

Accessibility Research in Digital Audiovisual Media: What Has Been Achieved and What Should Be Done Next?

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ABSTRACT

The consumption of digital audiovisual media is a mainstay of many people's lives. However, people with accessibility needs often have issues accessing this content. With a view to addressing this inequality, there exists a wide range of interventions that researchers have explored to bridge this accessibility gap. Despite this work, our understanding of the capability of these interventions is poor. In this paper, we address this through a systematic review of the literature, creating a dataset of and analysing $N = 181$ scientific papers. We have found that certain areas have accrued a disproportionate amount of attention from the research community – for example, blind and visually impaired and d/Deaf and hard of hearing people account for 93.9% of papers ($N = 170$). We describe challenges researchers have addressed, end-user communities of focus, and interventions examined. We conclude by evaluating gaps in the literature and areas that could use more focus on in the future.

CCS CONCEPTS

• **Human-centered computing** → **Accessibility technologies**.

KEYWORDS

Accessibility, systematic literature review, audiovisual, digital media, dataset

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1 INTRODUCTION

Audiovisual media pervades everyday life – we encounter TV broadcasts, films, and streaming content as part of our daily lived experience. The consumption of audiovisual media is a vehicle through which we engage socially, e.g. through shared viewing experience; civically, e.g. through access to news and current affairs; and culturally, e.g. through film and television series which embody human values and traditions. Access to media is, then, integral to participation in modern society, “*vital to informed political knowledge*” [153] and critical to maintaining contact with the world beyond our surroundings.

Despite its importance, audiovisual media and its enabling technologies are not always accessible. Audiovisual media itself is intrinsically complex – not only do audio and visual information present access challenges, but the inherent complexity of their combination can introduce further cognitive [190] and language [30] barriers. Further, while most media is currently consumed with conventional technologies, such as television [78] and smartphones [213], advances have and will introduce novel ways of enjoying audiovisual media – e.g. virtual, augmented and mixed reality (VR/AR/MR) [116, 125, 145]. While these technologies might afford new possibilities in terms of access, they also risk excluding users if their design is not considered with access at their core. Given the shift we currently see in the field of how audiovisual media is created and consumed, we are faced with an important moment to reflect on the accessibility work the community has done to understand how to address future challenges.

According to a review published by Vatavu [201] on media accessibility research at IMX/TVX found that only 4.2% of papers addressed users with disabilities. Although recent interventions for hard of hearing (DHH) people [207], blind and visually impaired (BVI) [219], and users with intellectual and developmental disabilities (IDD) [190], highlight an important avenue of research, we still see an under-representation. In this paper, we aim to extend this work and understand the current state of accessibility research in our field and set a direction for its future. To this end we have conducted a systematic literature review (SLR) focusing on accessibility interventions for digital audiovisual media, finding 181 papers spanning a 27-year period (1996–2022). Modelled on prior SLR of accessibility research [44, 109], we manually coded these papers

focusing on the *accessibility challenges* faced by disabled communities (type of content, viewing device, viewing context, type of challenge), what *disabled communities* are included (community of focus, participant groups, use or proxies and ability-based comparison), and what *accessibility interventions* were explored (user study method and location, participatory design, contribution type, and type of intervention). By focusing on these categories, we answer the following research questions:

- RQ1: What are the main accessibility challenges faced by people with disabilities when accessing digital audiovisual media?
- RQ2: Who does accessibility research in audiovisual media focus on?
- RQ3: What interventions are used to help support different accessibility needs?

This paper has three main contributions: (1) a dataset of 181 coded papers on accessibility interventions for digital audiovisual media in line with the PRISMA 2021 guidelines [162]; (2) an overview of research trends, analysis of areas that are over- and under-represented in the scientific literature, and identification of how this research is conducted and with what communities; (3) recommendations for future research, including areas which could use more attention and methodological aspects.

2 METHOD

We systematically reviewed scientific literature using the PRISMA method [162], following additional guidelines from Silva and Frâncila Weidt Neiva [188] and Siddaway et al. [187]. We first consider the scope of the SLR by defining requirements for the papers, secondly we discuss the steps involved for the creation of the dataset, and thirdly we describe the qualitative and quantitative analysis we conducted.

2.1 Scope

Access to novel interactive media experiences cannot be left as an afterthought. To this end, it is vital that we understand and embody inclusive design practices to accommodate for diverse accessibility needs. Prior work surfaces access challenges across the technology spectrum – from the interaction challenges for TV [19], to VR [125], affecting people with visual [213], hearing [40], cognitive [205], and motor impairments [89]. While much research has been published about individual accessibility interventions, there has so far been no broad survey of the literature that gives a general understanding of what this field has explored, and the gaps that currently exist in our knowledge of accessibility challenges and interventions. Within the broader scope of accessibility in Human-Computer Interaction (HCI), Mack et al. [109] have conducted a systematic review at *ACM CHI* and *ACM ASSETS*, finding that the presence of accessibility research at CHI has increased steadily, accounting for around 8% of all papers published in 2019, as well as noting a clear deficit in certain areas. There have also been more targeted reviews that examined specific communities, such as Brulé et al. [24] exploring scientific papers published on technologies designed for people with visual impairments, or Bhowmick and Hazarika [18] exploring patterns, themes, and active research communities addressing assistive technologies for people with visual impairments. Additionally, there have been overviews of specific

accessibility interventions, such as collaborative technologies for children with special needs [15], or reviews of specific interactions with media technologies, such as eye tracking research among the DHH community [2]. The focus of our work, however, aims at examining literature on accessibility interventions, which includes a wide range of communities and technologies. This differs with previous reviews, as the scope is focused on a subset of accessibility technologies, going into greater depth on this particularly timely and relevant topic. Therefore, to better focus this SLR and answer our research questions, we have limited our scope specifically to interventions which improve the accessibility of audiovisual media, and we have defined three requirements for our SLR:

- (1) **Digital audiovisual media** – we have limited our scope to digital audiovisual media. This requirement excludes any paper that explores issues in non-digital media, such as live performances (e.g. [199]), and media that does not have both audio and visual components, such as radio broadcasts (e.g. [225]).
- (2) **Accessibility interventions** – the eligible paper must address an intervention or interventions that aid in making the piece of media more accessible. These include such interventions as subtitles (e.g. [70]), audio description (AD) (e.g. [92]), second screen aids (e.g. [207]), audio and/or video manipulation (e.g. [42, 185]), or customization (e.g. [86]).
- (3) **Media content accessibility** – the eligible paper must address the accessibility of a piece of content, not the platform on which the content is consumed (e.g. [192]) or any interactions with said platform (e.g. [144]).

2.2 Dataset Creation

We used the guidelines outlined by Siddaway et al. [187] to generate our dataset of scientific papers on the topic of digital audiovisual media accessibility, which includes *identification* of papers, *screening* for potential inclusion, and determining *eligibility* for inclusion. Additionally, we conducted reference *snowballing* following guidelines by Wohlin [227]. Figure 1 summarises the process.

2.2.1 Identification. With the goal to find literature in HCI and digital audiovisual media accessibility, we chose to conduct our search using three major electronic databases for Computer Science and HCI research: the ACM Digital Library, SCOPUS, and IEEE Xplore. These databases offer a wide range of publication venues, including CHI and ASSETS, which are the two most popular venues for accessible computing [109]. Through an iterative approach, we chose to use generic truncated keywords, such as “*access**” and “*impair**”, as opposed to specific terms, such as “*deaf**”, as to not bias the search with our own terming. To focus the search towards audiovisual media, we also included other relevant keywords, such as “*video**”, “*television**”, and “*audiovisual**”. Initial searches using these keywords returned papers on areas we were not relevant, such as video games, so we excluded them in our search. While much work is being done with video game accessibility, we believe that video games belong to a different class of entertainment applications than the conventional audiovisual media we focused on in terms of consumption, user engagement, and interactivity of the content. We focused our search on the title, abstract and keywords of the papers, as testing with full-text search resulted in a large search

