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Zihao You

2565278@dundee.ac.uk

University of Dundee

Michael Crabb

University of Dundee

Rachel Menzies

University of Dundee

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Towards Adaptive and Accessible Subtitled Media: A Systematic Review, Taxonomy and Design Considerations

Zihao You^{1*}, Michael Crabb¹ and Rachel Menzies¹

¹Faculty of Science, Engineering and Business, University of Dundee, Nethergate, Dundee, DD1 4HN, United Kingdom.

*Corresponding author(s). E-mail(s): 2565278@dundee.ac.uk;
Contributing authors: m.z.crabb@dundee.ac.uk; r.menzies@dundee.ac.uk;

Abstract

Subtitled media has been used in many people’s lives to enhance their understanding of audio content on TVs, laptops and smartphones. The traditional one-size-fits-all approach to subtitle display has the potential to marginalise people based on their accessibility needs. To thoroughly understand the accessibility challenges faced by the disabled population when consuming subtitled media, we began collating and surveying literatures that research this aspect. This paper presents a systematic review of 147 academic papers from three electronic databases, spanning a 29-year period (1995-2024). Through deductive coding, we highlight considerations of crafting subtitle adaptation interventions and underserved communities. Our review reveals gaps in designing accessible subtitled media, particularly in terms of broader text display device selections and communities of focus. We discuss the factors that can influence the design of accessible subtitled media adaptations and call for more inclusive practices when involving end-users in studies.

Keywords: Subtitles, Closed Captions, Adaptive Media, Systematic Literature Review, Taxonomy

1 Introduction

Subtitles (or Closed Captions¹) have become increasingly commonly used in people’s everyday lives due to the emergence of streaming services and digital devices. Current access to subtitles within media has the potential to marginalise people with disabilities due to the traditional one-size-fits-all subtitle display approach. Prior works have proposed subtitled media adaptations in various modalities, including VR [1], translations [2], and highlighting [3], which have been

explored in communities such as blind or visually impaired [4], deaf or hard of hearing [5], and cognitively impaired people [6]. Although it highlights an important research avenue, no review exists that combines adaptive subtitled media with user groups to determine whether it caters to the needs of people with disabilities. This provides limited insight into the comprehensive picture of subtitle research and potentially overlooks underserved communities.

People use subtitles in various contexts, such as learning courses, TV shows, and current affairs, among others. However, disabled people’s experience in consuming media content has been significantly impacted, especially those with low

¹Closed captions (CC) also provide a text description of sound effects. Most streaming sites only have the option for ‘English[CC]’ for English subtitles and therefore in this work, we collectively refer to both as subtitles.

literacy skills [7] (around 9% of the global population) or reading disabilities [8] (at least 10% of the worldwide population). These percentages continue to grow due to ageing [9] and learning poverty occurring in low-income countries [10]. Making adaptations to subtitled media, therefore, becomes crucial to bridge the accessibility gaps between subtitled text comprehension and people with disabilities and create a more engaged and inclusive viewing environment.

As a result, we aim to explore accessibility research in subtitled media, identifying the communities that have benefited, and providing actionable research practices for future subtitle adaptation interventions. To achieve this, we conducted a systematic literature review (SLR) of how subtitles have been previously adapted, based on 147 papers published between 1995 and March 2024, with threefold contributions (categories derived from [11]):

1. **Dataset:** We have constructed an open-source dataset containing 147 qualitatively coded papers across 29 years (1995-2024), which focus on designing and implementing adaptable subtitled media.
2. **Survey:** We have systematically reviewed the literature inside the dataset and synthesised them into considerations in creating subtitle adaptations (i.e., *methods of delivering and consuming subtitles, participant demographics and approaches used to research subtitle adaptations*) and temporal trends (in terms of *subtitled media accessibility research, subtitle adaptation formats and communities of focus*).
3. **Theoretical:** Grounded in the qualitative findings from the literature base, we have provided a two-way taxonomy that maps subtitle adaptation types (in terms of *position, location, content and style*) to each community of focus (i.e., people with *visual, cognitive, physical, communication, emotional and intersectional* impairments).

Before making the aforementioned contributions, we attempted to position our work within

the overall context of subtitled media consumption and explore the key factors to alter subtitled text display (Section 2). We then presented the methodology and made 1 by detailing the process of creating the dataset (Section 3). After that, we reported the findings through thematic synthesis, trends (Section 4) and taxonomy (Section 5 and 6) to acknowledge 2 and 3. We concluded this paper by pinpointing underexplored areas of accessibility research within the subtitled media space and providing directions for the design and development of future subtitle adaptation interventions (Section 7 and 8).

2 Background and related work

2.1 Definitions of subtitled media

Traditional subtitles are words underneath the film/television screen that convey the audio information or translate it into another language [12]. Industry guidelines suggest that subtitles should normally be displayed as white text on a black background, positioned at the bottom centre of the screen (i.e., within the central 90% vertically and 75% horizontally) and with no more than 3 lines at a time [13]. An example of common subtitle display in the UK is shown in Figure 1.

Subtitles provide an alternative method for people to access the audio content within media. They can be used for several reasons, including loud environments, increasing understanding of characters with strong accents, and traditional audio accessibility challenges [14, 15]. Subtitles can also be used to provide access to media in a foreign language where the intent is either to assist in learning a secondary language [16, 17] or for general media consumption.

2.2 Literature on subtitled media adaptations

Consuming subtitled media for people with accessibility needs such as blind or visually impaired people [18] and deaf or hard of hearing people [14, 16, 18–20] can be more challenging when compared to traditional media viewing for typical users. This includes difficulties in following subtitle display speed or losing track of visual information whilst focusing on subtitled content [21].

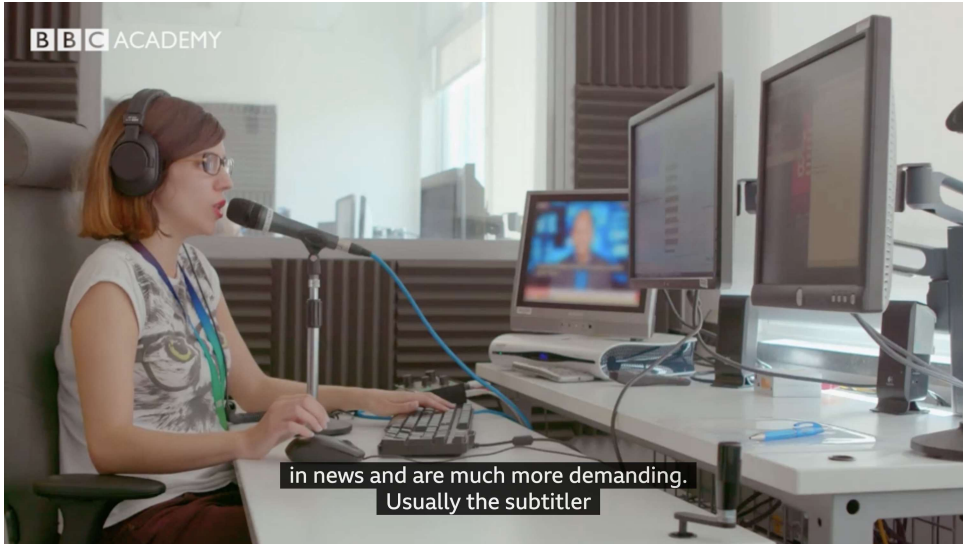


Fig. 1 Traditional subtitle display on BBC.

The challenges faced can lead to an increased likelihood of depression and social isolation [20]. This triggers a closer investigation of the specific adaptations made to the subtitles to facilitate the overall consumption, which will be summarised in the following subsections.

2.2.1 Adapting subtitle position

One method that can be used to alter subtitle display is to change their position within the media, as shown in Figure 2. In traditional media, this can be used to ensure that subtitles do not obscure any important onscreen content. For example, subtitles within quiz shows can be placed at the top of the screen instead of the bottom [22]. Specific approaches to subtitle position adaptations have been carried out in the past decade from different angles, which will be categorised below.

