DEPARTMENT OF COMPUTER SCIENCE

# Collaborative Writing Accessibility and the Distribution of the Labour of Access in Mixed-ability Teams of Visually Impaired and Sighted Users

[redacted]

A dissertation submitted to the University of Bristol in accordance with the requirements of the degree of Master of Engineering in the Faculty of Engineering.

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# Abstract

Collaborative writing has become an integral part of everyday life. There is a rich research history that explores groupware awareness and collaborative writing practices. However, very little is known about how mixed-ability teams, particularly those involving sighted and visually impaired users, work together when performing collaborative writing tasks. While popular collaborative writing systems implement accessibility features, these are often deemed unusable and impractical by screen-reader users. Using these systems creates extra labour for visually impaired users, which is often invisible to able-bodied collaborators.

To address these issues, this project aimed to study the accessibility of collaborative writing software by conducting in-depth interviews with visually impaired and sighted users. Thematic analysis was performed on the findings from this study, revealing several observations about the experience of collaboration working in a mixed-ability team. From the findings, I identified five system design requirements that are needed to make collaborative writing systems accessible. This included that the systems should have features that distributed the labour of creating access across the whole team. I applied these requirements and designed CollabConenct, an accessibility writing tool that works on top of Google Docs to support ability-diverse teams when collaborating.

To assess how well my tool solves the issues of collaborative writing systems and whether it is possible to distribute the labour of access, I conducted a design evaluation study. The findings from the study show that participants had an overall positive experience when using the tool, as they liked most collaborative awareness features of CollabConnect. This suggests that it is possible to distribute the labour of access in a way that is helpful to the blind and visually impaired (BVI) collaborators. However, the findings also uncovered larger issues of the nature of developing systems to be accessible, as BVI users do not trust their collaborators or larger corporations to create access or accessible systems.

# Declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Taught Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, this work is my own work. Work done in collaboration with, or with the assistance of others, is indicated as such. I have identified all material in this dissertation which is not my own work through appropriate referencing and acknowledgement. Where I have quoted or otherwise incorporated material which is the work of others, I have included the source in the references. Any views expressed in the dissertation, other than referenced material, are those of the author.

[redacted] Wednesday 10th May, 2023

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# Ethics Statement

An ethics application for this project has been reviewed and approved by the faculty ethics committee as application 14060.

# Supporting Technologies

- I used parts of the CollabAlly code and design to implement the summary dialog box when developing the Chrome Extension of my system [34].
- I followed the ARIA Authoring Practices Guide pattern for making a dialog box, called the 'Dialog (Modal) Pattern', and used parts of their example utility functions to implement Keyboard Support [30].

# Notation and Acronyms

| | | |
|---|---|---|
| BVI | : | Blind and Visually Impaired |
| HCI | : | Human-Computer Interaction |
| CSCW | : | Computer-supported cooperative work |
| WA | : | Workspace Awareness |
| WAI | : | Web Accessibility Initiative |
| W3C | : | World Wide Web Consortium |
| ARIA | : | Accessible Rich Internet Applications |
| APG | : | The ARIA Authoring Practices Guide |
| PA | : | Personal Assistant |
| GCP | : | Google Cloud Platform |

# Chapter 1

# Introduction

Collaborative writing and its most popular tools (Google Docs, Microsoft Word and Overleaf) have become an integral part of workplace and academic setting [58, 63]. In 2020, Google G Suite (which includes Google Docs, Sheets and others) reported over 2 billion monthly users [23].

There is a long history of research in Human-Computer Interaction (HCI) which has focused on groupware awareness and collaborative writing practices [58, 63]. A body of research has focused on writing strategies [45], and the differences between synchronous and asynchronous collaboration [**?**] and developing collaborative writing frameworks [28]. This research has been reflected in the design of document editing software by implementing collaborative awareness features. Collaborative writing usually involves tasks like writing, editing, adding and replying to comments. To know how to do these tasks, users need to have a certain level of awareness about their collaborators' work and presence in the document. Software features that communicate this collaborative awareness can range from comments, track changes and colourful cursors to detailed version history.

For example, in Google Docs, when a user is present in the document, a representative icon appears in the navigation bar. In the body of the document, every collaborator has a different coloured cursor indicating their position in the document. Most collaborative writing software have a version history section, for the user to see changes made since they last opened the document. Most of these features present the collaborative awareness information to the user visually.

Very little is known about how mixed-ability teams, particularly those involving sighted and visually impaired users, work together when performing collaborative writing tasks. As collaborative writing becomes popular, there is a need to fill the gap in the research into mixed-ability groups, the notion of distributing the labour of access and designing tools that support mixed-ability teams in collaborative writing.

As it is, collaborative writing systems do implement accessibility features, however these are deemed unusable and impractical by screen-reader users [19, 50, 16, 41]. Google Docs has screen reader and braille display support with the ability to turn on 'collaborator announcements'. These are speech audio cues that notify the user when a person enters and exits the document and when they are near what other people are editing. Google Docs or Microsoft Word have not developed any alternative, non-audio methods of conveying visual awareness information features for collaborator activities. Collaborator announcements and the body of the document are simply read out. Typically, a visually impaired person using a screen reader has to listen to the document text read out loud, which gets interrupted by collaborator announcements informing the user of text and comments changes or collaborator interactions. This workflow has been reported to be cognitively overloading to screen reader users [19].

As visually impaired users cannot use the same collaborative awareness information as sighted people and the accessibility support is not sufficient, there is extra labour that they need to put in to be able to do collaborative writing tasks. In a mixed-ability team, this labour is often invisible to the able-bodied collaborators [15].

This invisible labour of access consists of educating sighted collaborators, suggesting workarounds and alternative methods. Additionally, for BVI users this labour involves the intangible aspect of bearing the potential social 'cost' of creating access [19]. An example of an intangible social task is the ability to communicate their accessibility needs and finding alternative methods to perform collaborative writing tasks. Das et al. describe that in ability-diverse teams, accessibility stems from negotiating practices, workflows and alternative methods overtime [19]. Some examples include using a specific version of software, leaving inline comments, not replying to comments, using other means of communication to point out changes. For these changes to be implemented, the whole teams needs to agree on a workflow that works for them. This suggests that if accessibility is created by the whole mixed-ability team, the software should support such a pattern of behaviour.

Research into improving these accessibility features has focused on introducing multi-modal representations of collaboration awareness information. Main ideas involve replacing speech audio with implicit, non-speech audio cues or earcons with spatial audio [21, 34, 20]. Another is adding an on-demand summary dialog box that presents critical information about text, comment and collaborator changes to the visually impaired users [34]. Recent research suggests the idea of distributing this labour of creating access in collaborative writing settings across the whole team, onto the able-bodied collaborators.The CollabAlly designers considered extending their tool to involve a similar extension that would guide able-bodied users to summarise their text changes to give a more comprehensive idea of their edits to their visually impaired collaborators [34]. However, no tool has been developed that implements this notion of distributing the labour of access in collaborative writing.