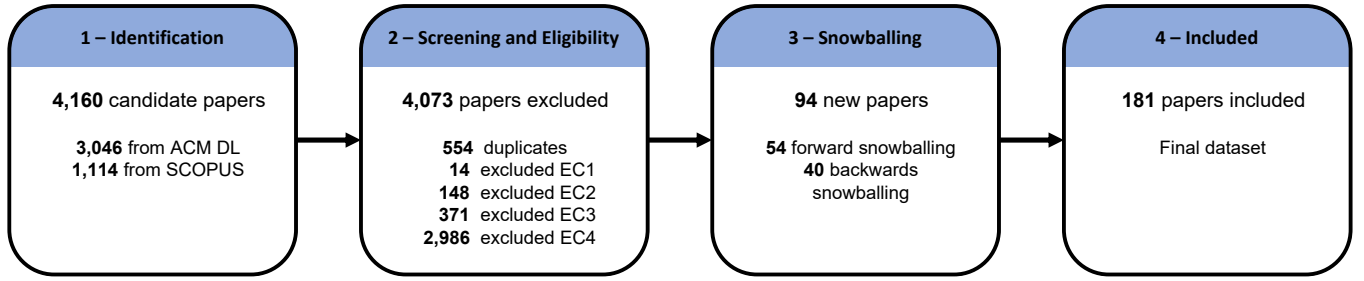


Figure 1: Flowchart summarizing the creation of our dataset.

space, including many false positives. The final search query, below, for the ACM DL returned 3,046 papers.

```

Title:((video OR tv OR television OR broadcast* OR
audiovisual OR "audio visual" OR "audio-visual") AND
(access* OR disab* OR impair*) AND NOT (game OR
games OR videogame OR videogames OR "video game" OR
"video games"))
OR Abstract:((video OR tv OR television OR broadcast* OR
audiovisual OR "audio visual" OR "audio-visual") AND
(access* OR disab* OR impair*) AND NOT (game OR
games OR videogame OR videogames OR "video game" OR
"video games"))
OR Keyword:((video OR tv OR television OR broadcast* OR
audiovisual OR "audio visual" OR "audio-visual") AND
(access* OR disab* OR impair*) AND NOT (game OR
games OR videogame OR videogames OR "video game" OR
"video games"))
  
```

Running the same query on SCOPUS and IEEE Xplore resulted in significantly more results, with over 75,000 for SCOPUS and over 17,000 for IEEE Xplore. This high number of results is likely due to using common keywords (e.g., “video”) and truncated keywords (e.g., “access*”). To deal with this large number of results, we limited the venues searched by having an author go through every venue in the database filter with over 25 papers and manually checked the 25 most relevant papers using the built in relevancy sort. A venue was excluded if less than 10% (≤ 3) of the 25 papers were deemed relevant. This resulted in the following final search query for SCOPUS, which returned 1,114 papers:

```

TITLE-ABS-KEY((video OR tv OR television OR broadcast* OR
audiovisual OR "audio visual" OR "audio-visual")
AND (access* OR disab* OR impair*)
AND NOT (game OR games OR videogame OR videogames OR "
video game" OR "video games"))
AND (LIMIT-TO(EXACTSRCTITLE, "ACM International
Conference Proceeding Series") OR LIMIT-TO(
EXACTSRCTITLE, "Communications In Computer And
Information Science") OR LIMIT-TO(EXACTSRCTITLE, "
Conference On Human Factors In Computing Systems
Proceedings") OR LIMIT-TO(EXACTSRCTITLE, "Procedia
Computer Science"))
OR LIMIT-TO (EXACTSRCTITLE, "Conference on Computers and
Accessibility") OR LIMIT-TO(EXACTSRCTITLE, "
Interactive Experiences for TV and Online Video") OR
LIMIT-TO (EXACTSRCTITLE, "Interactive Media
Experiences") OR LIMIT-TO(EXACTSRCTITLE, "European
Conference on Interactive TV and Video") OR LIMIT-TO
(EXACTSRCTITLE, "IEEE Transactions On Multimedia")
OR LIMIT-TO(EXACTSRCTITLE, "Conference On Computer-
Supported Cooperative Work And Social Computing"))
  
```

Running a similar venue exclusion step on the IEEE Xplore database returned no relevant venues. This is likely due to accessibility research being primarily published elsewhere outside of IEEE venues, such as *ACM CHI* and *ACM ASSETS* being two of the largest venues [109]. Therefore, we chose not to use IEEE Xplore for the dataset creation. The two queries were ran on 02/09/2022 and returned a total of 4,160 papers ranging from 1925–2022.

2.2.2 Screening and Eligibility. To remove all papers that were not within our scope, we followed the PRISMA 2021 guidelines [162] and created four eligibility criteria (EC1–EC4):

- EC1: **Availability of text** – the full text of the paper must be available in English.
- EC2: **Peer reviewed research** – the paper must be a piece of peer reviewed research, which includes conference papers, journal articles, posters, etc.
- EC3: **Digital audiovisual media** – the paper must focus on digital audiovisual media.
- EC4: **Accessibility intervention** – the paper has to explore an intervention to increase the accessibility of the content.

We continued with a screening step, starting by removing 554 (13.3%, 554/4610) duplicate papers. We then considered the remaining papers and excluded papers based on the eligibility criteria EC1–EC4 (see Table 1). We initially checked titles and abstracts to quickly remove any irrelevant papers, erring on the side of caution when unsure to not remove a relevant paper. Following this, the full text of the papers was read to determine eligibility. A spreadsheet was created in which each paper was labelled as relevant or irrelevant, with irrelevant papers also including the EC that excluded it. For example, the high number of papers excluded by EC4 were due to not being about accessibility in general, with a high number of more technical topics including video processing [158] or video transcoding [105]. There were also papers that explored some aspect of accessibility and audiovisual media, but did not investigate the use of interventions to make the content more accessible, instead using the content in a medical context [21] or exploring some aspect of disability [166]. While many of these papers could have been excluded by EC3 or EC4, the high number of technical papers that had nothing to do with accessibility made it easier to initially filter and exclude by EC4. After completing the screening and eligibility check, $N = 87$ papers were deemed relevant.

2.2.3 Snowballing. Following the screening and eligibility review, we conducted a snowballing step as outlined by Wohlin [227], which

Table 1: The number of candidate papers excluded because of duplicates and by the Eligibility Criteria, as well as the number of resulting relevant papers.

Eligibility Criteria	Number of papers
Duplicate papers	554 (13.3%)
EC1 - <i>Availability of text</i>	14 (0.3%)
EC2 - <i>Peer reviewed research</i>	148 (3.6%)
EC3 - <i>Digital audiovisual media</i>	371 (8.9%)
EC4 - <i>Accessibility intervention</i>	2,986 (71.8%)
Total relevant papers	87 (2.1%)

identified a total of $N = 94$ new papers. We performed four iterations of forward and backward snowballing until no new candidate papers were identified. Each iteration followed the same screening and eligibility verification as mentioned in Subsection 2.2.2, with backwards snowballing initially relying on paper title, authors, and publication venues. We used Google Scholar for the forward snowballing. In cases where the information present on Google Scholar was insufficient for making a decision, the full text of the citing paper was studied. A total of 54 papers were identified through forward snowballing and 40 papers were identified through backwards snowballing. This puts the final total number of papers in our dataset to 181, with 87 (48.1%, 87/181) identified through the identification and screening steps, and 94 (51.9%, 94/181) through snowballing, which is in line with the expected proportion of papers obtained through snowballing [72].

2.3 Analysis

We qualitatively coded the $N=181$ papers in our dataset and analysed paper and participant counts over the 27-year period. We also extracted and examined keywords frequencies for all papers in our dataset. The qualitative coding was performed by two authors, and a Fleiss' Kappa inter-rater reliability (IRR) [57] calculation was performed. The results of the qualitative coding were compared to results reported by Mack et al. [109] on the state of the broader HCI accessibility field. We chose to compare to this paper because of its broad scope of HCI accessibility research ($N = 506$ analyzed papers), as well as the robust method used to construct and code the dataset. Other reviews we could compare against tend to have more narrow scopes, such as focusing on specific communities [24], technologies [15], or smaller venues [201].

2.3.1 Qualitative Analysis. To analyse the dataset, we first created a codebook, which was done by three researchers. The three researchers discussed the codes over a period of time, with a sample of 10 papers being coded at each iteration to better understand how that codebook would work. It is important to note that the creation of this codebook, along with the screening of papers and any analysis we have conducted, is subject to the inherent biases of the researchers, all of whom identify as white, cisgender male and female of European background. None of the researchers involved with the development and analysis of the dataset identify as disabled, with two researchers having prior experience doing

accessibility research. The codebook was generated using an iterative approach, with codes chosen to answer our research questions. The final codebook can be seen in Table 2, including 13 categories each with 2-11 sub-codes each. For most of the categories, except for the exclusive binary categories, more than one code could be applied to a paper. This causes the percentages used in Section 3 to have a sum that does not equal to 100%.