A specific challenge when positioning subtitles relates to determining which screen areas are suitable for subtitle placement, with machine learning methods being previously used to explore this. Hu et al. [23] proposed two algorithms for detecting speakers and determining appropriate subtitles’ placement locations, which outperform both static subtitling and a previous dynamic method proposed by Hong et al. in 2010 [24] in terms of overall consumption experience and eyestrain level. Further improvements such as the *DEEP-HEAR framework* developed by Tapu and Mocanu et al. in 2019 [25–27] utilised both computer vision

algorithms and deep convolutional neural networks that effectively cope with fussy video scenes, background noise and detecting invisible speakers. The experimental evaluation carried out by them achieves an F1-score of 92% that is over an 8% performance increase compared to other state-of-the-art models as detailed in [24] and [23].

An alternative to using machine learning techniques to determine subtitle placement is to rely on user eye-tracking data. A typical example (used by [28], [29] and [30]) is to use eye-tracking data to estimate the users’ region of interest (ROI), which can then be used to assist in subtitle placement. Subtitle placement can then happen based on creative judgement (e.g., [29] and [30]) or automatically (e.g., [28]). Two gaze-adaptive methods (i.e., *Direct Captions* that consistently place the subtitles along with the gaze position regardless of the visual content and *Salience-Sensitive Captions* that overlap the text with important image content regions to work out the optimal position) proposed by Kurzhals et al. in 2020 [31] both showed a slight preference by users compared to traditional captions (i.e., 7.41% increase in participant numbers for *Direct Captions* and 3.7% increase in participant numbers for *Salience-Sensitive Captions* derived from a within-subject design study of 54 participants).

A critical element that needs to be considered when altering subtitle position is its impact on the overall viewing experience. Previous work



Fig. 2 Traditional subtitle display versus subtitle position adaptation.

has suggested that an alteration in subtitle position has mixed reactions from viewers and that a one-size-fits-all approach to positioning should not be adopted [29]. Giving viewers the ability to alter the position of subtitles in real-time can be seen as advantageous [32] and can better cater for individual needs and preferences.

2.2.2 Adapting subtitle location

As depicted in Figure 3, subtitles can also be altered by moving their position outside of the traditional viewing window. As an example, a simple adjustment, such as moving subtitles to be fully above or below media content, can lead to an increase in overall viewing experience [32].

Several studies have examined how subtitle content can be displayed on a companion device (e.g., smartphone) whilst the primary media is shown on a larger screen (e.g., television). A potential use case of this technique is using companion devices to show alternative language subtitles in environments where viewers require multiple languages in a single environment [22, 33].

A second area where subtitles are located outside of a traditional viewing window is in virtual reality. In this environment, multiple methods can be used to position subtitles [34] with user preference for position tending to be that subtitles move with user head position [35] and to be placed slightly below the eye-line, with 12.5 degrees being suggested as an optimum angle [36].

Additional consideration exists for subtitle placement within VR. Traditional media environments position subtitles as part of the User Interface (UI) and subtitles are fixed on the screen. Within VR, subtitles can be fixed on the screen or placed within the virtual environment. When subtitles are placed within the virtual environment, care must be taken to ensure they are still readable based on user depth perception and gaze patterns [37].

A final, contemporary method to provide additional caption information outside a traditional location is to use wearable vibrotactile interaction. Using this method, a speaker’s voice characteristics can be translated into vibrations that a viewer can feel on their wrist, allowing them to make inferences regarding speakers [38].

2.2.3 Adapting subtitle content

Subtitles can also be adapted to improve the overall experience, with these adaptations altering the actual content subtitles are displayed to the viewer, such as sentence rephrasing in Figure 4. Adaptations can include automatically inserting line breaks within subtitle files, improving information recall [39], with similar work happening to add punctuation automatically [40]. Subtitle content can also be adapted by changing the characters with subtitles enabled, which the viewer controls through a second screen device [15]. It is also possible to adapt subtitles based on user preference, with inferences for future adaptations based on previous experience [41].



Fig. 3 Traditional subtitle display versus subtitle location adaptation.



Fig. 4 Traditional subtitle display versus subtitle content adaptation.

2.2.4 Adapting subtitle style

Finally, subtitles can be adapted visually, including fonts (as displayed in Figure 5), sizing, and colour. Subtitle font size can be adapted so that a fixed container size is filled with text that meets a viewer's current needs (e.g., large text with a small number of words, small text with a large number of words) [42]. Adaptations to subtitle style can be controlled on the primary viewing device itself or also through a secondary device that can assist in controlling more complex adaptations [22, 33]. Previous work has also explored adding a blur to

subtitle background when they are being looked at, with real-time eye-tracking used as a technique to accomplish this [37].

Subtitle styling can also be altered based on audio levels within the original broadcast media, with caption qualities such as font-weight and character width being aspects that can be altered [43, 44]. Connections between subtitle content and on-screen media can also occur, highlighting on-screen elements to supplement subtitle information that is already present [45] or through the addition of new elements sourced through



Fig. 5 Traditional subtitle display versus subtitle style adaptation.

real-time online search [46]. Creating subtitles for non-speech sounds is a particularly challenging area, with work being carried out examining the suitability of text, graphic [47] and animations [48] as a way to display these to viewers.

Notwithstanding these contributions, it comes to our attention that none have attempted to survey the state-of-the-art subtitle adaptation interventions comprehensively and in depth. A gap has yet to be filled in terms of systematically analysing subtitled media adaptations across various disabled population groups.

3 Methodology

To gain a broader understanding of how subtitled media have been personalised and customised to various disabled populations, we conducted an SLR of academic papers over the past three decades to investigate how subtitled media have been adapted to various communities. We used the Miro² platform to brainstorm and document our thinking processes. We began by constructing a review question that defined the research scope. To ensure the relevance and quality of the selected papers, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) procedures [49], complemented with guidelines from Boland et al. [50] and Siddaway et al. [51]. This has resulted in a

dataset of included papers, which will be further analysed.

3.1 Scope

We aim to understand more about the challenges and opportunities of adapting subtitle systems for people with various accessibility needs. Several pre-existing SLRs lie within the domain of subtitles, accessibility research and media consumption. Work done in [52] surveys the current state of the video subtitling task and determines the best three methods. [16, 17] and [19] examine how subtitles facilitate language learning. Accessibility research in Human-Computer Interaction (HCI) has gained traction, with an increasing number of papers published at *ACM CHI* since 1994, reaching approximately 8% of the total in 2019 [53]. Similarly, around 6% of papers that appeared at *ACM IMX/TVX* between 2014 and 2020 integrate accessibility research with television and immersive media [54]. Narrower-scoped SLRs have also been found, such as those that focus on a specific modality (e.g., digital audiovisual media [18]) or community (e.g., blind or visually impaired [55] and deaf or hard of hearing [20] people).

While prior reviews have examined subtitles in relation to language learning, media consumption, or accessibility more broadly, few have systematically addressed how subtitled media adaptations themselves are designed and evaluated. In particular, there is a lack of synthesis on the specific factors, such as subtitle position, location, content,

²<https://miro.com/>

and styling, that influence accessibility outcomes across diverse audiences.

To address this gap, we piloted initial searches and sample screenings across multiple databases. Then we used the insights gained from these papers to refine our focus. This iterative process informed the development of our central review question and the following three requirements:

RQ: What factors influence subtitle position, location, content, and styling to enhance media accessibility?

1. Our scope includes population with any age, gender and nationality. This includes papers that do not explicitly state the communities of focus (e.g., [56]).
2. Selected papers must research one or more adaptation formats of subtitled media. This can be in terms of position (e.g., [57]), location (e.g., [58]), content (e.g., [59]), or style (e.g., [60]).
3. Selected papers must report a research outcome. This can be determined through qualitative/quantitative data from the study design (e.g., [61]) or a more technical perspective evaluation (e.g., [62]).

3.2 Dataset Creation

To address the review question and compile a dataset of papers on subtitled media adaptations, we followed the PRISMA guidelines [49]. This process involved three key stages: identification, screening, and eligibility assessment. During identification, we retrieved papers from selected databases and removed duplicates. In the screening stage, titles and abstracts were reviewed to exclude irrelevant records. Finally, full texts were assessed for eligibility based on our inclusion criteria. At each stage, we recorded the number of papers excluded and retained. The flow of studies through the review process is summarised in Figure 6.