## 1.1 Summary of Objectives

To address the issues of (in)accessible features of collaborative writing software and the distribution of labour of accessibility, the main aims and objectives of this project are:

1. Study accessibility of collaborative writing software by conducting in-depth interviews about the experience of BVI users using these tools.
2. Study collaborative writing awareness in mixed-ability teams by conducting in-depth interviews with sighted users.
3. Identify collaborative awareness features and their alternative representations for BVI users.
4. Identify features that can be implemented that can create access by sighted collaborators.
5. Implement some of these features in a Google Docs add-on, which guides the able-bodied collaborator to a more accessible 'formal' work.
6. Develop a Google Chrome extension which works with the developed Google Docs add-On and presents the collaborative awareness information provided by the sighted user (through the add-on) to the BVI user in a more accessible way.

# Chapter 2

# Contextual Background

In this chapter, I explore the various aspects of collaborative writing, such as experimental tools, frameworks, and workspace awareness, and examine how they impact the collaborative writing process. I also look at current collaborative writing software, such as Google Docs, and breakdown how it supports collaborative awareness. Additionally, I explore the topic of accessibility in collaborative writing, focusing specifically on visual impairment in the UK and the accessibility of collaborative writing software. Finally, I discuss the concept of ability-diverse teams, examining the invisible labour of access and its distribution in collaborative writing.

## 2.1 Collaborative Writing

With the development and increased usage of personal computers, collaborative writing to some extent, has always been present as well. Then, collaborators worked in an asynchronous sequential way, where documents were sent via email and each collaborator would add their section one at a time. One of the biggest advancement since is the ability to have multiple people editing the same document at the same time. However, if there are more people working on one piece of text at the same time, the need for some information arises. A collaborator has to know the identities of the other collaborators, their current status, any updates since the last review, and how to interpret the changes made by co-authors. To address these needs, an ideal collaborative writing software should explicitly and concisely provide users with answers to these questions within the tool.

As collaborative writing tools become more advanced, research has focused on providing the user answers to these questions. The main body of this growing HCI research explored how to design software for collaborative writing and how to implement features that support varying types of collaborative writing styles. The earliest research focused on developing a number of experimental systems. Many of these inspired features that we see in popular collaborative software nowadays.

### 2.1.1 Experimental Collaborative Writing Tools

A study published in 1991 showed that over the years, collaborating on document writing has been increasing in popularity [24]. This study reported that out of all university and company writing, 85% of them were written collaboratively. This trend inspired the design and several experimental collaborative writing tools. In 1992 McGuffin and Olson [44] constructed a simple groupware tool called ShrEdit. It had the most basic functionality of a collaborative writing tool, allowing multiple users to write in the same document and see each other's work.

A year later, Baecker et al. detailed the development of collaborative writing software SASSE [7]. The researchers iteratively designed two prototypes, the first supporting synchronous writing and editing and the second expanding this by adding features to support asynchronous work, brainstorming, outlining, and document reviewing.

Quilt [25] was developed to tackle the issues of co-authors sharing information and coordinating activity. They did this by implementing features for voice and text message sharing, document annotation and history of changes.

### 2.1.2 Collaborative Awareness and Frameworks of Collaborative Writing

In their paper, SASSE researchers explicitly mention support for collaborator awareness to be a major consideration for their tool design [7]. Dourish and Bellotti define collaborator awareness in collaborative settings as all the information that pertains to the activity of others which then provides context for individual activity. Collaborator awareness has a critical role in facilitating group progress and coordinating group activity [22].

In subsequent years, HCI researchers have used these tools (ShrEdit, SASSE and Quilt) to observe collaborative writing practices and developed theoretical frameworks and taxonomies to guide the design of collaborative writing tools. Posner and Baecker [47] set out to examine joint writing and find patterns in the processes by concluding an interview study. From this, they developed a taxonomy which identified roles, activities, document control methods, and writing strategies to be key components of collaborative writing processes. Document control methods are different ways collaborators may choose to manage control of collaboratively written text.

Lowry et al. developed a similar taxonomy, but extended it by including work modes [35]. Work modes are defined as a "group awareness and process decision as to when and where a CW [collaborative writing] group will do its writing, respectively, in terms of same or different place and same or different times" [35]. Work modes directly affect how much collaborators understand what is happening, which correlates to the amount of group awareness present. Group awareness has four different forms (informal, group-structural, social and workplace) which all impact collaborative awareness. The authors stress the importance of choosing, among other things, a well-developed collaborative writing software to promote successful outcomes.

#### Workspace Awareness Framework

Gutwin and Greenberg [28] build on these early ideas by developing a three part conceptual framework of workspace awareness (WA) with the intent to support the design of real-time distributed groupware. They define workspace awareness as "the up-to-the-moment understanding of another person's interaction with the shared workspace" [28]. This framework identifies 'what', 'who' and 'where' elements of workspace awareness (detailed in Table 2.1). An element is a common occurrence that stems from people interacting with their workplace environment, e.g., gaze, authorship, presence, identity. The WA elements themselves, maintaining and gathering WA information, and how WA is used in collaboration make up the three parts of this conceptual framework. Groupware designers are encouraged to consider three tasks that correspond to the three parts of the framework. The tasks are; determining what information to provide, deciding how to gather knowledge and deciding the space and method for using the knowledge. Additionally, the authors discuss how peripheral awareness of collaborator actions can better group activity coordination, determine assistance opportunities, predict conflicts, and recognize when the right time to switch between tightly-coupled work and loosely-coupled work.

| Relation | Category | Element | Questions |
|---|---|---|---|
| Present | Who | Presence | Is anyone in the workspace? |
| | | Identity | Who is participating? Who is that? |
| | | Authorship | Who is doing what? |
| | What | Action | What are they doing? |
| | | Intention | What goal is that action part of? |
| | | Artifact | What objects are they working on? |
| | Where | Location | Where are they working? |
| | | Gaze | Where are they looking? |
| | | View | Where can they see? |
| | | Reach | Where can they reach? |
| Past | How | Action history | How did this operation happen? |
| | | Artifact history | How did this artifact come to be in this state? |
| | When | Even history | When did that event happen? |
| | Who | Presence history | Who was here, and when? |
| | What | Action history | What has a person been doing? |
| | Where | Location history | where has a person been? |

Table 2.1: Elements of workspace awareness relating to the past and present according to Gutwin and Greenberg [28].

### 2.1.3 Collaborative Writing Practises

An extensive body of HCI and Computer-supported cooperative work (CSCW) research studied how groups of collaborators work together to produce and edit documents, which tools and applications they use and what type of information they seek out to perform collaborative writing tasks. In a number of cases this research led to development of features that support collaborative writing [43, 33, 9, 42, 32, 31, 13].

