social connectedness, life roles and activity, family, well-being, equality and access (Berg et al., 2020).
Developmental language disorder (DLD) is a language impairment from childhood with no obvious cause that persists into adulthood (RADLD, 2024).

Eligibility criteria

The PEO framework was used to define the Population, Exposure and Outcome (PEO) of interest, see Box 1.

Population

Papers included adults (>18 yrs) living with one of two language disabilities: aphasia and DLDs, see Box 2. Aphasia and DLD are the two communication disabilities where there is a 'pure' language processing issue, without an overlay of marked cognitive, social communication or speech impairments. Adults with progressive language conditions, more generalised head injury, other communication diagnoses and studies of children were excluded.

Adults with language disabilities in mixed population studies were included. See 'search strategy' for a rationale.

Exposure

Data visualization involves visual representations of data. Data visualizations are often graphic but can be tangible, as in data physicalisation where physical items are used to represent data (e.g., a pebble in a jar to represent a counted occurrence). Definitions of data visualization are quite loose, with connected terms such as knowledge visualization, visual analytics and information visualization interrelated (Schiuma et al., 2022). In this review, we did not consider images or symbols representing one idea (visual information) as data visualizations but included studies where more than one data value was configured in a visualization. Therefore, studies were excluded if visual materials, such as Talking Mats (Cameron & Murphy, 2002), were used as communication supports, for example a study that described drawing of key words and other supportive interview tools (Lysley & Black, 2004). Studies of infographics were also excluded (e.g., one icon to represent one idea Knollman-Porter et al., 2016).

This scoping review considered the following study designs as eligible for inclusion: experimental, quasi-experimental, case-control studies, case series, individual case reports and qualitative studies. Text and opinion papers were also eligible for inclusion.

Outcome

Decision making is the choice between two or more actions. An initial search included decision making as an outcome with the additional search terms ‘understand’ and ‘comprehend’.

Search strategy

The search strategy *initially* aimed to locate studies that used data visualization (exposure) for people with aphasia or DLD (population) in decision making (outcome). A pilot search was undertaken to test the search strategy. The results yielded three papers that minimally addressed the research questions. The search was therefore expanded to find evidence of the use of data visualization (exposure) in communication disabilities (population) and the need for a decision-making outcome was removed. Additionally, we included umbrella terms that included populations with cognitive/intellectual disability: intellectual and developmental disabilities (IDDs) and cognitive and learning disabilities (CALD), where language difficulties were included with a number of other conditions. Through discussion within the author team, an additional criterion was added: the *consumer* of the visualization needed to be the population with language disabilities. For example, a study where data about language disabilities were visualised for policymakers (Fan et al., 2020) was excluded.

Only studies published in English were included. There were no date limitations. The seven databases searched were CINAHL, Academic Search, Medline, PsychINFO, Ovid, ACM Digital Library and IEEE Xplore. Searches took place on 11–17 August 2023. An example search is shared in Box 3.

> **Box 3: Example search**
>
> Aphasi* OR dysphasi* OR ‘Developmental language disorder’ OR ‘language impairment’ OR ‘communication impairment’ OR ‘specific language impairment’ OR ‘people with disabilit*’
> AND
> ‘Data visuali?ation’ OR ‘information graphics’ OR visuali?ation OR ‘information visuali?ation’ OR ‘statistical graphs’ OR ‘accessible graphics’ OR ‘immersive analytics’ OR ‘graph perception’ OR infographic OR ‘situated visuali?ation’ OR ‘data physicalisation’[3]

Selection of sources

Following the search, all identified citations were exported and uploaded into Rayyan Software (Ouzzani et al., 2016) where duplicates were removed. Titles and abstracts were screened by the first author (N.D.). Potentially relevant texts were retrieved in full. All full texts were assessed independently against the inclusion criteria by two reviewers (N.D. and A.R.). Reasons for exclusion of sources at full text were recorded and are reported in Figure 1. Uncertainties were discussed by the research team (authors N.D., N.B., M.C., A.R., J.W. and S.W.). For example, studies of visual materials used to support comprehension in aphasia that did not have data units encoded were discussed (Elko et al., 2022).