Of the 13 categories, 5 were developed by the researchers and 8 were adapted from Mack et al. [109]. The categories developed by the researchers aimed to understand the characteristics of current and past trends in audiovisual media accessibility interventions research. These include the context in which the media is being consumed – such as the device being used, the environment in which the viewer consumes the content, and type of content being consumed – the challenges faced by the users, and the accessibility intervention being researched. The categories adapted from Mack et al. [109] were used to compare with more general accessibility research, as well as generate insights into the user study methods and what communities research is focused on. Once the codebook was finalised, two researchers coded the papers with the second researcher coding a random sample of 10% ($N = 18$) of papers (see Table 2).

2.3.2 Quantitative Analysis. We programmatically analysed paper and participant counts, and keyword frequencies over the 27-year period. We calculated mean, median, IQR and SD values for the participant counts, as well as analysed them with regard to the community of focus, the participant groups, and the use of proxies and ability based comparison. For the keyword analysis, we extracted 660 unique keywords, of which 209 (31.7%, 209/660) occurred at least twice. A researcher manually went through the 209 keywords and grouped similar keywords – for example, the keywords “blind”, “blindness”, and “blind people” were all combined into a higher-order grouping “BVI”. Sixteen such groupings were created, with three of these to group British English and American English spelling of keywords (e.g., “personalisation” and “personalization”). Of the 181 papers in the dataset, 13 (7.2%, 13/181) contained no keywords.

3 RESULTS

We present the results of our analysis in terms of *accessibility challenges* addressed, *communities* and *participants* involved, *research methods* and *interventions*. Following this, we look at trends over the 27-year period and quantitative results from the keyword analysis.

3.1 Accessibility challenges addressed

To understand the kinds of accessibility challenges people with disabilities face when accessing digital audiovisual media, we analyze the context in which the media is consumed that researchers focused on. These included the *type of content*, *viewing device*, and the *type of challenge* the researchers address.

3.1.1 Type of content. As shown in Table 3, research in this field is relatively balanced between TV broadcast content (32.0%, 58/181), video-on-demand (30.9%, $N = 56$), and web video (24.9%, $N = 45$). Only one paper focused on live video (0.6%), which looked at allowing DHH students to pause and highlight subtitles during a live video stream of educational content [101]. Papers labelled as “other”

Table 2: The final codebook and the calculated pairwise agreement, Fleiss' Kappa IRR, and IRR interpretation level for each category. The IRR for each category sub-code was calculated and averaged.

Category	Codes	Multiple codes	Pairwise agreement	IRR	Level
Type of content	TV broadcast; on-demand video; web video; live video; other	Yes	72.2%	0.477	Moderate
Viewing device	Television; desktop; smartphone; tablet; big screen; other	Yes	88.9%	0.911	Almost perfect
Viewing context	General viewing; education; commercial; other	Yes	94.4%	0.660	Substantial
Type of challenge	Viewing video; hearing audio; reading subtitles; understanding speech; following narrative; image clarity; on-screen clutter; other	Yes	72.2%	0.493	Moderate
Community of focus	BVI; DHH; motor/physical impairment; autism; IDD; other cognitive impairment; older adults; general disability; other	Yes	83.3%	0.851	Almost perfect
Participant groups	No user study; people with disabilities; people without disabilities; older adults; specialists; caregivers	Yes	88.9%	0.781	Substantial
Use of proxies	Yes; no	No	94.4%	0.444	Moderate
Ability based comparison	Yes; no	No	94.4%	0.444	Moderate
User study method	Controlled experiment; survey; usability testing; interviews; case study; focus group; field study; workshop/design; other; none	Yes	66.7%	0.774	Substantial
User study location	No user study; near/at researcher's lab; participant's home, residence, or school; neutral location; online/remote; other	Yes	72.2%	0.775	Substantial
Participatory design	Yes; no	No	88.9%	0.654	Substantial
Contribution type	Empirical; artifact; methodological; theoretical; dataset; survey; opinion	Yes	77.8%	0.910	Almost perfect
Type of intervention	Subtitles; audio description; tangible device; sign language; audio or video manipulation; content personalization; customization; in-person assistance; second screen; other	Yes	77.8%	0.837	Almost perfect

accounted for 21.5% ($N = 39$) of all papers, which for the most part included papers where the authors do not specify the type of content their research is focusing on. These also include research on content not listed, such as immersive 360° video [23, 141, 190] or interactive audiovisual experiences that allow DHH and BVI users to hear colors or see sounds [32]. Papers with more than one code accounted for 7.7% (14/181) of all papers, mostly looking at web-based VOD platforms (42.9%, 6/14) or exploring TV accessibility features that applied to both TV broadcasts and VOD content (35.7%, 5/14).

3.1.2 Viewing device. When it came to viewing device, almost half of papers studied television (45.9%, 83/181), followed by desktop/laptop computers (32.6%, $N = 59$). A relatively smaller number of papers focused on smartphones (9.9%, $N = 18$), tables (6.1%, $N =$

11), and big screen viewing (3.9%, $N = 7$). An additional 26.5% ($N = 48$) of papers had the label "other", which, again, included papers where the viewing device was not specified by the authors, such as papers that focused on development of accessibility software or algorithms [178]. There were also papers that looked at other devices, such as research on the use of subtitles with virtual reality headsets [84], or the use of various haptic devices, including small tactile robots that move over a tablet [74].

A total of 27 papers (14.9%, 27/181) contained more than one viewing device. The codes that occurred together the most were "smartphone" and "tablet" (37.0%, 10/27), which is 55.6% (10/18) of all papers that looked at smartphones, and 90.9% (10/11) of those looking at tablets. The only paper that focused on a tablet without a smartphone device was Guinness et al. [74]. Smartphones

Table 3: The frequency of applied codes for *type of content*, *viewing device*, and *viewing context*.

Type of content	Papers with code	This code only	Viewing device	Papers with code	This code only	Viewing context	Papers with code	This code only
TV broadcast	58 (32.0%)	50 (27.6%)	Television	83 (45.9%)	66 (36.5%)	General viewing	148 (81.8%)	137 (75.7%)
VOD	56 (30.9%)	43 (23.8%)	Computer	59 (32.6%)	48 (26.5%)	Educational	14 (7.7%)	12 (6.6%)
Web video	45 (24.9%)	36 (19.9%)	Smartphone	18 (9.9%)	1 (0.6%)	Commercial setting	7 (3.9%)	2 (1.1%)
Live video	1 (0.6%)	1 (0.6%)	Tablet	11 (6.1%)	0 (0.0%)	Other	23 (12.7%)	19 (10.5%)
Other	39 (21.5%)	37 (20.4%)	Big screen	7 (3.9%)	1 (0.6%)			
			Other	48 (26.5%)	38 (21.0%)			

(37.0%, 10/27) and tablets (18.5%, 5/27) were also used heavily in conjunction with TV. Papers explored “desktop” viewing alongside with smartphones (29.6%, 8/27), tablet devices (25.9%, 7/27), and TV (18.5%, 5/27). For the most part, these papers explored some system that happen to work on multiple devices, such as a subtitling system for Arabic script that visualizes voice characteristics of the speaker [180] which worked on desktop, smartphone and tablet devices. Some papers, however, did utilize smartphones or tablet devices as a second screen to make the media on the main screen more accessible in some way, such as using a smartphone to display subtitles in a cinema [40, 63]. When it comes to the “other” label, the most common crossover was with TV (25.9%, 7/27), including a paper evaluating the use of AR sign language interpreter while watching TV by using a head-mounted displays [207], and a system that communicates the emotional state of a TV movie through environmental lighting, emotive subtitles, and mobile application [1].