Birnholtz and Ibara [11] suggest that awareness features, such as seeing others' edits, can create conflict among collaborators. To minimize misunderstandings and conflict, collaborators often add comments to explain their actions. This highlights that edits in a document carry social messages in addition to their textual changes. The authors note that current collaborative writing software does not support the relationship between awareness features, communication, and social relationships, even though group maintenance is crucial for successful group activities [36]. In their subsequent work, Birnholtz et al. [12] investigate the socio-emotional and relational communication that takes place during collaborative writing. They found that collaborative writing can have both positive and negative effects on relationships, depending on whether collaborators are writing synchronously or asynchronously. They suggest that collaborative software should allow collaborators to demonstrate positive intentions when editing others' work.

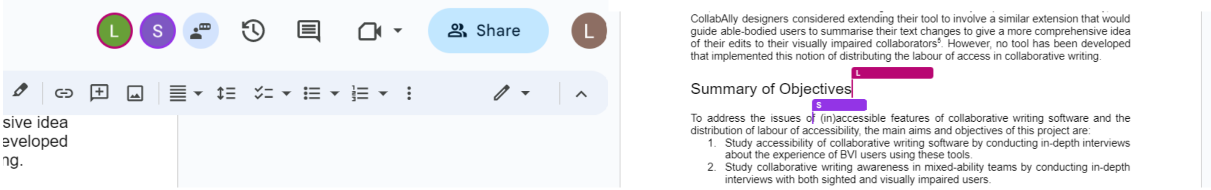
A number of researchers focused their work on studying how people use modern collaborative writing systems to produce documents and observed patterns of behaviours and strategies [65, 45, 57, 58]. As an example, Yim at el. explore the different techniques that groups of undergraduate students utilise to write documents on Google Docs [65]. They conclude that the divide-and-conquer style produced better quality text and that balanced participation can be connected to better writing quality. Similarly, Olson et al. studied collaborative writing practices in a variety of scenarios of student writing and observed a range of strategies and found that students take on fluid roles and work both synchronously and asynchronously [45]. Their conclusion is similar, where they found that documents produced by teams with balanced participation were better in quality.

In an interview study, Wang et al. [58] identified several reasons why people tend to not write collaboratively and avoid certain collaborative behaviours. In addition to normal writing roles (writer and editor), external roles (supervisor, senior/junior member of team or an expert) and their inherent relationships play an important role in collaborative writing. In certain relationships dynamics, users tend to be hesitant to edit text produced by their superior. Additionally, some users claimed to avoid collaborative writing as they felt their individual contribution could not be identified and they would not get due credit. These publications propose several design suggestions which include a role-based version history, being able to identify authors of text on hover, having an integrated private writing space and many others. Most of these studies, published in 2017, show that we are far from finished designing collaborative writing software, as there are still behaviours, patterns and nuances of collaborative writing that current systems don't capture. This is supported by a prominent thread of research focused on developing features and tools to enhance existing collaborative writing systems. Wang et al. developed two systems which use Google Docs revision history data. DocuViz [57] visualises group collaboration patterns and AuthorViz [45] implements colour-coding of each author's edited text in the final version. These tools are an example of summary techniques that intend to visualise collaborator contribution and how a document evolves over time. Both have been published as Google Chrome extensions and work with Google Docs.

Recent research has explored different ways to visualize collaborative actions and co-author contributions, including the use of organic visualizations by Perez-Messina et al. [46] and a framework for assessing and visualizing co-author quality by Torres et al. Eye-Write [56] proposes the use of gaze-sharing as a feature to enhance collaborative awareness, concluding that it improves mutual understanding, joint attention, communication flow, negotiation, and awareness of co-author activity. Some researchers have also developed new experimental systems, such as CEPT [66], which facilitates knowledge sharing among non-native speakers by summarizing work from multiple co-authors and enabling collaboration. The amount of current research into collaborative writing and visualisation of awareness shows that we are far form done focusing on collaborative writing for able-bodied users.

### 2.1.4 Collaborative Writing Tools

Modern commercially available systems for collaborative writing and editing include Google Docs, Microsoft Word and popular for academic writing, Overleaf. All of these have been designed to support group work by including features to enhance collaborative awareness. They include their own form of




(a) User icons in Google Docs

(b) User cursors in Google Docs

Figure 2.1: Example of a colour-coded cursors and icons in Google Docs

comments, track changes and live edits, revision history and edit notifications. These features are the same ideas from experimental tools and research frameworks.

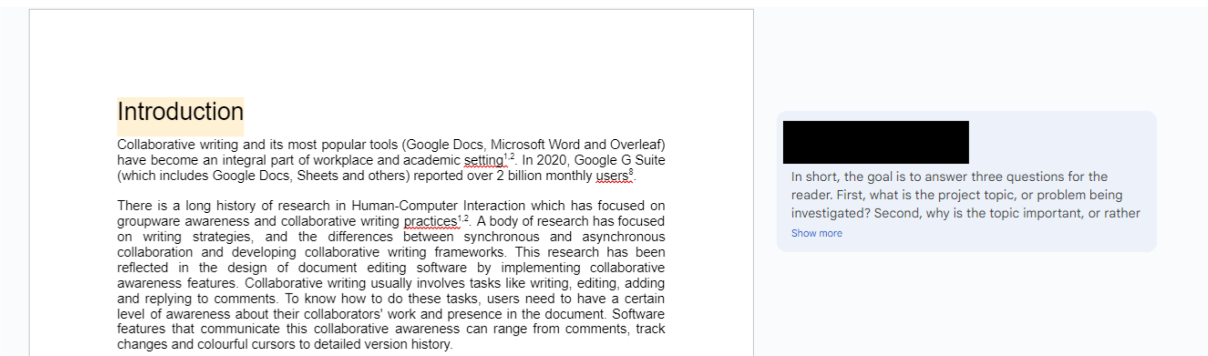
#### Google Docs support for Collaborative Awareness

I chose Google Docs as the platform to implement my tool, further explained in 4, therefore it is important to break down how this online software supports collaborative awareness. Google Docs is a web-based tool for collaborative writing and editing. A user (Owner) can create a document and share it to others with different access rights (Editor, Commenter, Viewer). It implements all the basic functionality of a word processor; inputting, editing, formatting, and outputting of text. Google Docs supports both synchronous and asynchronous collaboration as well as individual work. To do this, it implements several features that make it easy to interpret collaboration information visually.

I used use Gutwin and Greenberg framework [28] for workspace awareness to break down Google Docs collaborative features. Specifically, I ask the questions pertaining to WA elements (can be found in 2.1) and explain how Google Docs provides answers with its feature design. As multiple users can access a Google Docs document at the same time, it is important to know who is doing what and where at any point. All the collaborators who have their document open are represented with icons in the top-right of the page and each user is represented by a different colour (see Figure 2.1). The position of a user in a document is marked by a cursor, Figure 2.1b, whose colour corresponds to the colour of their icon, which can be seen in Figure 2.1a. This tells the user 'where' the 'who' are writing. With this same feature, if a text is being written, the users can see 'who' is writing it by associating that coloured cursor with their icon. If they are not actively typing, a user cannot tell what they are doing. If they are reading a section or researching in a different tab, which are both tasks associated with collaborative writing and editing, a user has no way of knowing this, other than communicating via a chat feature or through other means.