3.2.1 Stage 1: Identification

The identification stage focused on capturing research on how subtitled media have been adapted for different communities. We considered the three scientific databases that contain the highest number of papers returned in Section 3.1, namely, ACM Digital Library³, SpringerLink⁴, and ScienceDirect⁵. These sources span a wide range of relevant publication venues that focus on general HCI, media accessibility, and multimedia interaction. Search strings were developed based on the themes identified in Section 2.1 (subtitle adaptation areas) and the requirements defined in Section 3.1, including:

```
("caption*" OR "subtitl*") AND  
("location" OR "position" OR "  
content" OR "styl*")
```

The asterisk symbols have been used to capture all keyword variants, such as plural and present participle forms. Since the wildcards “*” are not supported in ScienceDirect, we removed all the asterisk symbols when we applied the search strings to this database. To reduce the number of false-positive papers returned, we performed further iterations on the above search string with the following modifications:

1. Removed the term “caption*”.
2. Replaced the term “content” with “placement”.
3. To meet 2, we concatenated the substring (“adapt*” OR “adjust*” OR “modif*” OR “alter*”) with the Boolean operator *AND* to ensure subtitles must be adapted. We used the *OR* operator to take into account synonyms for adaptations.
4. To limit the modalities that the subtitles can display, we appended another substring (“media” OR “video” OR “film” OR “television” OR “TV” OR “stream*” OR “online video” OR “broadcast”) with the operator *AND*. This search space considered several display formats connected by *OR* operators.

As a result, the final search query was:

³<https://dl.acm.org/>

⁴<https://link.springer.com/>

⁵<https://www.sciencedirect.com/>

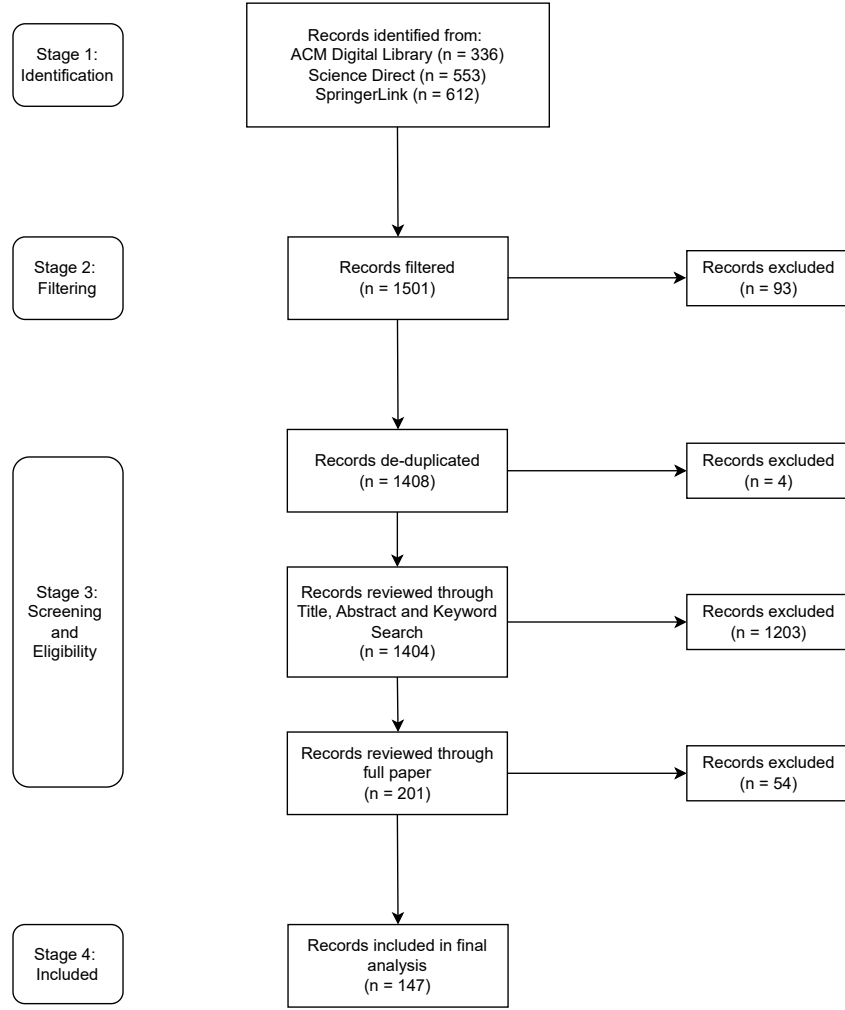


Fig. 6 The PRISMA procedure [49] with reference frequencies across all four steps of SLR: Identification, Filtering, Screening and Eligibility, and Included.

```

("subtitle") AND
("location" OR "position" OR "
  placement" OR "style") AND
("adapt*" OR "adjust*" OR "modif*"
  OR "alter*") AND
("media" OR "video" OR "film" OR "
  television" OR "TV" OR
  "stream*" OR "online video" OR "
  broadcast")

```

This search strategy was applied to two databases: ACM Digital Library and Springer Link. The ACM Digital Library returned 336 results. SpringerLink produced 612 references within the subdisciplines of User Interfaces and Human-Computer Interaction, comprising 445

conference papers and 167 journal articles. However, the original search query contained 16 Boolean connectors—exceeding the maximum allowed by the ScienceDirect database. To address this, we developed a simplified query tailored specifically for ScienceDirect, which returned 553 results:

```

("subtitle") AND
("location" OR "position" OR "
  placement" OR "style") AND
("adapt" OR "adjust" OR "modif")
AND
("media")

```

Both queries were run on 18/03/2024. We combined 1501 publications spanning three decades (1995-2024) and compiled them into the Mendeley Reference Manager⁶ software for filtering in Stage 2.

3.2.2 Stage 2: Filtering

To facilitate a more efficient screening process, we filtered records corresponding to entire conference proceedings and non-English papers (by checking the titles) in Mendeley before screening. This has excluded 93 papers, with the remaining 1408 papers being brought forward to Stage 3.

3.2.3 Stage 3: Screening and Eligibility

The screening process began by de-duplicating a further 4 out of 1408 references. To remove all works that were irrelevant to the scope of our SLR and add more rigour to the overall process, we formulated four eligibility criteria adhering to the PRISMA guidelines [49]:

1. **Full-text availability:** The paper as its full-text must be open access and written in English.
2. **Peer reviewed academic research:** The paper must be peer-reviewed by academic. This involves conference full papers, journal articles, workshop papers, conference posters, etc.
3. **Subtitled media adaptations:** The paper has to focus on subtitled media with at least one form of adaptation.
4. **Research outcome availability:** The paper must contain reported outcome.

This was followed by two separate rounds of screening - through title, abstract, keyword search (1st round) and full-text paper (2nd round). In both rounds, two reviewers (i.e., first and second authors) screened through the first 20 samples together, starting from the most recent paper to reduce bias and make the process more robust. We leaned more towards the cautious side to not exclude a paper when unsure.

In the first round of screening, the keywords “subtitl”, “caption”, and “participa” were used to assess references against the exclusion criteria outlined in 3 and 4. This resulted in the exclusion of approximately 86% of records (1,203 out of 1,404). The remaining 201 papers were tagged in Mendeley and exported to Sublime Text⁷ for further screening.

During the second round, a screening and selection tool was developed to support inclusion/exclusion decisions and capture the rationale for each. This stage led to the exclusion of an additional 27% of papers (54 out of 201), resulting in a final dataset of 147 papers for qualitative analysis.

3.3 Dataset Analysis

Digital copies of all 147 papers (published between 1995 and 2024) were obtained and imported into NVivo⁸ for deductive coding [63]. The coding process was conducted by two researchers—both male, with Eastern Asian and Western European backgrounds, and one of whom declared communication needs. While both have prior experience in accessibility research, potential biases and subjectivities were acknowledged and critically reflected upon throughout the analysis.

A codebook was developed to guide the analysis in relation to the review question. As shown in Table 1, the final version comprised 12 categories, each containing between 5 and 13 sub-codes. A single paper could be assigned multiple sub-codes within each category. Eight categories were adapted from Nevsky et al. [18], whose study focused on accessibility in digital audiovisual media—a broader domain than ours. These were used to examine subtitled media in relation to methods, devices, contexts, and communities, aligning with our user study focus. The remaining four categories were derived from the related work on subtitle adaptations discussed in Section 2.1, with sub-codes capturing distinct subtitle display approaches. These constitute five main areas of focus, including the consumption environment, end-user categories, user study metrics, contribution types and subtitle adaptation formats.