3.1.3 Viewing context. The results for viewing context of the media were somewhat one-sided, with most papers being on general viewing (81.8%, 148/181), followed by education (7.7%, $N = 14$) and commercial settings (3.9%, $N = 7$). This is primarily due to research focusing on making audiovisual media accessible in everyday situations, such as at the viewer’s home [1, 65, 115]. Papers that focused on educational context tended to explore ways to improve or automate subtitling [86, 101]. One paper explored ways to make immersive video experiences accessible to support people with intellectual disabilities learn new skills [190]. Within commercial contexts, most papers focused on creating second-screen accessibility aids to make content more accessible in cinemas, such as through adding personal subtitles [40] or AD [213] using the viewers smartphone. Papers labelled as “other” (12.7%, $N = 23$) included research that did not explore a specific intervention, such as a general overview of subtitling practices and challenges faced by DHH YouTube content creators [104], or included a unique context, such as making security surveillance video accessible to BVI users [26].

3.1.4 Challenges addressed. As can be seen in Table 4, the most common challenges researchers addressed were viewing video (43.1%, 78/181) and reading subtitles (42.5%, $N = 77$). This comes mostly in the form of papers implementing AD to help BVI people [219], or ways to implement or improve subtitles [95]. Other challenges authors addressed include following narrative (19.9%, $N = 36$), hearing audio (12.2%, $N = 22$), and understanding speech

Table 4: The frequency of applied codes for *challenge addressed*.

Challenge addressed	Papers with code	This code only
Viewing video	78 (43.1%)	37 (20.4%)
Hearing audio	22 (12.2%)	3 (1.7%)
Reading subtitles	77 (42.5%)	49 (27.1%)
Understanding speech	17 (9.4%)	6 (3.3%)
Following narrative	36 (19.9%)	3 (1.7%)
Issues with image	10 (5.5%)	2 (1.1%)
Screen clutter	0 (0.0%)	0 (0.0%)
Other	37 (20.4%)	8 (4.4%)

(9.4%, $N = 17$). We included a code for “screen clutter” as a challenges, as an initial manual look through broader media accessibility literature included this challenge, such as research on dementia-friendly TV news broadcast, which found that clutter on the screen distracted viewers [60]. However, no paper in our dataset focusing on accessibility interventions attempted to address this challenge. The code “other” accounted for 20.4% of papers ($N = 37$) and included papers on increasing the understanding of emotional information [1] and papers on facilitating BVI to consume media content in group environments with personal AD using acoustically transparent headsets [115].

Papers could be labelled with multiple codes, with 73 papers (40.3%, 73/181) falling under this category. The most common pairing being “viewing video” and “other” (26.0%, 19/73), with multiple papers addressing both AD creation, such as through crowdsourcing [133, 135], and AD presentation [20]. The label “following narrative” mostly occurred with the “other” labels (91.7%, 33/36), with the most common pairings being “viewing video” ($N = 14$) and “reading subtitles” ($N = 12$). This is primarily due to most of these papers involving using subtitles and AD interventions to help people with disabilities follow the narrative either by having visual elements described, or by having speech and other audio elements textually represented. There were also multiple papers [63, 93, 122] that explored larger systems which included multiple interventions, such as applications that addressed “viewing video” and “reading subtitles” (12.3%, 9/73) by offering both AD and subtitles [63].

The section above analyzed the different challenges faced by people with disabilities when accessing audiovisual media, here we

Table 5: The frequency of applied codes for *community of focus* and *participant groups*. We also present the proportions for each category found by Mack et al. [109] to compare our findings with the broader field of HCI accessibility.

Community of Focus	Papers with code	Mack et al.	This code only	Mack et al.	Participant Group	Papers with code	Mack et al.	This code only	Mack et al.
BVI	83 (45.9%)	43.5%	70 (38.7%)	41.1%	People with disabilities	104 (81.9%)	84.7%	66 (52.0%)	44.9%
DHH	97 (53.6%)	11.3%	77 (42.5%)	8.5%	People without disabilities	51 (40.2%)	32.1%	20 (15.7%)	1.0%
Motor impairment	3 (1.7%)	14.2%	0 (0.0%)	11.7%	Older adults	7 (5.5%)	8.4%	1 (0.8%)	3.1%
Autism	0 (0%)	6.1%	0 (0.0%)	4.2%	Specialists	8 (6.3%)	17.0%	1 (0.8%)	1.9%
IDD	1 (0.6%)	2.8%	0 (0.0%)	1.6%	Caregivers	1 (0.8%)	9.4%	0 (0.0%)	0.8%
Other cognitive	6 (3.3%)	9.1%	0 (0.0%)	5.7%					
Older adults	8 (4.4%)	8.9%	2 (1.1%)	5.7%					
General disability	16 (8.8%)	9.1%	8 (4.4%)	6.1%					
Other	5 (2.8%)	9.1%	0 (0.0%)	4.0%					

look at the communities and participants involved in that research. This will include the *communities* the research is focusing on, *who participates* in user studies, and the *use of proxies* and *ability-based comparison* in those studies. We will be comparing our results to the broader accessibility research space, by looking at results from Mack et al. [109], to get a better understanding on who research in audiovisual media accessibility focuses and what gaps exist.

3.2 Communities and participants involved

3.2.1 Community of focus. When looking at the communities of focus within our dataset, see Table 5, the DHH (53.6%, 97/181) and BVI (45.9%, 83/181) communities stand out, accounting for 93.9% (170/181) of all papers. Other communities are under-represented in our dataset, with papers addressing “general disability” coming at a distant third (8.8%, $N = 16$), such as interactions to make web video more accessible in a learning environment [183], a web video player designed to reduce accessibility barriers [205], or a system designed to create accessible and personalized immersive media experiences [122]. These were followed by papers aiming to help older adults (4.4%, $N = 8$), people with other cognitive impairments (3.3%, $N = 6$), motor impairments (1.7%, $N = 3$), and IDD (0.6%, $N = 1$). The label for “autism” did not appear in our dataset, while appearing in 6.1% of all papers within the Mack et al.’s [109] dataset. We also applied the code “other” (2.8%, $N = 5$) to papers with communities of focus we did not have a label for, such as a paper on a device that would read subtitles out loud for BVI people and people with dyslexia [129], or a paper that evaluated a similar system of subtitle reading for people with reading difficulties more broadly [107].

Some papers (18.2%, 33/181) considered more than one community of focus. Only the BVI (84.3%, 70/83) and DHH (79.4%, 77/97) communities were mostly included as the sole communities of focus. Half the papers focusing on general disability (8/16) and two papers focusing on older adults (2/8) had those as sole communities of focus, with all other communities of focus only appearing with some other community. Those papers that considered multiple communities focused primarily on the DHH and BVI community pairing (30.3%, 10/33), with papers evaluating systems that included interventions for both communities, such as subtitles and AD [63, 205], or a paper by Chambel et al. [32] that presented visual information

in an auditory format and audio information in a visual format. Papers that involved more than one community tended to include the DHH community, which was paired with general disability (24.2%, 8/33), other cognitive and older adults (both 15.2%, 5/33), motor impairments (9.1%, 3/33), and the “other” label (6.1%, 2/33).

When comparing to community of focus findings by Mack et al. [109], the DHH community is proportionally over-represented in our dataset at 53.6% vs. their 11.3%. The BVI community is also slightly over-represented, however much less so (45.9% vs. 43.5%). Other communities are all proportionally under-represented in our dataset, as can be seen in Table 5, with motor impairment having the largest difference (1.7% vs. 14.2%), followed by autism (0.0% vs. 6.1%), which did not appear a single time.

3.2.2 Participant groups. Table 5 shows the frequency at which different participant groups were involved in user studies, where the percentages are calculated based on the 127 papers that ran some sort of user study (70.2%, 127/181). The majority of user studies included participants with disabilities (81.9%, 104/127), followed by people without disabilities (40.2%, $N = 51$), specialists (6.3%, $N = 8$), older adults (5.5%, $N = 7$), and a single user study that included caregivers (0.8%, $N = 1$). When it comes to papers that included more than one participant group, the most common pairing was people with and without disabilities (24.4%, $N = 31$). People with disabilities and specialists followed at a distant second (4.7%, $N = 6$), followed by people with disabilities and older adults occurring together in 3.9% ($N = 5$) of user studies, and people without disabilities and older adults (3.1%, $N = 4$). Other participant group pairings appeared either once, or did not appear in our dataset.