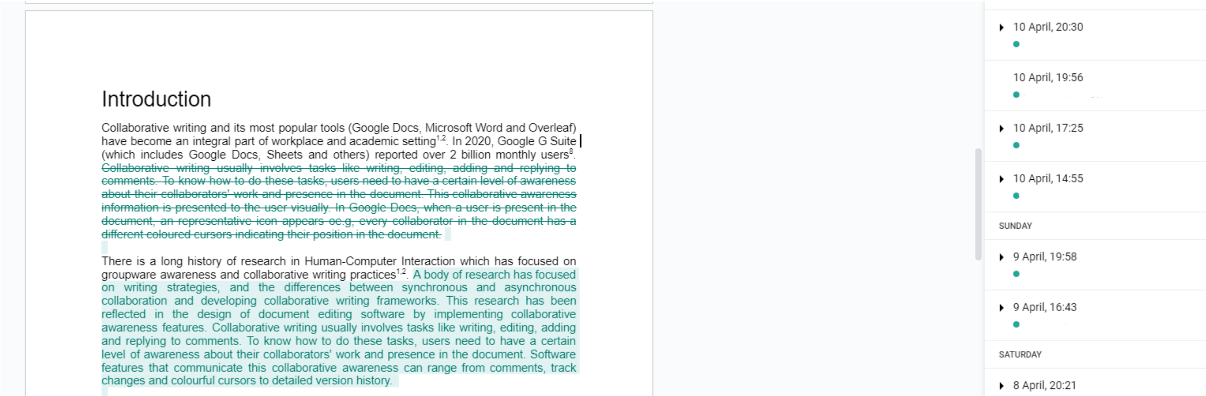
To further explain the 'what' element of action, collaborators can leave comments explaining their intentions. They can also inquire for an explanation from others. Comments are always associated with the text they are referring to, which gives the user appropriate context information. Visually, this is represented by the text being highlighted and the comment element hovering next to the text on the right (Figure 2.2). Additionally, when a comment is clicked on, the saturation of the colour used to highlight the relevant text segment intensifies, making the commented text more noticeable.

Figure 2.2: Example of a comment in Google Docs




It is also crucial to understand past events and actions of workspace awareness. Google Docs does with its version history feature, an example of which can be found in Figure 2.3. A user can see any text changes made to the document, who made them, and at what time they were made. A user can even revert back to a past version of the document. This feature supports asynchronous collaboration, as a user can identify the authorship of changes made when they were not present.

Figure 2.3: Example of version history in Google Docs




The features described above, and all other Google Docs collaborative features, use highly visual means of communication to convey collaborative awareness information; such as colour and colour-coded users, highlights, floating comment locations, and strikethroughs. Overall, these features are valuable to users and facilitate efficient and collaborative editing behaviours that support collaborative work. However, they are often inaccessible to blind users and screen reader users, because of their reliance on visual presentation.

## 2.2 Accessibility and Collaborative Writing

Section 2.1 details the extensive body of research and 30 year old history of HCI and CSW work in collaborative writing. Researchers have always been and still are very interested in how groups of people collaborate and how to design systems to support them by implementing features of collaborator awareness. In this section I compare that amount of research by introducing the existing work exploring the accessibility of these systems for users with visual impairments. I first introduce the topic of visual impairment in the United Kingdom to understand the importance of my research into accessibility of collaborative writing and the distribution of the labour of access.

### 2.2.1 Visual Impairment in the UK

Over 2 million individuals in the UK live with moderate-severe sight loss, with 180,000 people registered as sight impaired and 170,000 registered as severely sight impaired [2]. The number of people affected by vision loss has been increasing since 1991 [3].

There is a shocking sight loss employment gap observed in working age individuals. In 2020, the employment rate of people with a seeing difficulty was 48%, which is significantly less than 76%, the overall UK employment rate [5]. Only 1 in 4 blind and partially sighted people of working age are in employment [2]. Also in 2020, RNIB published a report [26] detailing the barriers people with vision loss face. 33% of their respondents state that the employer attitudes and their unwillingness to make sufficient adjustments are the most significant reasons for the employment barrier. Additionally, participants stated that getting and staying in employment is a significant barrier for them, coming second to only the barrier created by awareness and public attitudes. Similarly, a survey done by World Services for the Blind states the top barriers in employment are lack of transportation, training, negative attitudes from employers and lack of workspace accommodations [48].

Generally, the higher the qualification an individual holds, the more likely they will be employed [27]. In their 2020 report comparing people with sight loss to the rest of the population, RNIB stated that even with a higher degree, people with seeing difficulty were less likely to be employed than people without disability. According to Employment facts and stats 2020 report [4] published by RNIB, “registered blind and partially sighted people with a degree or higher still only have the same chance of getting a job as someone with no qualifications in the general public”. The employment rate drops to 26% for individuals with visual impairment who hold no degree [5]. In the academic year 2021/22 only 3,700 students disclosed that they are blind or have a serious visual impairment [29].

Collaborative writing has become prevalent in academic and professional settings. To improve the blind and visually impaired employment rate, it is important to make collaborative writing systems more accessible and usable. 60% of employers claimed that they would be willing to make changes to their workplace to accommodate a blind or partially sighted employee [4]. This suggests that developing tools that raise awareness about visual impaired could improve employer awareness of the labour that individuals with visual impairment put into creating access for themselves.

### 2.2.2 Accessibility of Collaborative Writing Software

Popular collaborative writing systems implement some accessibility support for blind and visually impaired users. Google Docs has screen reader and braille display support with the ability to turn on 'collaborator announcements'. These are speech audio cues that notify the user when a person enters/exits the document and when they are near what other people are editing. These accessibility features are not enough to support collaborative awareness to BVI users, on the contrary, their poor design often makes Google Docs unusable for screen reader users [19]. The usefulness and usability of such accessibility solutions has been examined in the past [19, 16, 17, 53], revealing how the most basic features needed for collaborative writing (comments, track-changes, version history, colour-coded collaborators) are not available to screen readers. This could be because of difficulty accessing them or missing context to make use of them [50].

Most notably, Das et al. [19] identify a plethora of reasons why and how Google Docs and Microsoft Word fail to accommodate accessibility to blind and visually impaired users. Here is just some of the issues they identified:

- There is a steep learning curve as they use different shortcuts to typical screen readers.
- Limited learning resources.
- Software is always changing and new updates sometimes change accessibility features, leading to users having to relearn.
- Working is cognitively overloading, as everything is communicated through speech audio.
- Users struggle to associate collaborator awareness information with its context, as it is not provided with the information.