Data charting and data items

Data were extracted from included papers by author N.D. using a data extraction form developed in discussion with other authors. The form documented the following information from each paper: title, author(s), year,

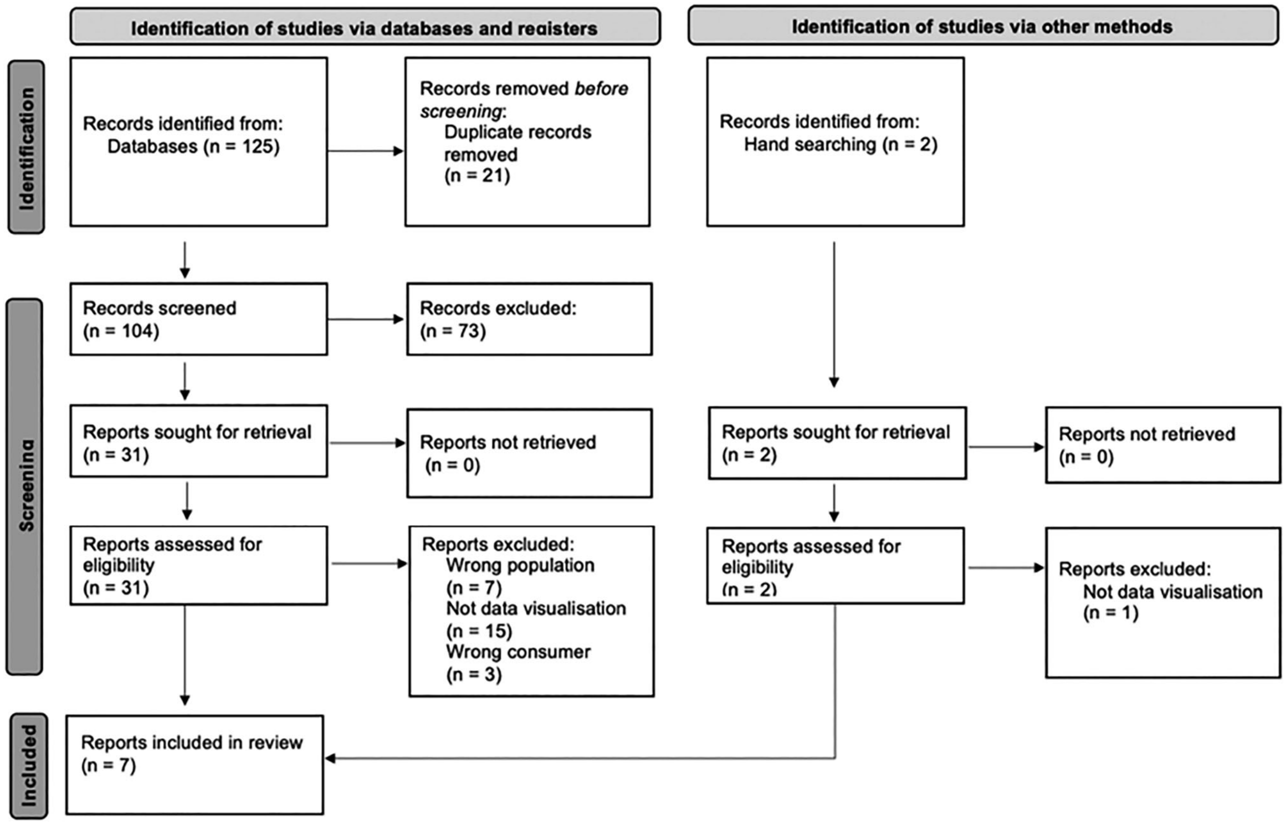

FIGURE 2 Flow diagram.

country, paper type, scientific field, participant number(s), participant group(s), main topic, sub-topic, method, task description, task category, data visualization, summary, key findings relevant to the review question and guidelines or recommendations.

Synthesis of results

Narrative synthesis (Popay et al., 2006) from the full text articles described how people with aphasia or people with communication diagnoses likely to have included DLD have interacted with data visualization. Techniques used in the narrative synthesis were grouping the extracted data in clusters and writing textual descriptions. Guidance across studies was grouped and presented in a table (Results, Table 3).

RESULTS

Selection of sources

Seven reports, representing six studies, were included in the review, see Figure 2. Database searches yielded 125 records. After title and abstract screening, 31 full text reports were retrieved and assessed for eligibility. Seven of these did not address language disabilities, 15 did not report on data visualization and 3 provided data visualizations for a consumer for example, policy makers. Two records were identified using hand searching, one from a reference search and one from the pilot search. One of these met criteria, giving a total of seven reports included in the review. There was 97% agreement (32/33) between reviewers on full text inclusion. The disagreement was resolved through discussion.