The two authors co-developed the codebook, meeting regularly to revise, remove, or introduce

⁶<https://www.mendeley.com/reference-management/reference-manager>

⁷<https://www.sublimetext.com/>

⁸<https://lumivero.com/products/nvivo/>

codes through consensus. Once finalised, both researchers began coding in parallel. To support consistency, the second author also retrospectively coded a 20% sample ($N = 30$), starting with the most recent publications.

3.4 Overview of Findings

Our results have been broken down into the following three sections, consisting of descriptive (Section 4) and analytical (Sections 5 and 6) findings. We provide an overview of our literature base and answer the review question by synthesising three factors (Sections 4.1, 4.2 and 4.3) that inform the design of subtitle adaptations. A temporal analysis of the research trends (Section 4.4) have also been conducted. Following this section, we attempt to gain insights from each research community in terms of their device and context consumption (Section 5) and the types of subtitled media adaptation (Section 6).

4 Dataset Overview

To begin addressing our review question, we present our findings by synthesising three factors (i.e., *methods of delivering and consuming subtitles*, *participant demographics*, and *approaches used to research subtitle adaptations*) that influence the design of accessible subtitled media. We conclude this section with a programmatic analysis of research trends over the entire 29-year period (1995-2024).

4.1 Methods of delivering and consuming subtitles

The first aspect considered when creating subtitle adaptations is modalities for subtitle delivery and user consumption. These involve the three categories *broadcast method*, *viewing device* and *viewing context* within the codebook. Multiple codes can be applied to a single paper. As a result, the number of papers does not add up to 147 for each category.

4.1.1 Broadcast Method

As displayed in Table 2, the number of papers that reported the broadcast method is evenly distributed among TV broadcast (23.1%, 34/147),

on-demand video (30.6%, 45/147) and pre-recorded web video (38.8%, 57/147). Only four papers (2.7%) focused on live streaming, which is commonly seen in the gaming context [64]. Approximately one-fifth of papers ($N = 28$) researched media as physical formats or other less common broadcasting methods, such as AR/VR [65, 66] and videoconferencing [67, 68]. This also contains the papers that mentioned the media types in general.

4.1.2 Viewing Device

Regarding the devices consumed, desktops and laptops have dominated, reflected by the high proportion of literature exploring these (85.0%, 125/147) as seen in Table 3. Around 20% of the literature includes television ($N = 27$), smartphone ($N = 29$) or tablet ($N = 29$). Little work investigates subtitle consumption via large-scale cinematic displays (4.1%, 6/147). Devices classified as “other” (10.9%, 16/147) include VR headsets [58, 69–71] and hardware used in the context of a museum guided tour [72].

4.1.3 Viewing Context

In terms of the consumption contexts, more emphasis has been placed on entertainment (66.0%, 97/147) and education (59.2%, 87/147) than business (41.5%, 61/147) and social (27.9%, 41/147) settings, as depicted in Table 4. No papers have been categorised as “other”. This is because if a paper merely states “film” or “video”, we would assume that it refers to the general viewing context and apply it to all four codes above.

4.2 Participant Demographics

The second aspect considered when adapting subtitle displays is the end-user types involved in the research. Two categories *community of focus* and *participant groups* in the codebook will be analysed and discussed in this section. Papers that focus on several communities or do not report end-user involvement will also be addressed.

4.2.1 Community of Focus

An accessibility toolkit [73] has been used to synthesise our community of focus findings. This model groups the disabled population based on

Table 1 The final codebook containing 92 subcodes across 12 code categories.

Category	Codes
Broadcast Method	TV Broadcast; On-Demand Video; Live Streaming; Web Video (Pre-Recorded); Physical Media (and Others)
Viewing Device	Television; Desktop/Laptop; Smartphone; Tablet; Big Screen; Other
Viewing Context	Entertainment; Education; Business/Professional; Public/Social; Other
Community of Focus	Visual: Blind or Visually Impaired; Visual: Colour Vision Deficiency; Cognitive: Intellectual and Developmental Disabilities; Cognitive: Other Cognitive Impairment; Cognitive: Neurodivergent; Physical: Motor/Physical Impairment; Communication: Deaf or Hard of Hearing; Communication: Aphasia; Emotional: Mental Health Conditions; Intersectional: Intersectional Impairments
Participant Groups	No User Study; People with Disabilities; People without Disabilities; Older Adults; Specialists; Caregivers
User Study Method	Controlled Experiment; Survey; Usability Testing; Interviews; Case Study; Focus Group; Field Study; Design Workshop; Diary Study; Ethnographic Study; Longitudinal Study; Other; None
User Study Location	No User Study; Near/At Researcher’s Lab; Participant’s Home; Residence; School/University; Neutral Location; Online/Remote; Other
Contribution Type	Empirical; Artifact; Methodological; Theoretical; Benchmark/Dataset; Survey; Opinion
Subtitle Position Adaptation	ML Technique; Eye-tracking Data; Optimal Placement; User’s Control; Other
Subtitle Location Adaptation	Companion Device Display; VR Display; Depth Conflict; Vibrotactile Interaction; Environment-based Display; Other
Subtitle Content Adaptation	Language Translation; Line Break; Punctuation; Rephrase; User’s Preference; Complexity Level; Cultural Localisation; Other
Subtitle Style Adaptation	Font; Size; Colour; Background Blur/Deblur; Audio Level; Highlight; New Element; Non-Speech Sound; Text Animation; User-defined Style Templates; Other

Table 2 The frequency of papers with code for Broadcast Method.

Broadcast Method	Papers with code
TV Broadcast	34 (23.1%)
On-Demand Video	45 (30.6%)
Live Streaming	4 (2.7%)
Web Video (Pre-Recorded)	57 (38.8%)
Physical Media (and Others)	28 (19.0%)

visual, cognitive, physical, communication, emotional, and intersectional impairments, as shown in Table 5⁹. The two most represented communities in the literature are deaf or hard of hearing (39.5%, 58/147) and blind or visually impaired (12.9%, 19/147). Conversely, little to no attention has been paid to the intellectual and developmental disabilities (0.7%, 1/147), neurodivergent (0.7%, 1/147), aphasia (0.0%, 0/147), and mental health conditions (0.0%, 0/147) populations. During the codification process, we also found papers

that did not explicitly state the targeting communities, such as transforming subtitled text into a graphic novel [74] or exploring the potential of naming characters that can be presented on existing subtitles [75]. Therefore, we did not apply any codes to this set of papers as we assumed that the end users are the general public. Literature that focuses on the disabled population in general (e.g., [76] and [77]) has been classified as intersectional impairments, as any disability type can apply.

⁹To limit our scope, we only consider people with diagnosed disabilities in this work. This means that we will not include situational impairments as discussed in [73].

Table 3 The frequency of papers with code for Viewing Device.

Viewing Device	Papers with code
Television	27 (18.4%)
Desktop or Laptop	125 (85.0%)
Smartphone	29 (19.7%)
Tablet	29 (19.7%)
Big Screen	6 (4.1%)
Other	16 (10.9%)

Table 4 The frequency of papers with code for Viewing Context.

Viewing Context	Papers with code
Entertainment	97 (66.0%)
Education	87 (59.2%)
Business or Professional	61 (41.5%)
Public or Social	41 (27.9%)
Other	0 (0.0%)

4.2.2 Participant Groups

Out of 147 papers found, 77 of them reported at least one user study. As can be seen in Table 6, the most common participant group in user studies corresponds to people without disabilities (68.8%, 53/77), followed by people with disabilities (44.2%, 34/77), specialists (24.7%, 19/77) and older adults (22.1%, 17/77). Very few studies included caregivers (1.3%, 1/77) as participants. Papers that did not report a user study are mostly early-stage research [2, 6], or a technical evaluation has been carried out instead [62, 78].

4.3 Approaches used to research subtitle adaptations

In addition to subtitle delivery and consumption methods and participant demographics, the strategies employed in conducting user studies also influence the design of adaptable subtitle displays. To better understand this, we analysed the categories *user study method* and *user study location*, along with the number of participants involved in each study, to identify patterns in study scale and user involvement.