As screen reader users struggle to interpret collaborative awareness information they are required to do additional labour to understand who is doing what and where.

In their following work, Das et al. revisit this interview data and group the challenges screen reader users face during asynchronous collaborative writing and editing into four key categories:

1. "distinguishing between document content, collaboration markup, and comments/edits from others,
2. understanding how document content evolves through underlying edits,
3. managing disruption in workflow created by verbose spoken announcements for collaboration markup,
4. controlling the influx of collaboration information." [21]

To improve accessibility of basic document editing and formatting features and fix some of the aforementioned issues, researchers have developed Microsoft Word or Google Docs extensions [16, 41, 49]. Schoeberlein and Wang [49] iteratively developed Microsoft Word add-in prototypes, which focused on providing context, in the form of pop-up windows, about specific comments and track changes. This has proven to make the comments and revision easier to understand by screen reader users.

Recent research into improving these accessibility features has focused on introducing multi-modal representations of collaboration awareness information. Main ideas involve replacing speech audio with implicit, non-speech audio cues or earcons with spatial audio [21, 61, 34, 20]. Another ideas was adding an on-demand summary dialog box that presents critical information about text, comment and collaborator changes to the visually impaired users [34].

For example, to indicate text modifications, Waqar et al. [61] designed a collaborative writing system that utilises speech input and audio alerts. Namely, Das et al. [21] studied incorporating non-speech audio and different voice-fonts in asynchronous editing situations. Their findings highlight the potential of audio techniques in conveying comments and recent edits in a document to screen reader users. They concluded their work by suggesting which audio representation should be used in what context.

### 2.2.3 Recent Solutions

Most relevant to our work are two novel systems developed to tackle all the accessibility issues listed above, Co11ab [20] and CollabAlly [34]. Co11ab was developed by Das et al. as a Google Docs add-on which implements non-speech audio notifications, follow mode and jump to cursor features and an audio scrollbar. CollabAlly works on Google Docs as well, but it is implemented as Chrome Extension, it has functionality to support both synchronous and asynchronous collaboration with a summary dialog box and makes use of non-speech audio, voice fonts, spatial audio and earcons. Despite being tools aimed at making collaborative writing more accessible in mixed-ability teams, CollabAlly and Co11ab are specifically designed for blind and visually impaired collaborators. This leaves options for further research into making solution that involve the whole team, which I aimed to accomplish in this project.

#### Co11ab

Following their research into audio representation for asynchronous writing, Das et al. set out to apply their findings and developed Co11ab. This extension implements features that try to address key challenges BVI users face when synchronously editing a shared document. Co11ab works with a user's screen reader and Google Docs while maintaining its underlying functionalities. Through a set of new shortcuts, a user can utilise novel features to access collaborative information. To know who is doing what and where, a screen reader user may make use of query location, follow mode and jump to location features. To avoid concurrent edits, Co11ab implements relative proximity notifications through the loudness and pitch of a non-speech sound, an earcon. To get a high-level overview of collaborative awareness information and their location in a document, a user can use the audio scrollbar feature. This scrollbar works on the basis of hierarchical navigation and either provides the overview of the whole document or user selected sections.

#### CollabAlly

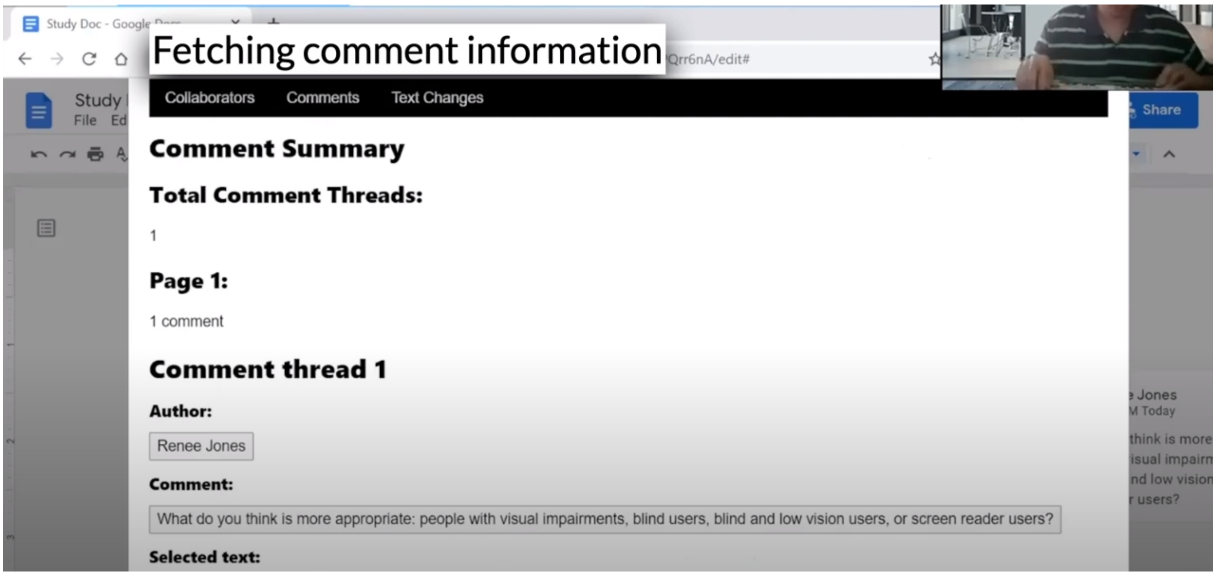
Inspired by research of Das et al. [21], CollabAlly authors developed a tool that provides accessibility features to screen reader users to facilitate synchronous and asynchronous collaborative writing on Google Docs. Uniquely, they developed their system through a series of co-design sessions between the lead authors and a blind co-author. From their session, they compiled their findings into six design considerations that were also utilised to develop the tool. According to them, a well-designed collaborative writing software that is accessible to and usable by a screen reader user should:

1. Support common collaboration activities
2. Provide both on-demand and automatic updates.
3. Provide contextual information.
4. Provide easy navigation.
5. Support various modalities.
6. Simplify operations.

The features CollabAlly implements can be categorised into two groups, audio notifications and a summary dialog box. As part of their accessibility feature, Google docs implements collaborator announcements. CollabAlly changes these speech audio cues ("Amy has joined the document" and "Joe has left a comment") to be non-speech spatial earcons. A user can access a dialog box which compiles changes to three types of collaborative information. The dialog box provides a summary about collaborators (who is where), text changes (who changed what to what and where) and comments (who commented what and where). Additionally, a user may choose to explore specific elements they are interested in. Figure 2.4 shows an example of the dialog box in use, where a user has opened the 'Comments' tab. Here, they get information about how many comment threads there are, and further down the summary is the additional information about that specific thread - who authored a comment and what the comment says. Not visible in Figure 2.4 is the selected text - what the comment is referring to and a button that gives the user the ability to go to find the specific location of the selected text and therefore jump to where the comment is in the document.