Study participant characteristics

Four of the six studies reported participant data. In total, data from 147 participants were reported, 52 of whom were controls. Communication diagnoses where reported were Broca's aphasia (×20), Wernicke's aphasia (×20) and right hemisphere brain damage (×20). Umbrella terms (CALD, IDD) included in the expanded search additionally described the following conditions: autism or autistic spectrum disorders (×13), learning disabilities (×8), intellectual disability (×4), IDD (×6), cerebral palsy (×1), foetal alcohol syndrome (×1), developmental delay and sensory processing disorder (×1) and Williams syndrome (×1).

TABLE 1 Paper characteristics.

Paper	Field	Method	Country
Chopko et al. (2021)	Learning Disability Organisation and Computer Science	Coproduction and survey	United Kingdom
Dahmen et al. (1982)	Health	Group comparison	Germany
Lee et al. (2020)	Computer Science	Narrative review	United States
Marriott et al. (2021)	Computer Science	Narrative review	United States
Wu et al. (2023)	Computer Science and Cognitive Disability	Interview	United States
Wu et al. (2021)[a]	Computer Science and Cognitive Disability	Group comparison and interviews	United States
Wu et al. (2021)[a]	Computer Science and Cognitive Disability	Newsletter	United States

[a]Publications use the same data.

Paper characteristics

The included papers came from the fields of health, computer science and disability rights. Five of the seven papers were from the United States. Two papers reported the same data and results, see Table 1. Hereafter these papers will be treated as one study.

Narrative synthesis

Information was extracted from included studies relating to aphasia, DLD, data visualization idioms, task (see, Table 2) and guidance (see, Table 3) and organised in a data extraction form. Textual descriptions of each are addressed in turn in this section.

Aphasia

Aphasia was directly studied in just one study (1/6) (Dahmen et al., 1982). This was an empirical study exploring disorders of calculation. The study found that visual representations of numbers (e.g., four dots in a circle to represent the number 4) supported comprehension in people with aphasia, except for those with Wernicke's aphasia. Dahmen et al. (1982) suggested that people with Wernicke's aphasia experience difficulties in processing visual information.

DLD

No papers in the scoping review explicitly addressed adults with DLD. Five studies (six papers) described participant groups that could include people with DLD (Chapko et al., 2021; Lee et al., 2020; Marriott et al., 2021; Wu et al., 2021; Wu et al., 2023). These studies may inform the search for practices that support effective visualization and as such have been included.

One paper described a participant with developmental delay and sensory processing disorder (Wu et al., 2023) a description that may represent a profile similar to a developmental language difficulty. Others described the participant group more generally as people with disabilities, disabled adults, intellectual developmental disabilities (Chapko et al., 2021; Lee et al., 2020; Wu et al., 2021; Wu et al., 2023) and included participants with CALDs described as a range of disabilities that include 'language, reading and writing' (Marriott et al., 2021, p. 49).

Most of these papers (5/6) were published in the field of computer science or were collaborations between computer science and design fields. One was a collaboration between a disability group and computer science (Chapko et al., 2021). Two of the papers in this group were narrative papers and as such did not report participant data. Instead, they described a particular aspect of the field such as the lack of inclusive data visualization (Lee et al., 2020; Marriott et al., 2021). Two were interview studies (Wu et al., 2021, 2023) that explored people's experiences and understanding of data visualization. The final paper described the process of codesigning visualization (Chapko et al., 2021).

Data visualization idioms and tasks

A number of different visualization idioms (Munzner, 2014) were described across the six studies: classic charts (pie, bar); maps; health apps; stars for film reviews; shapes (dots), physicalisations (beads on a string); and multimodal visualization (e.g., interactions with visualization via speech and touch).

The tasks that participants carried out with visualization were described in 4/6 studies. Some studies described

TABLE 2 Participant and data visualization characteristics.

Paper	Participant group	Number of participants	Data visualization idioms	Task
Chopko et al. (2021)	Learning disabilities	8	Bar charts, pie charts	Understand data Express data
Dahmen et al. (1982)	Aphasia, right hemisphere damage and controls	100	Numbers visualised; Shapes	Understand data
Lee et al. (2020)	People with disability	n/a	Examples of physicalisation, personalised: Beads on strings Examples of multimodal: Sketch Insight (pen and touch), Orko (speech and touch)	n/a
Marriott et al. (2021)	Visual, cognitive (incl. language) and motor disabilities	n/a	n/a	n/a
Wu et al. (2023)	Intellectual disability, verbal and nonverbal autism, cerebral palsy foetal alcohol syndrome, Williams syndrome, developmental delay and Sensory Processing Disorder	15	Weather charts; bar charts; film reviews with star ratings; health app	Meta understanding of data Use of data
Wu et al. (2021)	Intellectual disability, Autism and controls	24	Line graphs; bar charts; pie charts; stacked bar charts; tree maps. Embellishments were abstract, chart junk or icons	Understand data