4.3.1 User Study Method

Table 7 summarises all study methods found in 77 papers that explicitly reported a user study. Questionnaire (79.2%, 61/77) is the most common method, as over three-quarters of the papers have included surveying end-users. Another three

widely used methods refer to controlled experiment (48.1%, 37/77), interviews (44.2%, 34/77) and usability testing (27.3%, 21/77). Case study (9.1%, 7/77), focus group (10.4%, 8/77), field study (3.9%, 3/77), design workshop (3.9%, 3/77), ethnographic study (2.6%, 2/77) and longitudinal study (6.5%, 5/77) have been less commonly used within the literature. Six papers presented unique approaches that researched users in class coursework [79] or exam [80, 81] format. Papers with multiple study methods also exist, such as the work that explored the accessibility barriers of Massive Open Online Courses (MOOCs) through surveys (from the learners’ perspective) and interviews (from the video production engineers’ perspective) [82].

4.3.2 User Study Location

Table 8 shows that a majority of user studies were run in person, either at a lab (45.5%, 35/77) or a home/school (58.4%, 45/77) setting. Around one-fourth of the literature (N = 20) reported online/remote studies. We also found seven papers with studies conducted in neutral spaces (e.g., local deaf club [83], day-care centre [84], theatre [85]) and three papers that do not explicitly specify the research location.

4.3.3 Sample Size

Out of all 77 papers that contain user studies, 73 of them explicitly reported the number of people who participated in the study, as seen in Table 9.

Table 5 The frequency of papers with code for Community of focus.

Community of focus	Papers with code
Visual: Blind or Visually Impaired	19 (12.9%)
Visual: Colour Vision Deficiency	3 (2.0%)
Cognitive: Intellectual and Developmental Disabilities	1 (0.7%)
Cognitive: Other Cognitive Impairment	9 (6.1%)
Cognitive: Neurodivergent	1 (0.7%)
Physical: Motor/Physical Impairment	10 (6.8%)
Communication: Deaf or Hard of Hearing	58 (39.5%)
Communication: Aphasia	0 (0.0%)
Emotional: Mental Health Conditions	0 (0.0%)
Intersectional: Intersectional Impairments	9 (6.1%)

Table 6 The frequency of papers with code for Participant Groups.

Participant Groups	Papers with code
No User Study	70 (47.6%)
People with Disabilities	34 (44.2%)
People without Disabilities	53 (68.8%)
Older Adults	17 (22.1%)
Specialists	19 (24.7%)
Caregivers	1 (1.3%)

The median number of participants per study was 30 ($Mean = 59.5$, $IQR = 40.0$, $SD = 95.9$). The lowest number of participants involved in a study was 1, which associates with a specific code (e.g., people with disabilities [86], deaf or hard of hearing [87]). Studies having over 200 participants also exist, such as consecutive focus group studies with people with various impairment types (i.e., visual, hearing, physical and motor, learning) to investigate their media usage [88]. The median number of participants for each category ranges from 2.0 to 90.5 (*Community of focus*) and 1.0 to 30.0 (*Participant Groups*). Some data are not representative, especially for codes with low paper counts (i.e., less than five). Five disabled groups have not been reported in any user studies (i.e., intellectual and developmental disabilities, neurodivergent, aphasia and mental health conditions).

4.4 Analysis of 29-year research trends

After exploring the factors involved in adapting subtitles, we began to examine the comprehensive picture of accessibility research in subtitled media. We analysed how the research evolves throughout the period from 1995 to 2024, in terms of specific adaptation formats and communities of focus. We

divided the period evenly into five intervals (i.e., 1995-2000, 2001-2006, 2007-2012, 2013-2018 and 2019-2024) to better convey the change in paper counts over time. Since the literature base was extracted and analysed in the first quarter of 2024, papers published beyond this time frame did not appear in our dataset.

4.4.1 Temporal trends in subtitled media accessibility research

Accessibility research has gained traction over the past few decades [53]. This also applies to the research within the subtitled media space, as depicted in Figure 7. Two peaks can be seen throughout 1995 to 2024, with the number of papers surpassing 10 in 2015 and the 2020 to 2023 period. Although our literature base ceases part-way through 2024, we predict a similar publication count (i.e., double digits) on the accessibility of subtitled media research in that year.

4.4.2 Temporal trends in subtitle adaptation formats

An increasing trend has been observed across all four subtitle adaptation categories (i.e., position, location, content, and style), as seen in Figure 8. Some categories have shown a more rapid increase

Table 7 The frequency of papers with code for User Study Method.

User Study Method	Papers with code
Controlled Experiment	37 (48.1%)
Survey	61 (79.2%)
Usability Testing	21 (27.3%)
Interviews	34 (44.2%)
Case Study	7 (9.1%)
Focus Group	8 (10.4%)
Field Study	3 (3.9%)
Design Workshop	3 (3.9%)
Diary Study	0 (0.0%)
Ethnographic Study	2 (2.6%)
Longitudinal Study	5 (6.5%)
Other	6 (7.8%)
None	70 (47.6%)

Table 8 The frequency of papers with code for User Study Location.

User Study Location	Papers with code
No User Study	70 (47.6%)
Near/At Researcher’s Lab	35 (45.5%)
Participant’s Home/School/University	45 (58.4%)
Neutral Location	7 (9.1%)
Online/Remote	20 (26.0%)
Other	3 (3.9%)

than others during the three-decade period. In particular, content adaptation increased significantly after 2007, and style adaptation began to soar from 2013. The other two categories (i.e., position and location) revealed a steadier increase. Adapting the location of subtitles has not been explored until 2018, when research began customising the subtitle display within virtual reality (VR) environments [85].

4.4.3 Temporal trends in communities of focus

Similar to the findings from accessibility research in subtitled media published over time, an overall growing trend has also been found for each community of focus (i.e., visual, cognitive, physical, communication and intersectional). There are dips for two population groups, however, between 2013 and 2024 (visual impairments) and 2007 and 2018 (intersectional impairments) periods, which can be visualised on Figure 9. Communication and visual impairments constitute the majority of the focus in papers published between 1995 and

2024. This is because deaf or hard of hearing and blind or visually impaired are the two most represented communities, as discussed in Section 4.2.1. The other three communities display modest proportions, with cognitive and physical impairments beginning to appear from 2007 and intersectional impairments starting to show up from 2001.

5 Device and Context consumption for Communities explored

To gain a thorough understanding of how subtitled media consumption differs by each disabled group, we drew from the insights gained in Sections 4.1.2, 4.1.3 and 4.2.1 and investigated the device and context usage for various communities of focus (i.e., *visual impairment* (N = 22), *cognitive impairment* (N = 11), *physical impairment* (N = 10), *communication impairment* (N = 61) and *intersectional impairment* (N = 9)).

Table 9 Participant counts for the 73 papers that reported a user study (4 papers did not report sample sizes), split by Community of focus and Participant Groups.

Group	No. of Papers	Median	Mean	IQR	Range
Overall	73	30.0	59.5	40.0	1–626
Visual: Blind or Visually Impaired	8	11.0	31.1	26.0	3–154
Visual: Colour Vision Deficiency	1	2.0	2.0	0.0	2–2
Cognitive: Intellectual and Developmental Disabilities	0	0.0	0.0	0.0	0
Cognitive: Other Cognitive Impairment	3	77.5	77.5	0.0	8–147
Cognitive: Neurodivergent	0	0.0	0.0	0.0	0
Physical: Motor/Physical Impairment	3	74.5	74.5	0.0	1–148
Communication: Deaf or Hard of Hearing	31	14.0	18.5	23.0	1–161
Communication: Aphasia	0	0.0	0.0	0.0	0
Emotional: Mental Health Conditions	0	0.0	0.0	0.0	0
Intersectional: Intersectional Impairments	4	9.5	13.0	17.0	3–30
People with Disabilities	34	17.5	33.6	24.0	1–161
People without Disabilities	53	30.0	55.3	54.5	2–443
Older Adults	17	1.0	6.1	10.5	1–30
Specialists	19	6.0	32.0	14.0	1–237
Caregivers	1	6.0	6.0	0.0	6–6