Compared to Co11ab, this system makes use of only one keyboard shortcut, which opens the dialog box. Once opened, a screen reader user navigates within the dialog box as they normally would any

Figure 2.4: CollabAlly demo of using the 'Comments' section of the summary dialog box, taken from a demo video uploaded to YouTube [6]




other web page. The authors argue for this design choice by saying that Google Docs has been deemed inaccessible because of how many different shortcuts there are and how much they differ from the ones used to operate a screen reader [19, 34]. This causes a steep learning curve and the inability for users to collaboratively write easily without prior training. Furthermore, from their design considerations, a system should provide both on-demand and automatic updates. In CollabAlly, audio notifications provide automatic updates and the dialog facilitates on-demand access to collaborative awareness information. We can compare this on-demand requirement to the high-level overview challenge Co11ab aimed to solve by implementing an audio scrollbar.

## 2.3 Ability-diverse Teams, The Invisible Labor of Access and Its Distribution

### 2.3.1 Ability-diverse Teams

A growing body of research in the fields of CSCW and HCI focuses on examining how ability-diverse teams collaborate in various professional, academic, and personal environments. Zolyomi et al. [67] conducted a study on collaboration within neurodiverse student teams in higher education. Their findings highlight the challenges students face in effectively communicating their individual differences and maintaining team cohesion. Similarly, Wang and Piper [59] explored how deaf and hearing professionals collaborate in co-located work settings. They proposed the concept that accessibility arises from multi-modal interactions and team practices that evolve over time.

Branham and Kane [14] conducted an investigation on how BVI individuals and sighted partners, that share home spaces, negotiate accessibility. They found that relationship maintenance played a crucial role in creating accessibility in such contexts. Furthermore, other studies have explored collaborative design processes involving children and educators, both with and without vision impairments [39, 40]. Similarly, researchers have examined how visually impaired athletes and spectators develop an understanding of different social contexts through their interactions [54].

In addition to investigating collaborative practices, researchers have also created multi-modal applications and conducted co-design sessions to facilitate collaboration among individuals with visual impairments and those without, for example in the context of coding [37, 55]. Some researchers also explored the use of these methods in areas such as storytelling [18] and editing diagrams [38] through a tool that combined auditory and haptic views. In most cases, the participants of these studies found the new systems much better in facilitating access and support for accomplishing their tasks. Collectively, this literature highlights the importance of understanding and designing new systems to facilitate collaboration among ability-diverse teams.

### 2.3.2 Collaborative Writing in Ability-diverse Teams

In their initial interview study [19], Das et al. focused their research on gaining insights about how blind and visually impaired users cooperate with sighted people in mixed-ability teams. Their findings answer questions about how ability-diverse teams decide on which tools to use, coordinate their work practices and workflows, and maintain workspace awareness when their activities are distributed across time (synchronous or asynchronous work) and space (remote or local settings). They group the struggles that BVI users face in ability-diverse teams into four interconnected processes that shape the way they engage in collaborative writing. These are:

1. "Learning and Maintaining an Ecosystem of (in)Accessible Tools
2. Adapting to Complexities in Collaboration Awareness
3. Balancing the Cost and Benefit of Accessibility
4. Navigating Structural Disadvantage and Power Dynamics within Organizations" [19].

The authors explain collaborative writing accessibility in terms of sociomaterial configurations, where issues of accessibility often arise from both technical breakdowns and social factors. They also highlight the invisible labour of creating access by blind collaborators, by sayings " ... when accessibility is culturally and politically positioned outside the realm of 'routine' or 'formal' work for able-bodied people, this labour put forth by people with disabilities is likely to remain either invisible to or a "burden" or "extra work" for able-bodied collaborators." [19].

### 2.3.3 Invisible Labour of Access

The notion of visibility of work was first introduced by Starand and Strauss [51], who argued that "no work is inherently either visible or invisible. We always 'see' work through a selection of indicators: straining muscles, finished artefacts, a changed state of affairs...indicators change with context, and that context becomes a negotiation about the relationship between visible and invisible work". What the work in question is and who is doing the 'seeing' are important factors that define a context. Taking this into consideration, researchers and designers should be cautious about how the perception of work is influenced by individuals and shaped by technologies in various situations, which can have significant social implications for all parties involved.

An emerging body of research is concerned with how we think of accessibility, what it means to create access, who or what should create it and how we can take these new ideas and alter the way we design tools. Branham and Kane [15] were interested in exploring how blind and sighted colleagues achieve collaborative accessibility in office settings. BVI employees encountered pervasive misunderstandings about their access needs, with office spaces and cultures remaining largely inaccessible. Additionally, blind employees had to invest significant time and energy in educating their colleagues on how to effectively assist them. Their findings revealed additional work BVI participants had to perform to access necessary tools to perform their jobs. This work was unrecognised by colleagues and supervisors in the workplace, therefore they call this work invisible.

Wang and Piper [60] studied the writing practices of dyslexic professionals and how well writing tools support their needs. The participants described the challenges they face when writing for academic audiences and how the tools they use break down and are not useful in these situations. The authors identify two ways in which the participants fill the gap left by tools breaking down by developing workarounds. For one, they make use of other tools and re-appropriate their use to become language sources. Secondly, to make up for technology limitations, they manage ad-hoc collaboration. This means they ask friends or colleagues they trust to be their personal editors. Because of tools not fulfilling their needs, an individual writing tasks becomes a collaborative task. Additionally, participants reported the intangible labour they have to shoulder to negotiate accessible writing practices and culturally ingrained ableist expectations about editing and deadlines from collaborators. The authors emphasise the importance of shifting the perception of accessibility from being solely a relatively invisible labour to a collective team effort. Additionally, they suggest that enhancing accessibility in writing processes requires a reevaluation of social attitudes towards collaboration, acknowledging the diverse access needs of all team members and actively negotiating for inclusive participation.

Das et al. describe that to access collaborative writing tools, blind and visually impaired users have to perform both tangible and intangible invisible labour [19]. One part of it is keeping up with collaborative writing tools and finding alternative methods when tools break down to be able to perform collaborative writing tasks. A significant aspect of this work entails emotional labour and social stress, as BVI collaborators must carefully evaluate the costs and benefits of advocating for accessible practices. This involves weighing the importance of accessibility in a given situation against the potential burden it may place on collaborators, as well as anticipating potential social consequences. Das et al. describe that in ability-diverse teams, accessibility stems from negotiating practices, workflows and alternative methods overtime. Some examples include agreeing to use a specific version of software, sighted collaborators leaving inline comments and not replying to comments, using other means of communication to point out changes.