more than one task. Tasks predominantly explored the *understanding* of data presented by the visualization (3/4) (Chapko et al., 2021; Dahmen et al., 1982; Wu et al., 2021). One paper asked co-researchers with learning disabilities to *express* data in visualizations (Chapko et al., 2021). Perhaps of most interest to the research questions for this review, the final paper (Wu et al., 2023) explored participants' *use* of data visualizations that is, whether seeing data visually, such as stars on film reviews, led to decisions or actions. This paper also explored the barriers to the use of data visualizations.

Key findings: What is known about data visualization for language disabilities

One study has considered people with aphasia (Dahmen et al., 1982). Nothing has been reported regarding data visualization specifically for adults with DLD.

In the absence of literature about language disability, we considered the information that does exist, that is, language disability in the context of learning disabilities. Findings from interviews (Wu et al., 2023), showed that people with learning disabilities, including those with language disabilities, did make use of personal data. It was used for self-advocacy (e.g., measuring and demonstrating change); social understanding (e.g., collecting and analysing short video clips); activities of daily living (e.g., checking the weather before leaving the house); and decision making (e.g., to stop listening to music if the hours of listening were too high). In some cases, carers were monitoring personal data about a participant.

Cognitive and emotional barriers have been identified for people with learning disabilities using data visualizations (Wu et al., 2023). Cognition is a barrier for several reasons: data are abstract; no education or training is provided for understanding data; and interacting with data requires cognitive skills such as retention and recall.

TABLE 3 Guidance for effective visualizations for people with intellectual disabilities.

Guidance	Author	Example
Reduce abstraction	Marriott et al. (2021)	No example provided
Use a multimodal approach	Lee at el. (2020)	'Use multiple modes of input such as touch, pen, speech, natural language and gesture to allow a person to interact and control the system' p. 87
Design for mobile devices	Lee at el. (2020)	To be inclusive, data visualization designers should design for mobile devises as 'Smartphone ownership has surpassed PC ownership' (p. 85) and interaction mechanisms on a mobile and PC are different.
Consider guided explorations of data	Marriott et al. (2021)	'Explicitly scaffold understanding' p. 49
Use tangible data	Marriott et al. (2021)	'Alternative novel approaches should be considered, such as … the use of tangibles and iconicity to reduce abstraction' p. 49
Use familiar metaphors	Wu et al. (2021)	'People build more natural associations between certain concepts (e.g., dollar sign and spending) than they do with others (e.g., stick figure and population) due to acquired familiarity' p. 12
Make data personal	Lee et al. (2020); Wu et al. (2023)	'Data becomes most meaningful when it is relevant to the individual and addresses a problem or achieves a goal of their personal interest' (Wu et al. 2023, p. 14)
Humanise data	Wu et al. (2023)	'Cognitively accessible visualization should humanise data, finding the connection between numbers in the graph and the people who are viewing it' p. 15
Avoid pie charts	Wu et al. (2021)	'People with IDD were more than twice as accurate with stacked bar charts than pie charts.' p. 9

Additionally, data analysis is currently conceived as a task for a lab or classroom and not for everyday decision making. Emotional barriers were described as an avoidance of data because of previous experiences of negative stereotypes of disability in data. As a response, Wu and colleagues called for cognitively accessible data visualization through personalising and humanising data. This can be achieved using physical (Wu et al., 2023) or tangible personal data (Lee et al., 2020). These studies also argue that physical or tangible examples of data visualization also support data agency.

Guidelines for effective visualization for people with language disabilities

Although no guidance exists for people with aphasia and DLD, four of the included studies outlined guidance or recommendations for creating data visualization for people with language disabilities *as part of* learning disabilities (Lee et al., 2020; Marriott et al., 2021; Wu et al., 2021, 2023), see Table 3. Recommendations from these papers could be extrapolated to have bearing on people with language disabilities.