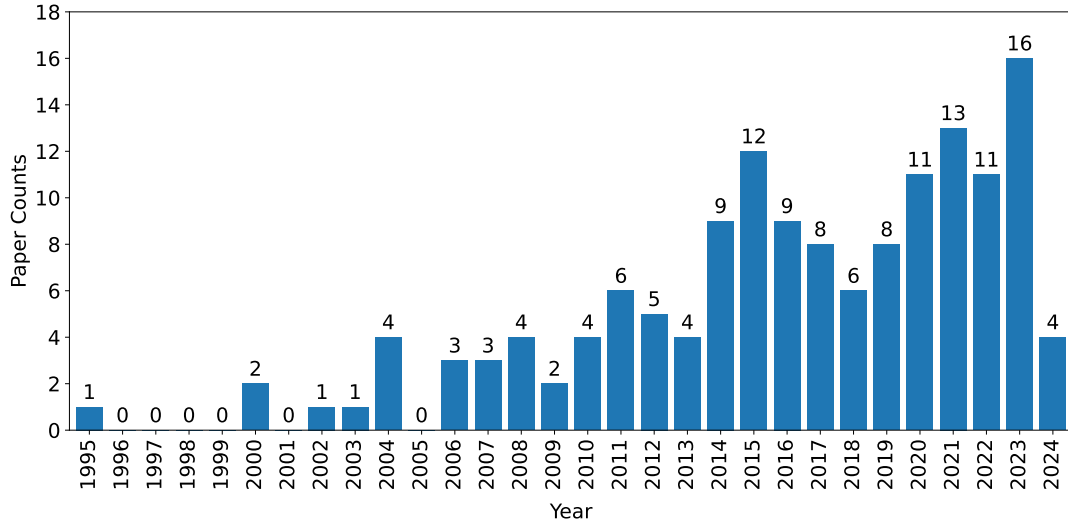


Fig. 7 Number of papers on subtitled media accessibility published over time between 1995 and 2024.

5.1 Visual Impairment

We explored the devices and contexts in which people with visual impairments consume. This primarily refers to the blind or visually impaired community, as most papers (86.4%, 19/22) with a visual impairment code focus on this population. People with colour vision deficiency appear in the remaining three papers.

5.1.1 Viewing Device

We found that research was primarily conducted using two types of devices: *television* (e.g., for translating and reviewing subtitles [89] and evaluating prototype [4]) and *desktop or laptop* (e.g., for video calling [90], evaluating media players' accessibility [91] and assistive video learning [92]). Portable devices for multimedia museum guides (i.e., *smartphones* and *tablets*) and consoles for

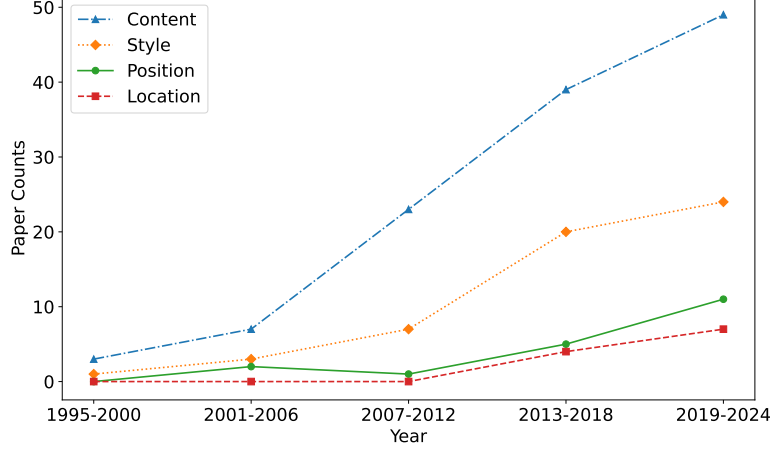


Fig. 8 Number of papers published over time that addressed Subtitle Position Adaptation, Subtitle Location Adaptation, Subtitle Content Adaptation and Subtitle Style Adaptation.

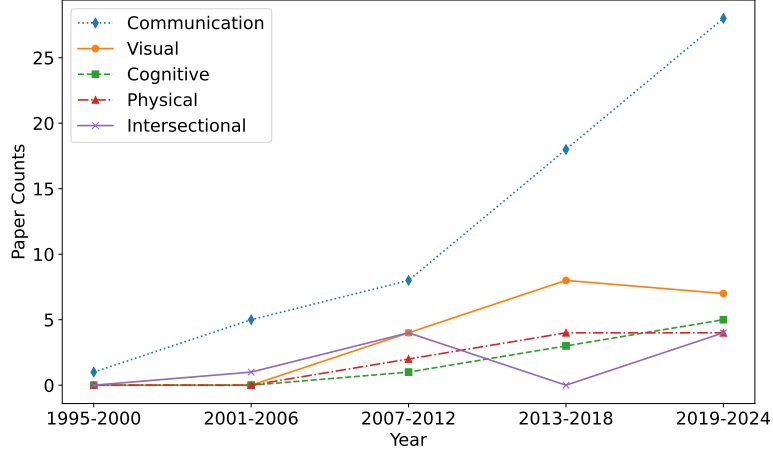


Fig. 9 Number of papers published over time that addressed Community of focus.

video gaming have been reported by Ruiz [93] and Fernandez et al. [94].

5.1.2 Viewing Context

A wide variety of genres have been reported, which applies mostly to papers that did not state the exact viewing contexts (e.g., [4] and [92]). Papers that focus on specific viewing contexts include *business or professional* settings for video conferencing [90], *public or social* settings for multimedia museum guides [93], and *entertainment* settings for gaming [94].

5.2 Cognitive Impairment

We investigated the devices and contexts in which people with cognitive impairments access subtitled media. Since more than four-fifths ($N = 9$) of papers with the cognitive impairment code merely state cognitive or learning difficulties, we classified these as *other cognitive impairment*. Other papers report intellectual and developmental disabilities ($N = 1$) and neurodivergent ($N = 1$) populations.

5.2.1 Viewing Device

The most commonly reported device category in the literature base refers to *desktop or laptop* (e.g.,

for simplifying subtitles [6], embedding accessibility features into AR/VR applications [95] and as a coding web application [96]). There are also three papers to which we applied all codes, as the devices consumed were generically stated (i.e., adaptive AR/VR system [65], media usage study [88], and accessible VR360 content in the cultural context [66]).

5.2.2 Viewing Context

The viewing contexts we have discovered consist of *entertainment*, *education*, and *public or social*, with *education* being the most consumed context and research combining *education* and *entertainment* is also common (e.g., [97] and [98]). One paper has *education* and *public or social* code combination [93], and two papers did not specify the exact viewing context [65, 88].

5.3 Physical Impairment

The analysis of device and context consumption for people with physical impairments is presented as a single category ($N = 10$). This is because none of the papers in our database have reported this classification beyond *motor or physical impairment*.

5.3.1 Viewing Device

Like previous viewing device findings, *desktop or laptop* remains the most frequently appearing (e.g., for coding web application [96], assistive video learning [92] and game accessibility analysis [99]) in studies. Three papers have been identified that broadly describe the devices used (i.e., model-driven video game development [94], a media usage study [88], and EasyTV services that address several accessibility challenges [100]). One paper has the *smartphone* and *tablet* combination, which corresponds to mobile media guides for museums [93].

5.3.2 Viewing Context

Education and *entertainment* are the contexts we have found most of the time, which appear as either (e.g., [96] and [94]) or both (e.g., [98] and [97]) inside the codebook. Moreover, we found one paper that combines *education* with *public or social* [93] and two papers with a generic viewing context [88, 92].

5.4 Communication Impairment

A significant proportion of the papers (40.8%, 60/147) in our database target populations with communication impairments. This consists mainly of the deaf or hard of hearing (95.1%, 58/61) community, and their device and context consumption were discussed. On the contrary, people with aphasia ($N = 0$) are not reported anywhere in the literature base.

5.4.1 Viewing Device

We discovered that studies most frequently explored *desktop or laptop* device for subtitled media consumption (e.g., for visualising non-speech sounds subtitles [47], improving automatic subtitling segmentation [101] and generating interlingual live subtitles [2]), followed by *television* (e.g., for consuming dynamic subtitles [29] and finding out subtitling issues [102]). There are also papers with multiple device combinations, such as *desktop or laptop* with *tablet* and *smartphone* (for integrating sign language video tracks into subtitled media contents [103]), and *smartphone* with *other* (for watching the theatre play in the VR environment [85]).

5.4.2 Viewing Context

The two most commonly appeared contexts are *entertainment* (e.g., [101], [29] and [102]) and *education* (e.g., [86], [96] and [104]). Nine papers in total have no specified context. We also found several papers that report multiple viewing contexts, such as *education* with *public or social* [93], and *entertainment* with *business or professional* and *public or social* [105].

5.5 Intersectional Impairment

The final community of focus we examined is literature that reports on either individuals who do not specify a disability type or those with multiple disabilities ($N = 9$). Their device and context usage for subtitled media consumption have been discussed.