The paper counts are roughly in-line with the broader HCI accessibility community, with most participant groups being slightly proportionally under-represented. The most over-represented group in our dataset were people without disabilities (40.2% vs. 32.1%), and the most under-represented participant group were specialists (6.3% vs. 17.0%), caregivers (0.8% vs. 9.4%), older adults (5.5% vs. 8.4%), and people with disabilities (81.9% vs. 84.7%). When it comes to user studies with a single participant group, people with and without disabilities are slightly over-represented (52.0% vs. 44.9%, and 15.7% vs. 1.0%), while caregivers (0.0% vs. 0.8%), specialists (0.8% vs. 1.9%), and older adults (0.8% vs. 3.1%) are slightly under-represented.

Table 6: The frequency of applied codes for *study method* and *study location*. We also present the proportions for each category found by Mack et al. [109] to compare our findings with the broader field of HCI accessibility.

Study method	Papers with code	Mack et al.	This code only	Mack et al.	Study location	Papers with code	Mack et al.	This code only	Mack et al.
Controlled experiment	51 (40.2%)	11.5%	8 (6.3%)	11.5%	Near/at research lab	29 (22.8%)	27.3%	20 (15.7%)	19.5%
Survey/questionnaire	96 (75.6%)	1.3%	1 (0.8%)	1.3%	Home/residence/school	12 (9.4%)	28.9%	7 (5.5%)	17.8%
Usability testing	73 (57.5%)	41.7%	5 (3.9%)	9.6%	Neutral location	6 (4.7%)	6.7%	1 (0.8%)	3.1%
Interviews	48 (37.8%)	42.1%	1 (0.8%)	5.7%	Online/remote	21 (16.5%)	20.5%	16 (12.6%)	10.1%
Focus groups	13 (10.2%)	5.9%	2 (1.6%)	0.8%	Other	73 (57.5%)	41.1%	71 (55.9%)	28.1%
Case study	0 (0.0%)	4.0%	0 (0.0%)	0.2%					
Field study	0 (0.0%)	17.8%	0 (0.0%)	4.6%					
Workshop/design	15 (11.8%)	18.4%	0 (0.0%)	3.1%					
Other	0 (0.0%)	16.1%	0 (0.0%)	0.8%					

3.2.3 Proxies and ability-based comparison. Proxies were used in 10.2% (13/127) of all papers that included a user study, which is slightly higher than in the broader HCI accessibility community (10.2% vs. 8.0%). For the most part, proxies were used as stand-ins for the community of focus when giving feedback on a system or device prototype [1, 115, 205], with convenience sampling being a common reason. We also identified that 9.4% ($N = 12$) of user studies compared participants with and without disabilities, which is slightly lower than the Mack et al. [109] dataset (9.4% vs. 13.6%). Participants without reported disabilities were sometimes used to represent the control against which performance, preferences, or needs of the participants with disabilities were compared [54]. Some user studies also ran cross task performance, where participants with and without disabilities were placed in separate groups [76].

3.3 Research methods for accessibility in audiovisual media

We explore research methods used and how studies are conducted, looking at study methods, the location user studies took place in, use of participatory design (PD), and we report study sample sizes.

3.3.1 User study methods. As can be seen in Table 6, the majority of user studies conducted used questionnaires (75.6%, 96/127) and usability testing (57.5%, $N = 73$). Additionally, a relatively large numbers of studies employed controlled experiments (40.2%, $N = 51$) and interviews (37.8%, $N = 48$), with workshops and design sessions (11.8%, $N = 15$) and focus groups (10.2%, $N = 13$) being relatively less common. We included labels for case studies and field work in our codebook, however, our dataset does not include any papers that used these research study methods.

Of the 127 papers in our dataset that had a user study, 110 (86.6%) used more than one study method. The most common grouping of study methods was usability testing and questionnaire (21.3%, $N = 27$), with 12.6% of papers running these two methods as well as also including interviews ($N = 16$). Following closely were studies that ran controlled experiment and questionnaire (19.7%, $N = 25$), with 7 more papers additionally running interviews (5.5%). Furthermore, the next most common study method was running a controlled experiment with no other methods (6.3%, $N = 8$), which accounts for 47.1% (8/17) of all papers with a single user study method. All other combinations of methods appeared in fewer than 5% of papers.

3.3.2 User study locations. For the most part, we find that authors do not specify the location of their research, with 56.7% (72/127) of papers that report a user study being labelled “other”, which is mostly due to authors being unclear about the user study location. For example, Aydin et al. [11] mention recruiting BVI participants, screening the participants through a short phone interview, the monetary compensation the participants received, the laptop the usability testing took place on, and the procedure to run the study. The authors do not, however, ever explicitly mention where the study is taking place. Among papers that do mention the location the study took place in, 23.6% ($N = 30$) took place near or at the authors research lab, such as Kurzahls et al. [94] who, in their abstract, state they ran a “laboratory study”. The second most common location was “online or remote” (16.5%, $N = 21$), followed by at home, residence or school (9.4%, $N = 12$), and neutral location (4.7%, $N = 6$). Additionally, 12 papers (9.4%) ran studies in more than one location, with 5 papers having user studies ran both at a research lab and online (3.9%), and 4 in neutral locations and online (3.1%). When compared to the broader HCI accessibility community, the “other” label is quite a bit more common (57.5% vs. 41.1%). All other user study locations are under-represented, with “home, residence or school” having the largest gap (9.4% vs. 28.9%), followed by “online or remote” (16.5% vs. 20.5%), “near or at a research lab” (22.8% vs. 27.3%), and “neutral” location (4.7% vs. 6.7%).

3.3.3 Participatory design. Participatory design (PD) allows users of accessibility technology to be involved in the research process and directly interact with the proposed intervention, through helping understand challenges people with disabilities face [190] or taking part in the design process [205]. Within our dataset, 22 (17.3%) user studies papers adopted PD methods, which is higher than the Mack et al. [109] dataset (17.3% vs. 10.3%). User study papers that involved caregivers ($N = 1$), specialists ($N = 6$), and older people ($N = 4$) tended to use PD methods more often than not. PD always included either people with disabilities (81.8%, 18/22), older adults (9.1%, 2/22), or both (9.1%, 2/22). User studies involving people with IDD ($N = 1$), motor impairments ($N = 2$), and other cognitive impairments ($N = 3$) tended to use PD methods more often in their studies than other communities. Research focusing on BVI ($N = 11$) and DHH ($N = 9$) participants, as well as papers on general disability ($N = 2$), rarely used PD.

Table 7: User study participant count for the 124 papers that clearly reported a user study and a sample size (3 user study papers did not report sample sizes), broken down by community of focus and participant group.

Group	N	Median	Mean	IQR	Range
Overall	124	30.0	52.0	34.3	2-602
BVI	58	20.0	46.4	27.8	2-602
DHH	66	34.0	59.8	35.8	9-314
Motor	3	25.0	25.0	5.0	20-30
IDD	1	18.0	18.0	0.0	18-18
Other cognitive	5	25.0	62.4	10.0	18-219
Older adults	6	39.0	64.7	11.8	16-219
General disability	4	17.5	43.0	34.5	4-133
Other	2	115.5	115.5	103.5	12-219
People w/ disabilities	102	30.0	48.9	37.0	2-602
People w/o disabilities	50	34.0	73.8	34.5	12-602
Older adults	7	30.0	30.4	17.0	16-45
Specialists	8	25.5	35.8	27.5	4-133
Caregivers	1	18.0	18.0	0.0	18-18

3.3.4 Sample sizes. We analyzed user study sample sizes in the 124 user study papers that clearly reported a sample size, which can be seen in Table 7. For instance, Konstantinidis et al. [93] report running a user study, as well as reporting some user results, but do not report the total number of participants. Therefore, this paper is excluded from our analysis. Overall, the median number of participants in a user study was 30 ($M = 52.0$, $IQR = 34.3$, $SD = 73.5$), which is higher than the median sample size (18) in the broader HCI accessibility community [109]. User studies that included either people with disabilities or older adults have a slightly higher median of 29.5 ($Mean = 47.7$, $IQR = 39.0$, $SD = 68.5$). The median number of participants ranges from 18 (IDD) to 115.5 (Other). When it comes to participant groups, the median number of participants ranged from 18 (Caregivers) to 34 (People without disabilities). Note that there was a small number of user study papers for most communities of focus and participant groups, with only papers on the BVI (58) and DHH (66) communities, as well as user studies involving people with (102) and without (50) disabilities having double digit paper counts. These low paper counts make analyzing the sample sizes for the other communities of focus and participant group more challenging, since we cannot state much with certainty these sample sizes are truly representative.