The guidance suggests accessible visualization can be created in two ways: (1) by reducing the processing load and (2) by increasing the personal relevance of the data visualizations. The processing load can be reduced by using concrete images or tangible objects and familiar metaphors. For example, some symbolic metaphors are universally recognised (red cross for no/forbidden) and others are not (man walking out a door to indicate where to click to leave a webpage). The exposure to detailed data in visualizations can be staged and thereby scaffolded, either by a person guiding the reader or by interactive features such as sliders or zoom functions. Data can be more personally relevant by identifying yourself in a data set. Data can be more accessible if they are someone's own data for example, health data (steps, heart rate) or usage data (screen time, home energy use). Data that gives insight into a personal story may be more accessible because they humanise data, showing connection between people and their lives (see, Lupi & Posavec, 2016).

It should be noted that this guidance may conflict with that for improving accessibility for people with visual impairments such as the use of higher contrast, more abstract symbolisation, and removal of reliance on colour.

DISCUSSION

Summary of evidence

Research exploring the use of data visualization for people with language disabilities is scant. No studies were found that explicitly investigated data visualizations for adults with DLD. One study, published more than 40 years ago, explored how people with aphasia process data visualization for numbers. This represents a fundamental gap in knowledge, meaning data visualizations are not intentionally made accessible to a significant proportion of the adult population.

What is known

The few studies included were predominantly found in computer science accessibility literature for adults with intellectual disability where some participants had language disabilities.

In the health literature, there is a focus on visual materials to support communication where vision bolsters some of the impaired language processing (Pierce John et al., 2019; Sowerbutts & Finer, 2019). For example, training to support conversation in communication disabilities to reveal the competence of people with communication disability promotes using visual supports (Simmons-Mackie et al., 2016). Excluded papers explored the preferences of people with aphasia for different visual characteristics such as the preference for coloured drawings or photographs over icons (Knollman-Porter et al., 2016; McKelvey et al., 2010; Noël, 2015; Rose et al., 2011). Grey literature advises the use of visual materials (graphic organisers, visual planners, charts, etc.) to support people with DLD (Archibald, n.d.) but evidence for supportive practice is limited (Sowerbutts et al., 2021). So, although there is research exploring the use of visual materials for people with aphasia, and advice to use visual materials for people with DLD, there has been no research exploring visualization of data or its use in decision making by people with language disabilities. Data visualizations are configurations of multiple data (not written communication) and inherently more complex. Given this difference, the research gap is perhaps unsurprising.

Adults with DLD are not a well conceptualised, recognised, supported or researched group (Botting, 2020). There are mixed reports of success and challenges of people with DLD in adulthood, meaning it is important to consider this population (Hagen et al., 2023). In this review, consideration for people with DLD when designing data visualization was only found when language difficulties were grouped with IDD or CALDs. DLD research suggests that while children with DLD sometimes show difficulties with general cognitive skills, this may fluctuate and be less pronounced in adulthood (Botting, 2020). Data visualization is generally designed to reduce the reliance on working memory by externalising cognition. Despite this, specific cognitive skills such as working memory are an issue for most individuals with DLD (Henry & Botting, 2017), and this may impact data visualization understanding. As such, practices that support populations where cognition is impaired to access data visualization may be useful in understanding the accessibility needs of adults with DLD.

For most people with aphasia (75%), the message they most want the public to receive is that aphasia does not affect intelligence (Bennington et al., 2024). Aphasia is conceived as masking competence, that is, the aphasia hides the competence of the person and can be revealed by the skill of the conversation partner (Kagan 1998). However, studies have shown people with aphasia can also have difficulties with specific cognitive functions such as working memory (DeDe et al., 2014), attention (Murray, 2012), inhibition and problem solving (Suleman & Kim, 2015). It has been suggested that this makes them more likely to make a quick intuitive decision than a slower deliberated one (Suleman & Kim, 2015). A cognitive model of decision making with visualizations highlights that working memory takes a high load in contemplative decisions, that it does not take in easy, automatic decisions (Padilla et al., 2018). Although people with communication disabilities are competent adults, specific cognitive difficulties are likely to co-occur with language disabilities and are likely to affect decision making. There is potential for data visualizations, if inclusively designed, to support language and cognitive processing to enable adults with communication disabilities to make considered everyday decisions and reveal the competence of this group.

Tasks in data visualization

The tasks that users undertake with data visualization are of interest. Task can tell us both what the data are being used for and what skills are required. Published taxonomies of visualization tasks describe low-level tasks (such as identifying the range represented) and high-level tasks (such as sensemaking) (Amar et al., 2005; Brehmer & Munzner, 2013). Users need the skills to read or decode data visualizations, skills such as identifying the direction of a trend or the highest and lowest values. Studies found that chart type affected performance in these low-level tasks, for example, users with IDD were better at decoding key information from stacked bars than pie charts (Wu et al., 2021).