5.5.1 Viewing Device

Same as results in the previous subsections, *desktop or laptop* still being the most reported device by studies when viewing subtitled text (e.g., for

simplifying subtitles [6], video calling [90] and personalising contents using model-driven engineering [77]), followed by *television* (e.g., for examining the user inclusivity [84]). Some literature also combines multiple viewing devices, such as *television* with *desktop or laptop* and *smartphone* and *tablet* (e-learning tool that improves access to learning materials [106]).

5.5.2 Viewing Context

We have identified *education* (e.g., [6], [106] and [77]) as the most represented consumption context. *Entertainment* is also a common viewing context, either on its own [64] or in combination with *business or professional* [107]. There are also two papers without specified contexts (i.e., investigating user inclusivity of digital television services [84] and analysing interactive digital TV accessibility in Brazil [76]).

6 Taxonomy of Subtitle adaptation formats for Communities explored

After exploring subtitled media consumption patterns for each specific community, we look into the types of subtitle adaptations (i.e., *position*, *location*, *content* and *style*) and investigate how each of these has been explored for different disabled groups. This has been reported as a two-way taxonomy depicted in Table 10, contributing theoretically as stated in 3 that foreshadows areas that require more attention from researchers.

6.1 Position

Table 10 reveals that the most explored community for subtitle position adaptation refer to people with *communication impairment* (N = 13). Among them, we have found a frequent code combination - *deaf or hard of hearing* and *optimal placement* that appears in eight papers [29, 31, 32, 46, 66, 68, 102, 109]. Other code combinations that have been explored include those found in the literature, such as the pair *deaf or hard of hearing* and *other*, which shifts the subtitle letter above and below the baseline to convey the arousal level [60]. The position of the subtitles can be moved under *user's control* for the *deaf or hard*

of hearing community to identify the speaker more easily [110].

Moreover, we also found papers that target several impairment categories. This includes the mass survey in [88] that gathers information from four impairment categories (i.e., *visual*, *cognitive*, *physical* and *communication*), and works in [66] and [92] both focus on three impairment groups (i.e., one for *visual*, *cognitive*, *communication* and the other for *visual*, *physical* and *communication*).

There are two papers with code *other* in the space of subtitle position adaptation, which corresponds to add-ons placement within the video [130] and moving the individual subtitle characters according to the baseline level [60].

6.2 Location

Adjusting the subtitle display to be outside the viewing screen has been the least represented type in our literature base, as shown in Table 10, with the *communication impairment* being the dominant population (N = 6). Upon further examination, three papers contain the *deaf or hard of hearing* and *VR display* code pair [65, 71, 85]. Two report niche adaptation methods. One projects the subtitled text onto a transparent display (i.e., classified as *environment-based display*) that can be used in a museum guided tour for the *deaf or hard of hearing* population [72]. The other places subtitles underneath the video frame or in a separate window (i.e., coded as *other*) that facilitates real-time communication for *deaf or hard of hearing* people using teleconferencing platforms [68].

Interventions toward multiple impairment categories also exist. One paper investigates *depth conflict* (by bringing the subtitled text closer to the viewer in XR space) and involves people with every impairment category except for *emotional impairment* [95]. Another VR subtitle paper explores three different impairment groups (i.e., *visual*, *cognitive* and *communication*) [65].

One paper has been classified with the code *other* in the space of subtitle location adaptation. This refers to moving the subtitled text outside the bottom of the video frame [68].

6.3 Content

Altering the subtitle content has been the most represented adaptation format, with the highest

Table 10 The taxonomy for the Type of Subtitled Media Adaptation explored across different Communities of Focus.

Type of Subtitled Media Adaptation	Position	Location	Content	Style
Visual: Blind or Visually Impaired	[66, 88, 92]	[65, 95]	[4, 66, 89–94, 97–101, 108]	[4, 65, 66, 87, 88, 90–99]
Visual: Colour Vision Deficiency	n/a	[95]	[4, 89]	[4, 95]
Cognitive: Intellectual and Developmental Disabilities	n/a	[95]	n/a	[95]
Cognitive: Other Cognitive Impairment	[66, 88]	[65, 95]	[6, 66, 93, 97, 98]	[65, 66, 88, 93, 95–98]
Cognitive: Neurodivergent	n/a	[95]	n/a	[95]
Physical: Motor/Physical Impairment	[88, 92]	[95]	[92–94, 97–100]	[88, 92–99]
Communication: Deaf or Hard of Hearing	[29, 31, 32, 46, 60, 66, 68, 88, 92, 102, 109, 110]	[65, 68, 71, 72, 85, 95]	[2, 15, 46, 47, 61, 66, 67, 81, 83, 85, 86, 90, 92–94, 97–101, 103–105, 108, 110–127]	[46, 47, 60, 65–68, 85, 87, 88, 90, 92–99, 102, 109, 110, 114, 117, 119, 122, 123, 128, 129]
Communication: Aphasia	n/a	n/a	n/a	n/a
Emotional: Mental Health Conditions	n/a	n/a	n/a	n/a
Intersectional: Intersectional Impairments	n/a	[95]	[6, 64, 77, 84, 90, 106, 107]	[64, 76, 90, 95]

overall frequency ($N = 77$) as seen in Table 10. Approximately 55% of papers ($N = 43$) include people with *communication impairment*. Along with insights gained from Table 5, the common code pairs include *deaf or hard of hearing* in combination with *language translation* (e.g., [103], [2] and [86]), or *user’s preference* (e.g., [120], [104] and [15]).

The second most common community of focus correspond to visually impaired people ($N = 14$). Similarly, frequent mappings also exist between *language translation* (e.g., [100], [66] and [91]) and *user’s preference* (e.g., [99], [94] and [90]) to *blind or visually impaired* people, due to the majority classes in our database (i.e., 58/147 for *language translation*, 48/147 for *user’s preference* and 19/22 for *blind or visually impaired*). One paper with *blind or visually impaired* and *other* pairing proposed an alignment algorithm between subtitled texts and dialogues that enriches narrative films [108].

People with *intersectional impairment* ($N = 7$), *physical impairment* ($N = 7$) and *cognitive impairment* ($N = 5$) are relatively under-explored. Those are commonly reported in conjunction with other, more frequently appearing communities of

focus. For example, papers in [93], [97] and [98] also involve people with *visual* and *communication* impairments.

In addition, we found that approximately 44% of papers ($N = 34$) reported *other* methods for adapting subtitle content. Examples include subtitle segmentation [131, 132], subtitle tokenisation [62, 125], subtitle manual correction [126, 133] and provision of “context-aware” subtitles for situational-impaired users [82].

6.4 Style

Like the other three types of subtitled media adaptation, communication-impaired people remain the most explored community (44.6%, 29/65) for adapting the subtitle style (distribution shown in Table 10), with a wide variety of code combinations. Traditional style adaptation includes an AR-based visual-captions interface that has been built, enabling the *deaf or hard of hearing* community to customise the subtitle *colour* and *font*, as well as adjust the *size* via fingers [46]. Novel-style adaptation has also been found. For instance, using *new element* to convey subtitled text (e.g., hand sign for raising hand, musical

note for background sound) that supports *deaf or hard of hearing* people engagement at theatrical performances [117].

People with *visual impairment* also frequently appear, constituting around 23% (N = 15) of the literature that reports subtitle style adaptation. Out of which over 85% (N = 13) adjust the subtitled text *size* that caters to *blind or visually impaired* population needs (e.g., [65], [96] and [94]). Enabling the *blind or visually impaired* community to configure subtitle style settings manually (i.e., coded as *user-defined style templates*) has also been a common approach used by academics (N = 6) (e.g., [66], [95] and [98]).

On the other hand, fewer voices have been received from people with *physical impairment* (N = 9), *cognitive impairment* (N = 8), and *intersectional impairment* (N = 4) regarding the adaptation of subtitle styles.

We also found a small number of papers (N = 11) that explore subtitle style adaptations not listed in the aforementioned codes (i.e., coded as *other*). For instance, the change of subtitled text opacity [56, 109] and the combination of subtitled text and video frames in a comic fashion [74].