3.4 Accessibility interventions

So far, we analyzed the challenges faced by people with disabilities, the communities and participants involved in research, and the research methods used to explore these challenges. Here, we outline the different interventions authors have researched and how these contribute to HCI literature.

As can be seen in Table 8, the most explored accessibility interventions were subtitles (48.1%, $N = 87$) and AD (33.1%, $N = 60$), which accounted for 77.3% (130/181) of all papers in the dataset. Breaking down the interventions used based on the community of focus, we find that 82.5% ($N = 80$) of papers addressing the DHH

Table 8: The frequency of applied codes for type of intervention.

Type of intervention	Papers with codes	This code only
Subtitles	87 (48.1%)	48 (26.5%)
Audio description	60 (33.1%)	35 (19.3%)
Tangible device	11 (6.1%)	1 (0.6%)
Sign language	9 (5.0%)	2 (1.1%)
Audio/video manipulation	25 (13.8%)	9 (5.0%)
Content personalization	2 (1.1%)	0 (0.0%)
Customization	25 (13.8%)	0 (0.0%)
In person assistance	0 (0.0%)	0 (0.0%)
Second display	14 (7.7%)	1 (0.6%)
Voice commands	0 (0.0%)	0 (0.0%)
Other	63 (34.8%)	11 (6.1%)

community involved the use of subtitles, and 67.5% ($N = 56$) of BVI papers using AD. Subtitles were also heavily used in research that focused on general disability ($N = 12$), other cognitive impairments ($N = 4$), motor impairments ($N = 2$), and older adults ($N = 4$). On the other hand, AD was mostly confined to BVI research, with only 4 papers exploring its use outside the BVI community. Figure 2 shows how different interventions were used with different communities of focus. Other popular interventions were audio and/or video manipulation (13.8%, $N = 25$), such as a paper exploring the use of zoom magnification to help people with central vision loss [41], and customization (23.8%, $N = 25$), such as a system allowing the viewer to customize aspects of ASL interpreting [97]. Second displays (7.7%, $N = 14$), tangible devices (6.1%, $N = 11$), sign language interpreters (5.0%, $N = 9$), or content personalization (1.1%, $N = 2$) were not widely explored. Papers were labelled as “other” ($N = 63$) if the authors explored an intervention that we had not listed, such as allowing the user to interact with a video to bookmark sections to go back in case they had issues understanding the content [205]. We find that 40.9% ($N = 74$) papers explored more than one intervention, with the most common combinations were the use of AD and subtitles with the “other” label. For example, Matousek et al. [112] explored a system that uses subtitles to generate highly intelligible text-to-speech dubbing of content for DHH people, so that speech is easier to distinguish from other sounds. Other pairing of interventions mostly (77.0%, 57/74) saw the use of subtitles and/or AD with some other interventions. Looking at research contribution types, as outlined by Wobbrock and Kientz [226], most of the papers in our dataset fall into artifact (56.4%, $N = 102$), empirical (44.8%, $N = 81$), and theoretical (30.9%, $N = 56$) contributions.

3.5 Trends and keywords

Our analysis of qualitative coding in the previous sections looked at the overall state of research. Here, we are going to look at the evolution of accessibility research over the 27-year period, analysing how communities of focus, challenges and interventions, and user studies have shifted over time. In order to smooth out year-on-year changes and generate a more general idea of trends, we binned papers into five time periods: 1996–2002, 2003–2007, 2008–2012,

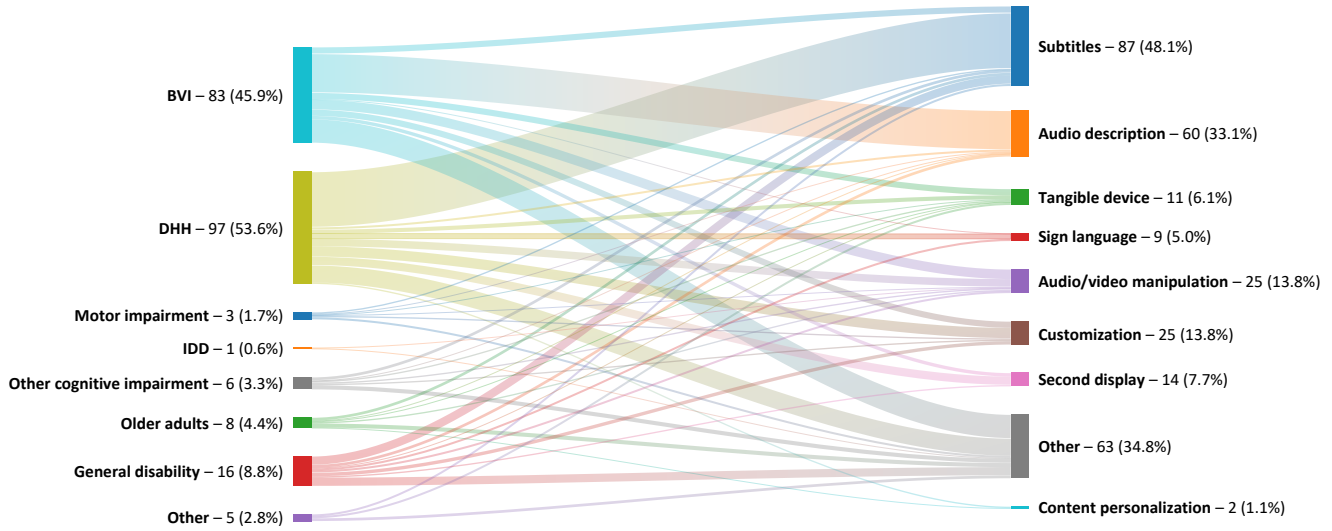


Figure 2: Sankey diagram representing the *type of intervention* explored different *community of focus*.

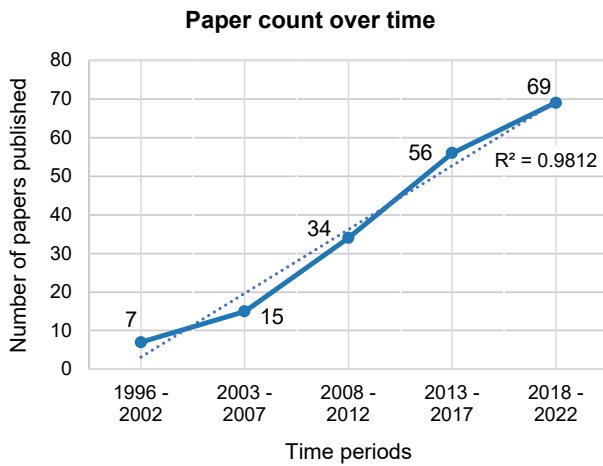


Figure 3: Number of papers on audiovisual media accessibility published over time, showing the number of papers increases with time. The R^2 statistic represents the trend between the number of papers published and time period.

2013–2017, and 2018–2022. It is also important to note that this research was conducted prior to the end of 2022, so papers published at the end of the year, as well as papers published earlier but had not yet have the chance to be cited, would not appear in our dataset, which could limit the occurrence of more novel interventions. As can be seen in Figure 3, the number of papers published on accessibility interventions increases steadily over time, with 7 papers published between 1996 and 2002, and 69 papers published between 2018 and 2022. We also report programmatic analysis of keyword trends.

3.5.1 Community of focus. As one would expect by looking at the overall community of focus data, the DHH and BVI communities make up the majority of the focus in papers published in each time period, appearing in more than 90% of papers for each time period. We also find that research on interventions for “general disability” starts showing up in the 2008 to 2012 period, somewhat replacing the “other” label which sees a steady decline from 1996 to 2007 (from 14.3% to 2.9%). Other communities of focus do not show any significant trends, appearing in some time periods but not others, such as research on interventions for older adults not appearing in the 2003 to 2008 and the 2018 to 2022 periods, while having modest showings in the 1996 to 2002 (14.3%), 2008 to 2012 (8.8%), and 2013 to 2018 (7.1%) periods.

When it comes to participants involved in user studies, we see people with and without disabilities make up much of the participation, with a combined presence in at least 81.4% of all user study papers published in all period. The dip in relative participation for people with and without disabilities in 2013 to 2017 co-insides with the relative increase of older adults (10.2%) and specialists (8.5%) participation.