What practices support effective visualization

The studies included in this review predominantly explored understanding of existing data visualization for users with cognitive disabilities. The included papers highlighted an equity issue and called for more research into inclusive data visualization design for people with CALDs, emphasising that existing guidelines are not informed by research (Marriott et al., 2021). This review draws attention to the lack of research addressing the needs of people with language disabilities in using data visualizations. There are teams addressing the accessibility of data visualizations more generally. One example is Chartability: guidelines to developers for creating accessible data visualization for people with disabilities (Elavsky et al., 2022). We hope that future work will design data visualization with the needs of people with language disabilities in mind and this is likely to require new guidance. For example, guidance for written and web-based materials for people with aphasia recommends the use of written and visual labels together, a belt and braces approach (Roper et al., 2018; Rose et al., 2012; Wilson et al., 2016). However, in the past, this approach to data visualizations has been criticised with negative terms such as 'chartjunk' describing redundant, doubling up of information (Tufte, 2001). There has since been a movement to frame purposeful non-data design elements more positively (Parsons & Shukla, 2020). A key consideration going forward is how important information is foregrounded and how to orientate people with language disabilities to data in visualizations.

Future research

We need data visualization that supports people with language needs in social participation: civic engagement, employment and education (Wu et al., 2023). There is potential for data visualization to support people with language disabilities in decision making if visualizations are designed with language needs in mind. Accessibility could be achieved through greater personalisation, physical or tangible data, designing for mobile devices and humanising data (Lee et al., 2020; Marriott et al., 2021; Wu et al., 2021, 2023). To achieve this, research is needed that illuminates how people with language disabilities currently use data visualizations and what the barriers and facilitators are. Current guidance for cognitive disabilities could be tested with this population but it may be that new guidance is needed on how to design data visualizations that are accessible to a population with language disabilities.

Clinical implications

For people with disabilities to live independent lives, society needs to adjust to allow equal access to information and services (Oliver, 2013). Data visualization is now ubiquitous in our everyday decisions (Wu et al., 2023), typically on a smartphone in our pockets (Lee et al. 2020 et al., 2020). For example: How do I get there? (map data); How long will it take? (travel data); What are other's experiences of this product—should I buy it? (shopping reviews); Will I need a warm jumper? (weather data). If we are to enable equal access to participation, this gap in knowledge must be addressed. The process of this review has brought this literature from the field of computer science into the purview of readers outside of the computing domain, with a view to integrating relevant literature for a wider audience with interests in language disability.

Limitations

Few studies were found that met the inclusion criteria, even after the criteria were widened to include participant groups with cognitive disability. The small number of existing studies give only preliminary understanding of where limitations are in existing data visualization designs. We may need fundamentally new solutions to create inclusive data visualization for people with communication needs.

The studies were independently judged against the inclusion criteria by two authors at full text screening, but the abstract screening and data extraction was carried out by one author only, which may introduce bias.

As this was a scoping review, the quality of the papers was not assessed. Papers included were mostly qualitative and/or exploratory and two papers offered a narrative discussion, without empirical data, calling for more research in this area. This is perhaps indicative of the early stage of the research in this area.

CONCLUSIONS

Research on inclusive data visualization for users with language disabilities has not been published. However, this review has identified a small body of literature on how data visualization is understood and used by people with aphasia and developmental language disabilities in the context of wider learning disabilities.

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CONFLICT OF INTEREST STATEMENT

The authors report no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

ORCID

Niamh Devane https://orcid.org/0000-0001-8448-1478
Nicola Botting https://orcid.org/0000-0003-1082-9501
Madeline Cruice https://orcid.org/0000-0001-7344-2262
Jo Wood https://orcid.org/0000-0001-9270-247X

ENDNOTES

[1] We have chosen to use the term communication 'disability' throughout this work in preference to language 'impairment'. This seeks to reflect the barriers affecting participation in society which extend beyond an individual medical diagnosis to consider also the environmental and attitudinal context within which communication is taking place (United Nations, 2020).

[2] To describe the academic field of data visualization the American spelling is adopted here. All other uses of 'visualise' use the English spelling. The singular 'visualization' describes a process of encoding data visually, interpreting visual output, as well as the output itself.

[3] Searches were re-run on 15 January 2024 with a wildcard in physicali?ation. No new studies that met criteria were returned.

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SUPPORTING INFORMATION

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