7 Discussion

We surveyed 147 academic papers between 1995 and 2024 to investigate the consumption and adaptation of subtitled media by several disability groups. An overall increasing trend has been observed, and subtitle delivery modalities, user consumption methods, participant demographics, and research methods influence the design considerations for subtitled media adaptations. We also found that the current state of subtitled texts has primarily been displayed on computer screens, rather than on cinema screens, and for entertainment purposes, rather than in social settings. The deaf and blind population have been the primary intervention focus of the community, as opposed to neurodivergent, aphasia and mental health conditions groups. Researchers prefer evaluating with end-users through surveys, controlled experiments and interviews rather than field studies, design workshops and ethnographic studies. Moving forward, our discussion will help guide future accessibility research in the subtitled media space by critically responding to the review question through design considerations, analysing

device consumption trends, and acknowledging the limitations of this systematic review.

7.1 Considerations of designing accessible subtitled media adaptations

To fully respond to the review question (**What factors influence subtitle position, location, content, and styling to enhance media accessibility?**) stated in Section 3, we have synthesised three main factors (from the codebook in Table 1) to consider when adapting subtitled media to improve accessibility. These are methods of delivering and consuming subtitles, participant demographics, and approaches used to research subtitle adaptations, as discussed in detail below.

7.1.1 Factor One: Methods of delivering and consuming subtitles

Subtitled texts have been primarily researched in web videos (38.8%, 57/147) and watched on computers (85.0%, 125/147), while being rarely found in live streaming (2.7%, 4/147) and on big screens (4.1%, 6/147) (as depicted in Table 2 and 3). This is likely because people with disabilities (e.g., cognitive [134], visual and physical impairments [135]) might struggle to follow media content that does not have pause options and are less prone to consume the subtitles in a public space (e.g., cinema), which has also been reflected inside the Section 4.1.3 viewing context findings (i.e., public or social (27.9%, 41/147) being the least represented consumption context). As from Morón et al. [136] suggestions of conducting further research to investigate the effects of subtitle displays and adaptations on smaller screens, we see the potential of exploring this aspect on larger screens as well.

7.1.2 Factor Two: Participant Demographics

In terms of demographics, we have identified a considerable amount of literature focusing on deaf or hard of hearing (39.5%, 58/147) and blind or visually impaired (12.9%, 19/147) communities (see Table 5), aligning with the result from a broader scoped SLR that researches audiovisual media accessibility [18]. This falls within our

expectations, as altering the visual display of subtitled media can directly impact the consumption for the deaf population, as well as the audio adjustment of subtitles affecting the viewing experience of the blind population. On the other hand, communities including intellectual and developmental disabilities (0.7%, 1/147), neurodivergent (0.7%, 1/147), aphasia (0.0%, 0/147) and mental health conditions (0.0%, 0/147) have been little explored. Given the worldwide population of aphasic people (15 million) [137] and people with mental health conditions (970 million) [138], future research should aim to fill this accessibility gap between them and subtitled media, with approaches different from those for the deaf or blind population [139, 140]. This is because, through manual searches, we have found that people with aphasia tend to struggle to follow the pace of subtitles [21], and improving access to written information can reduce the linguistic demands on them [141]. People with mental health conditions, subtitles can provide reassurance by getting rid of potential hallucinations in dialogue for people with schizophrenia [142] and help people with Obsessive-Compulsive Disorder (OCD) not to miss details within the media [143]. Another reason for the underexplored areas is the absence of any intended benefit to the subtitled media adaptations. For example, people with colour vision deficiency will not benefit from adjusting the subtitle position. An exception refers to people with motor/physical impairment, literature identified for this user group focuses on their challenges in controlling the subtitled media rather than consumption, as they are likely to have similar accessibility needs from subtitled media as typical users. Regarding the type of participants involved in the 77 papers with user studies, older adults (22.1%, 17/77) and caregivers (1.3%, 1/77) have been seldom reported (as shown in Table 6). Given the population ageing [144] and the increasing effectiveness of user studies involving caregivers [145], we encourage researchers to draw more attention to these participant groups.

7.1.3 Factor Three: Approaches used to research subtitle adaptations

When understanding user requirements for subtitled media adaptations, the use of questionnaires (79.2%, 61/77) has become the optimal approach

(Table 7 reveals this). This is likely due to the loose time constraint imposed for completion, potentially minimising the cognitive load for people with disabilities. On the contrary, few user studies employ a field study (3.9%, 3/77), design workshop (3.9%, 3/77), diary study (0.0%, 0/77) or ethnographic study (2.6%, 2/77) approach. Therefore, we suggest that niche user study methods should receive more voices in the future, especially for the design workshop [146] that enables people with disabilities to brainstorm and prototype the subtitle adaptation solutions they want. We also found that researchers prefer to conduct user studies in people’s homes, schools, or universities (58.4%, 45/77) over neutral spaces (9.1%, 7/77), as depicted in Table 8. This is not surprising, as researchers are less likely to carry and set up study equipment away from their office to a place they may not be familiar with.

7.2 Changes of device consumptions over time

Grounded in the insights gained from how each community uses different devices to consume subtitled media (Section 5), we have taken a step further through a 29-year temporal analysis of the device consumption findings (Section 4.1.2). The use of television and computers is distributed evenly throughout the entire three decades, suggesting widespread adoption of devices for displaying and adapting subtitled text. Mobile devices have gained traction since 2010, starting with the use of avatars developed by Vy and Fels [110] to identify the speaker in subtitles on portable devices. We are unable to find papers that explore subtitled media adaptations on big screens after 2020. The low reference frequency (4.1%, 6/147) potentially opens avenues for future research on adapting subtitled text in larger and panoramic screens, echoing recommendations by Brown et al. [35].

7.3 Limitations of this systematic review

Like other literature surveys, this SLR has limitations. This includes aspects such as database usage, term variation, and coding bias.

Despite closely following PRISMA guidelines [49] and additional guidance from Boland

et al. [50] and Siddaway et al. [51], we did not include all papers within the scope of subtitled media accessibility. Databases (e.g., Web of Science, IEEE Xplore) not selected for review due to low return numbers can still include papers that meet the requirements stated in Section 3.1. Furthermore, we set the subject disciplines to be Computer Science and HCI when searching databases. However, researchers from art, design or psychology backgrounds can also develop interventions for subtitled media adaptations. As a result, future SLRs could consider a broader range of databases with more diverse fields to gain a deeper understanding of the creation of subtitled media adaptations from various angles.

As reported by other SLRs [18, 53, 147, 148], we also encountered varied language uses to describe a specific term across our literature base. For instance, in the community of focus category, “colour blindness” could be referred to as “colour vision deficiency”, and “learning difficulty” could be classified as “other cognitive impairment”. Additionally, when coding the “survey” as a user study method, we found some papers that used “questionnaire” as an alternative term (i.e., in noun format). Language inconsistencies, along with shifts in term definitions over time, could both potentially impact our codification decisions.

Although our team consists of a second reviewer coding a 20% sample of the database, subjectivity and errors can still occur due to the large volume of qualitative data that needs to be manually processed for each paper. We also acknowledge the various cultural and ethical backgrounds and English language proficiencies that may influence individuals’ interpretations of specific data. Therefore, we see potential for automating certain aspects of SLR processes [149] in the future to mitigate analysis and judgment biases.

8 Conclusion

We systematically reviewed 147 papers researching subtitled media adaptations spanning 29 years, produced an open-source literature base and taxonomy that helps pinpoint underserved communities. Our review highlighted important considerations for designing and developing subtitle adaptation interventions, the devices and contexts in which each disabled group consumes

subtitled media, as well as how each community of focus has been explored for various types of subtitled media adaptation. To promote more accessible and inclusive practice when creating future subtitled media adaptations for people with disabilities, we compile the following three directions that future researchers and practitioners can follow:

- We recommend a wider range of places where the subtitled text can be displayed and adapted, such as cinema screens or specific object surfaces, rather than on traditional devices like televisions, computers or mobile devices.
- We call for the involvement of a more diverse community in the design and development of the subtitle adaptation interventions. This includes people with neurodiversity, aphasia, and mental health conditions, apart from the frequently represented blind and deaf people. We would also like to emphasise the exploration of the solutions’ potential generalizability to disability groups outside of the main community of focus.
- Echoing the insights drawn by Mack et al. [53], we suggest more accessibility considerations should be in place when deciding the method and place to carry out the user study and experimenting with less frequently reported methods (i.e., field study, design workshop and ethnographic study) and locations (i.e., public space).

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