3.5.2 Challenges and interventions. When it comes to challenges addressed, we see two major foci – viewing video and reading subtitles – combine to account for more than half of papers, generally increasing with time from 57.1% in the first period to 91.3% in the most recent. Other challenges also get addressed at a relatively constant rate, with relatively high presence between 1996 and 2007, and again between 2013 and 2017. Interestingly, in the 5-year period between 2013 to 2017, we see a significant increase in the raw number of papers published that address challenges of hearing audio (from 5 in all previous periods to 13 papers in this period), following narratives (from 12 to 13 papers), understanding speech (from 5 to 8 papers), and “other” challenges (from 7 to 16 papers) compared to the prior 17 years. This explains the relative decrease

in prevalence of viewing video and reading subtitles, more so than those challenges seeing a decrease in interest.

The accessibility interventions researched have a similar pattern to previous categories, with the two major topics of focus being subtitles and AD. The prevalence of these, however, generally decreases with time, from 77.8% to 46.5%, in favour of other interventions. Interventions labelled as “other”, for instance, sees an initial increase followed by a decrease. While no other intervention accounts for a substantial portion of the paper count, there is a general increase in the number of interventions being researched, with second displays and sign language interpretation seeing more focus recently, with 10.1% and 7.2% in the most recent period respectively.

3.5.3 User studies. User studies are common in each time period, dipping slightly in the 2003 to 2007 period before gradually increasing, as can be seen in Table 4. The distribution of user study methods is constant, with questionnaires, usability testing, controlled experiments, and interviews generally being the most common methods throughout. We see a small number of papers that run workshops or design sessions, as well as the appearance of focus groups starting in the 2008 to 2012 period.

The location of these user studies, for the most part, are labelled as “other” due to the unclear nature of location reporting by authors. Excluding those, we are left with 55 user study papers that have explicitly stated the location of their user study. Among this, albeit small, sample, we can see an interesting pattern. The proportion of user studies that take place at neutral locations and homes, residences and schools decrease over time, being somewhat replaced by online and remote user studies, especially in the most recent time period (65.4%). Looking at year on year data, we can see that there is a significant increase in online and remote user studies, with 4 such studies occurring prior to 2020 and 17 after. This is more than likely due to the COVID-19 pandemic forcing researchers to run their studies remotely. Device distribution sees a steady decrease in focus on TV from 85.7% to 37.7% with time, being steadily replaced initially by desktops, followed by the emergence of smartphones and tablets starting in the 2013 to 2017 period. Devices labelled as “other”, which includes papers where no device was explicitly mentioned, are also relatively common over the time periods.

3.5.4 Keywords. The frequency at which keywords were used in our dataset tends to match the qualitative coded data we manually collected from the papers. The only communities of focus in the 10 most common keywords were the BVI (64) and DHH (28) communities, the only interventions being subtitles (73) and AD (67). We also see the gradual decline in research focusing on TV (from 13.3% to 6.3%) and film (from 5.1% to 0.6%) over time. Research focusing on AD rises quickly, becoming the most frequently used keyword in the 2008 to 2012 period (12.1%), before falling in popularity (6.5% in the most recent period), while subtitles saw steady use in most periods, up to 11.3% in 2018 to 2022. We also see the appearance of artificial intelligence (AI) and machine learning (ML) as a technology in the 2013 to 2017 period and increasing significantly in the next (0.3% and 3.9%), such as AI and ML systems to automate existing interventions [219, 231]. In contrast, the web and online keywords see a rise to 6.1% in the 2008 to 2012 period, before steadily decreasing to 1.5% more recently. The use of the “accessibility” keyword sees a steady increase year-on-year, from

2.6% in 2003 to 2007 and increasing to 11.0%, which aligns with findings by Mack et al. [109] suggesting accessibility as a field of research is growing.

4 DISCUSSION

Our SLR regarding research on accessibility interventions for audiovisual media has described the current state of the field and presented areas that have received disproportionate attention when compared to the HCI accessibility field more broadly. We will now examine our findings to answer our research questions on what challenges are faced by people with disabilities when accessing audiovisual media and what interventions researchers have focused on to help support these requirements, as well as who this research focuses on. Furthermore, we will highlight areas of potential future improvement, proposing directions for future researchers.

4.1 Challenges faced by people with disabilities when accessing digital audiovisual media

To answer RQ1, on the main accessibility challenges faced by people with disabilities when accessing digital audiovisual media, we examined the accessibility challenges researchers addressed in their papers, including the type of content, viewing device, and viewing context. Through our analysis, we observed that research tends to focus on more traditional areas of audiovisual media consumption, for instance looking mostly at general viewing context (81.8%), with the device usually being TV (45.9%) or desktop (32.6%), and a preference for TV broadcasts (32.0%) and video on demand (30.9%). These include work by Thorn and Thorn [196] on subtitle presentation rate and Wolffsohn et al. [229] on the use of real-time edge detection and image enhancement on TV broadcasts. While it makes sense to improve the accessibility of more common media consumption patterns, this has left some major gaps that future research should acknowledge and try to fill. For instance, relatively few papers that explore issues such as “following narrative”, “hearing audio”, and “understanding speech”, with most of these papers using subtitles to address the challenge. We see that alternative methods that leverage novel technologies exist, such as the use of object based audio technologies [184, 221], however, these accessibility challenges should get more attention with a greater variety of interventions. Moreover, with an increased interest in novel media consumption patterns such as immersive AR and VR content, the variety of accessibility challenges explored should reflect these shifts.

We also see that research on mobile devices, such as second screen subtitles using a mobile device [121], has received relatively less attention. The use of mobile devices has, in recent years, seen a significant increase in popularity [47, 163], greater than what we see in our dataset (see Figure 4). Moreover, current research primarily focuses on applying *existing* accessibility interventions to mobile devices [40, 93, 168]. This leaves a significant accessibility gap for viewing patterns for people with disabilities, especially when it comes to novel types of content, such as short form social media content such as TikTok [220]. We, therefore, call for researchers to explore the specific accessibility challenges of accessing media on mobile devices, both as the main viewing device and as a second screen, in order to make this popular viewing pattern accessible to people with disabilities. Another area that has not been much