Interdependence, as described by Bennet et.al [8], refers to the idea that technology designed to support people with disabilities should not be viewed solely as a solution to an individual problem, but rather as a tool to facilitate inter-connection and collaboration between individuals with and without disabilities. Interdependence is a core principle of the social model of disability, which views disability as a social construct rather than an individual medical problem. In this work, authors also bring forth the immense and overlooked contribution to the effort of creating access by people with disabilities.

#### The Distribution of the Labour of Access

Several recent works mention the concept of distribution of the labour of access, what it means and how it could be applied to technology design [8, 34, 64, 60]. The interdependence framework challenges the traditional views of assistive technology being the means of overcoming individual barriers, or "filling the gap" left by the disability. Rather, it introduces this collective effort to create access. In the context of the distribution of the labour of access, interdependence means recognizing that the burden of ensuring accessibility should be shared more equitably among all members of society (or a mixed-ability team), and that people with disabilities should not be solely responsible for advocating for their own needs and making adaptations to their environment or technology.

Findings by Das et al. support this idea and suggest that in collaborative writing, access is not created by an individual effort, but also by sighted collaborators adjusting their practices to be more accessible [19]. If accessibility is created by the whole mixed-ability team, the software should support such a pattern of behaviour. In a similar vein, the CollabAlly designers considered extending their tool to involve a similar extension that would guide able-bodied users to summarise their text changes to give a more comprehensive idea of their edits to their visually impaired collaborators [34].

To distribute the labour of access, the tool has to be implemented for all collaborators. Even though CollabAlly and Co11ab are tools to make collaborative writing more accessible in mixed ability teams, they are tools designed only for blind and visually impaired collaborators. This leaves open questions about how to design systems that incorporate able-bodied people and whether input from such collaborators would be helpful to facilitate effective collaboration. This project will aims to answer some of these questions.

## 2.4 Summary

In this chapter, I introduced the topic of collaborative writing and discussed experimental tools, frameworks, and current software. I contextualized collaborative writing in terms of accessibility and highlighted the challenges faced by visually impaired individuals in the UK, as well as the limitations of existing collaborative writing software in meeting their needs. Additionally, I explored the challenges of accessibility in ability-diverse teams and discussed the concept of invisible labor and the distribution of the labour of access.

# Chapter 3

# Technical Background

In this chapter I present the main technologies used to develop CollabConnect, which are a Google Docs Editor Add-on and a Chrome Extension. I detail how each works and what information they can access and provide to the end user and how they are developed. To connect the two parts, I used a CloudSQL database and to access the database I made a backend deployed on Cloud Run. Since my tool is focused on accessibility of collaborative writing systems, I explain how blind and visually impaired web users can access content on the internet. In addition I detail how developers can create accessible resources so that screen reader users are able to do so easily and comfortably.

## 3.1 Google Docs Add-on

Google Docs is a web-based tool for real-time collaborative writing and editing of documents. A user can extend the features offered by Google Docs by installing an add-on from the Google Workspace Marketplace. Once a user has installed an Add-on, it will always show up in the menu for any document they have created or have opened. There are two types of extension that can be developed to work on exciting Google services, Google Workspace Add-ons and Editor Add-ons. The two types are different in terms of the applications they extend, how they are created, and the restrictions they have.

### 3.1.1 Developing a Google Docs Editor Add-on

Generally, building an Editor Add-on requires four steps: creating an Apps Script project, coding the add-on, testing the add-on and publishing the add-on.

#### Coding an App Script Project

Google App Script is a scripting platform that makes it easy to build light-way applications that integrate, automate, and extend Google Workspace. In regards to a Google Docs extension, there are two types of App Script projects, standalone and bound. A user can only run a standalone script which makes changes to a document, if they have the correct permission for said document. A script that is bound to a document, called the container, has extra capacity to alter the user interface of Google Docs (add menu items and open pop ups and sidebars).

A Google Docs add-on can read, edit, visualise, and format text and any other elements in documents. The structure of a Google Docs document can be compared to that of an HTML document, that is, both are composed of elements which are contained in other elements, in a hierarchical way. A developer can customise the Google Docs interface by adding menus, dialog and alert boxes and sidebars. Lastly, add-ons have certain events (installing an add-on, opening a document) that can be utilised as triggers for specific functions. It is important to note that only a bound script can interact and modify the user interface (UI) of a document, and specifically, it can only interact with the UI of one instance of an currently open document. A Google Docs add-on can only access the elements inside the document body.

#### Testing and Publishing an Editor Add-on

Because of the way add-ons can be installed and used on shared documents, Editor add-ons have a complex authorisation model. The complete life cycle of an editor add-on involves installing the add-on from the marketplace, opening the document and running the add-on. If an add-on requires access to user data, they have to authorise it when they run the add-on for the first time. To initiate the authorization process, an authorization prompt is presented to the user. This prompt clearly outlines the application's desired permissions, such as reading a user's email information or creating documents. These permissions are defined as OAuth scopes within the add-on's script project. After testing the add-on, a developer can decide to publish their add-ons to be publicly available to install in the Google Workspace Marketplace. Publishing an add-on is a lengthy process composed of several steps.

## 3.2 Google Chrome Extension

Google Chrome can be extended by installing Chrome Extensions, which are software programs developed to enhance, improve the user experience or add a specific functionality. Published extensions are available for download from the Chrome Web Store.

### 3.2.1 Developing a Google Chrome Extension

A developer needs to have some knowledge of web development to create a Chrome extension, because they are developed with the same technologies and languages. Scripting and logic is written in JavaScript, while HTML and CSS are used to develop and style the web elements the user interacts with. Developing a Chrome Extension can be explained in four steps; creating a manifest file, writing the extension code, testing and lastly, publishing the extension. A Chrome extension is composed of different parts and files, for example a manifest file, content scripts and service workers. A service worker is a script that runs in the background and listens for and handles browser events. The content scripts are used to inject code into host pages and provide the capability to modify and interact with web pages. They can perform different actions, such as adding new elements to the page (a popup page), altering the appearance of a website or modifying DOM elements. The content script and the service worker communicate by passing messages to each other.

After developing and testing a Chrome Extension, the author may choose to publish the extension so it is available to the public. Publishing an extension involves creating a developer account, uploading the extension package (all the necessary files), and filling out the required information. Anybody can create a developer account with a Google account and after paying a one time fee of 5 USD. After finishing all the required steps, the extension gets sent for approval, which usually takes a couple of days. Once the extension has been approved, it is available to install on the Chrome Web Store.

## 3.3 Google Cloud

### 3.3.1 Cloud SQL

Cloud SQL is a cloud-based fully-managed relational database service. It allows users to create, maintain, and manage relational databases in the cloud using a variety of database management systems such as PostgreSQL, SQL Server and MySQL, which is used in my tool. On top of the basic advantages of using a database based in the cloud, Cloud SQL integrates well with other GCP services. Specifically, it is very straightforward to connect to a Cloud SQL database from a Google Docs add-on by utilising the JDBC service and adding the correct OAuth permission scopes.