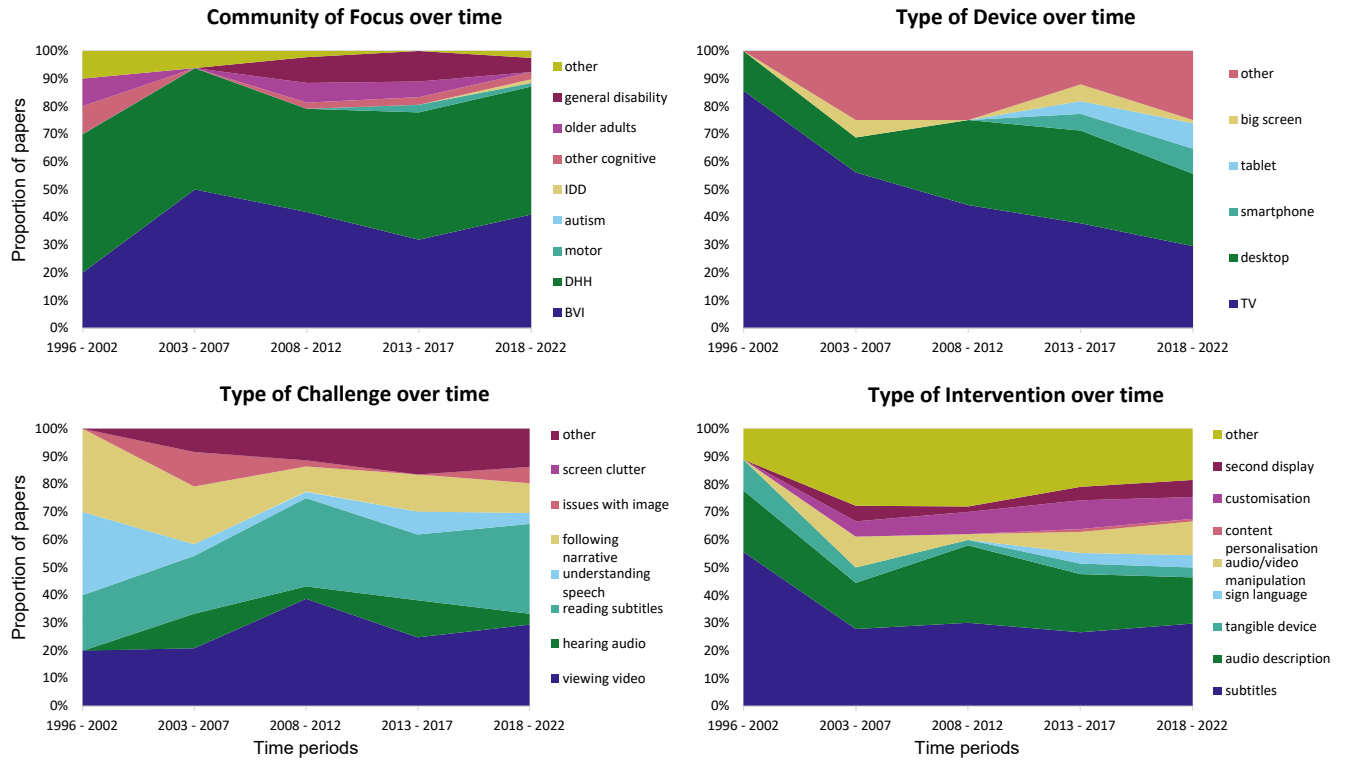


Figure 4: Proportion of papers published over time that addressed, from top left to bottom right, *community of focus*, *type of device*, *type of challenges*, and *type of intervention*.

explored is live streaming video content, which has also seen a significant increase in viewership in the past couple years [77, 228]. The real time aspect of this type for content could allow for interesting new accessibility interventions, such as exploring the use of real time caption highlighting and pausing of live streamed content to help DHH students follow along [101]. Similar techniques that use the real time aspect of live streaming could be leveraged by future researchers to improve accessibility of this type of content.

4.2 Communities of focus for accessibility research in audiovisual media

When examining our results to respond to RQ2, on who accessibility research focus on, we find that an overwhelming majority of papers focus on the DHH and BVI communities. Considering we are looking at *audio* and *visual* media, interventions addressing communities that have hearing or visual impairments are well represented. This has left other communities significantly under-represented within our dataset, such as autism (0.0%), IDD (0.6%), and other cognitive impairments (3.3%). The challenges these communities face when accessing audiovisual media differ from the DHH and BVI communities and require different approaches to improving access [164], and therefore should receive more standalone attention when exploring accessibility interventions. Older adults were also under-represented, along with disability communities we had not explicitly labelled, such as aphasia or dementia, both

being disabilities that occur more often in older adults and likely to become more prominent with an aging population [127, 200]. Language impairments such as aphasia require more specialized accessibility interventions, as common interventions (e.g., subtitles) are unlikely to help fully bridge the accessibility gap [73, 170]. The under-representation of these communities and their prevalence within the broader accessibility HCI research community suggest that this is an area of potential growth in the future.

As Bannon et al. [14] suggest, there is a tendency to use PD as “*simply the involvement of any stakeholder*” in user studies. A high number of papers in our dataset that fall under this category of PD, in which participants with disabilities are involved in a limited context, often a single small feedback session. PD allows researchers to better understand participants needs and helps design interventions that are more adapted to the people who ultimately use said intervention [118]. For instance, using PD to iterate through designs, which initially can be done using paper-based prototypes, allows the final design to align with users needs and expectations [89, 210]. We, therefore, encourage future user studies to involve people with disabilities more directly, as well as encourage researchers to involve specialists and caregivers more often, as both these participant groups have the possibility to present insights or aid participants with disabilities [28].

4.3 Interventions for addressing accessibility in audiovisual media

In answering RQ3, on what interventions are used to help support different accessibility needs, we examined user study methods used and accessibility interventions explored. When it comes to the types of interventions explored, subtitles (48.1%) and AD (33.1%) are the most common interventions. This was somewhat expected, as these two interventions are the default method to make audiovisual media accessible to DHH and BVI people, with these two communities being so well represented in our dataset. We understand, therefore, the inherent importance and benefits of working to better understand or improve these interventions. However, similarly to mostly focusing on the DHH and BVI communities, this leaves much potential research under-explored. With the rapid evolution of technology, including the advancement of immersive media, many new techniques and areas of research can be explored in the context of accessibility interventions. Importantly, new technologies and conceptualisations of how we can render audiovisual media allow us to explore highly-customised, unique accessibility interventions which can fit individual needs.

For instance, Object-Based Media (OBM), which allows every individual to receive their own version of a piece of digital content by breaking it up into its constituent parts and rendering it their end, has the potential for profound implications for access [81]. However, presently, OBM has so far mostly been leveraged to implement pre-existing accessibility interventions such as subtitles and audio descriptions (e.g. [123]). Only limited work explores highly-configurable digital content for accessibility – for instance, Ward et al. [222] who explore using OBM to adapt audio channels such as incidental sound to support deaf or hard-of-hearing individuals. Further, we have seen ML techniques and AI being used in more recent papers to improve or automate the creation of subtitles [110] and ADs [219, 231]. With the vast possibilities these new technologies offer, we suggest researchers explore their possibilities in improving the accessibility of audiovisual media, focusing on interventions other than subtitles and AD. An example of this could be to use ML and AI techniques to transform some aspect of the content to allow for customization or personalization to match the viewers accessibility needs, or the use of recent advanced in AI text-to-image generation.

4.4 Limitations

We identify several limitations with this SLR, as with all systematic reviews. Our dataset does not cover all research on accessibility interventions for audiovisual media. This is despite us following PRISMA guidelines [162], along with additional guidelines from Silva and Frâncila Weidt Neiva [188] and Siddaway et al. [187], as well as a snowballing procedure outlined by Wohlin [227]. As described in Section 2, we initially used three databases (ACM DL, SCOPUS, IEEE Xplore) for our search, before dropping IEEE Xplore after it returned too many false positive results. There are, however, other databases that we did not include (e.g., SAGE Journals, Elsevier, Springer, Routledge, etc.) which likely would have returned papers relevant to our scope. Moreover, the search query and identification method used may have limited the papers we found, especially with our SCOPUS search query, which limited

the venues searched to reduce the exploding search space and high number of false positive results. While the snowballing step did return papers from different sources, such as Springer and Elsevier, this introduced new challenges in cleaning the data up [18]. The creation of the codebook and manual coding of our dataset introduced personal biases, which we tried to limit through having a second researcher go through 10% of the papers, discussing major disagreements, and calculating an IRR. Additionally, we experienced variable language when applying community of focus labels similarly to Brulé et al. [24], where terms such as “blind”, “visually impaired”, “low vision” and others were used. Similar challenges exist with other communities, especially when it comes to neurodiversity and cognitive and/or learning disabilities [109]. There is also an issue when it comes to the shift of terms over time, with the meaning of terms describing communities, technologies, or study methods changing over the 27-year period, something that we did not explore. Our comparison of the dataset we produced against that produced by Mack et al. [109] is also limited in that their systematic review focused on CHI and ASSETS only.

5 CONCLUSION

We analysed research on accessibility interventions for audiovisual media over a 27-year period, the implications of that research, and made suggestions to researchers on what future research should focus on. Through this work, we provide insights into the accessibility challenges researchers have addressed, the communities and participants involved in research, and the interventions that have been explored. For example, we saw that a significant amount of research focused on the DHH and BVI communities and highlighting a serious under representation of IDD, autism, and other cognitive impairments as communities of focus. Therefore, we encourage future research to consider the following recommendations:

- With the rise of novel technologies to consume media, we recommend researchers to investigate new accessibility interventions more suited to the viewing context and device, rather than exploring the use of existing interventions originally designed for different contexts (e.g., subtitles and audio description).
- We call for a wider range of communities of focus to be involved in research, as different disabled communities can have their own challenges and may require accessibility interventions that take these into account.
- We echo the call by Mack et al. [109] and others to involve people with disabilities in research. More so than simply running controlled experiments or usability testing of prototypes, we should explore more participatory design techniques involving various stakeholders that reflects the potential inaccessibility of certain user study methods.

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AUTHOR STATEMENT

AN led this work with guidance from TN and ES. AN, TN, and R-DV conceptualised the work. AN created the dataset and manually coded it, with TN coding a 10% sample. AN wrote the paper, with guidance and feedback from TN, R-DV, and ES.

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