### 3.3.2 Cloud Run

Cloud Run is a fully managed serverless compute platform that allows a containerized application to be run on the Google Cloud Platform (GCP). As a serverless service, Cloud Run provides many benefits to developers, but what was important for this implementation was its easy integration with other GCP services, such as Cloud SQL.

## 3.4 Web and Accessibility

Web developers should create accessible websites so that they can help remove barriers and promote inclusivity for people with disabilities who rely on assistive technologies like screen readers, braille displays, or voice recognition software to access the web. Web accessibility refers to the design and development of websites, web applications, and digital content that can be accessed and used by all users. In my project, I developed a chrome extension that a user needs to be able to access with a screen reader. As such, I made sure to follow the best accessibility practices as described by the Web Accessibility Initiative.

### 3.4.1 Screen Readers

Screen readers are software programs that help people who are blind or visually impaired use computers and access web content. They work by using a combination of text-to-speech technology and keyboard commands to navigate and interact with the content on a computer screen. This allows the screen reader user to hear the contents of the screen. Additionally, screen readers also provide users with keyboard commands and shortcuts to navigate through different sections of a web page or document, such as headings, links, and form controls. The most widely used screen readers are JAWS for Windows, NVDA and VoiceOver for Apple's MacOS and iOS.

From a technical perspective, screen readers use a variety of techniques to navigate a web page. This includes text recognition, image recognition, and parsing of HTML code. They can also use additional markup such as WAI-ARIA attributes and alt text. These can provide additional context and information about the content being read, making it easier for the user to interpret it. As such, it's important for web developers to know about how to create screen reader accessible websites, so that people with visual disabilities can access and use their content. Developers can achieve this by using semantic HTML markup, providing text alternatives for non-text content like images and videos, and using ARIA attributes to provide additional information about user interface elements. The best accessibility practices that developers should follow can be found in multiple web accessibility resources, such as the ones produced by Web Accessibility Initiative.

### 3.4.2 Web Accessibility Initiative - Accessible Rich Internet Applications

The Web Accessibility Initiative (WAI) is a program launched by the World Wide Web Consortium (W3C). The goal of WAI is to make the web more accessible to all users by providing guidelines, techniques, and resources for accessible web development.

WAI-ARIA [1], Accessible Rich Internet Applications Suit, is a technical specification that provides a framework of sets of attributes that can be added to HTML tags to provide additional information about the role, state, and properties of user interface elements on a web page. For example, WAI-ARIA attributes can be used to indicate the purpose and behaviour of form controls, menus, and widgets, or to indicate changes in the state of dynamic content, such as notifications or alerts. It is important to note that using WAI-ARIA should be done in conjunction with following other accessibility practices, such as utilising proper semantic markup, providing keyboard accessibility, and using descriptive text alternatives for images and other non-text content.

### 3.4.3 ARIA Authoring Practices Guide

The ARIA Authoring Practices Guide (APG) is a resource produced by the ARIA Working Group of the W3C. The document provides recommendations for the use of ARIA attributes, roles and other specifications described in WAI-ARIA. It presents developers with building blocks so they can develop useful and accessible web applications.

The APG covers a wide range of topics combining accessibility and web technology specifications from multiple sources. The guide explains how to make accessible user interfaces using features of WAI-ARIA with HTML, CSS and JavaScript. The APG includes a library of web accessible user interface patterns and their example implementations. In addition, it describes the use of ARIA attributes, as well as recommendations for providing keyboard accessibility, managing focus, and handling dynamic content.

## 3.5 Summary

In this chapter, I discussed the technologies used to develop CollabConnect. I introduced how one can extend the basic functionality of Google Docs and Google Chrome by developing Google Docs Editor Add-ons and Chrome Extensions. Additionally, I provided detailed information on developing a Google Docs Editor Add-on and a Chrome Extension. In the same vein, I explained what a CloudSQL database and Cloud Run are, as they were necessary to develop CollabConnect. I also discussed how developers can create accessible web content.

# Chapter 4

# Prototype Design

In this section I detail the high level prototype design of CollabConnect, a collaborative writing tool that is designed to support mixed-ability teams in collaborative writing. Due to the time constraint of this project, I first formed a prototype design, informed and inspired by similar tools like CollabAlly and Co11ab. After making these initial decisions I ran a formative interview study with both sighted and visually impaired people to get an insight into what the actual users of CollabConnect would want in the tool. This prototype design was then further iterated upon. The main points to decide in the beginning were what collaborative system to implement CollabConnect on, what would the information exchange be and what would the interface all the members of the team interact with look like.

## 4.1 Implementation details

### 4.1.1 Platform

The two main commercially available editors are Microsoft Word and Google Docs. From a global market perspective, the market of office suite technologies is divided between Google G Suite and Office 365 by Microsoft. G Suite accounts for approximately 48 percent of the market share, while Office 365 holds approximately 46 percent [52]. It is fair to say that both technologies have a substantially large user base. Implementing CollabConnect on either would potentially reach a wide audience. Even if both are widely used, Microsoft Word requires a subscription to Microsoft Office 365, while Google Docs is free to use. Additionally, Google Docs is accessible through a web browser and can be accessed from any device with an internet connection. Google Docs is designed for real-time collaboration by allowing multiple users to work on a document simultaneously, with changes being updated in real-time. This differs from Microsoft Word, where changes only appear when the user manually saves them. In conclusion, I decided to implement the tool as an Editor add-on for Google Docs, as it offered the right type of environment and was free to use.

### 4.1.2 Overview

To summarise the main points from 2.2, there are two main problems with collaborative writing software in terms of accessibility for visually impaired users:

1. Collaborative writing systems are inaccessible and unusable for screen-reader users.
2. Blind and visually impaired users have the sole burden of creating access.

CollabConnect was designed to solve these issues. The general idea was to create a tool that is composed of two parts, the one sighted users interact with (Side A) and the one BVI users interact with (Side B). Importantly, Side A makes collaborators provide additional context to BVI users, which solves the second issue. To solve the first problem, for the design of Side B, I carefully considered how to communicate this information provided by Side A to BVI users. Side A is implemented as a system made up of a sidebar and popup dialog boxes. The side BVI users interact with is a single summary dialog box, opened by a keyboard command, which presents the collaborative awareness information to the user organised in three tabs.

## 4.2 Initial Design

In their framework for workspace awareness, Gutwin and Greenberg [28] propose three tasks developers should consider to help them design systems to fully support collaborative awareness. These are; determining what information to provide, deciding how to gather knowledge and deciding the space and method for using the knowledge.

### 4.2.1 What information to provide

In section 2.1.4 I breaks down Google Docs main features and how they support users by providing awareness of collaborative actions. I specifically point out colour-coded collaborators and cursors, version history and leaving comments. Different kinds of information need to be. Here, I organise collaborative awareness in terms of synchronous collaboration, shown in 4.1, and Figure 4.2 details asynchronous collaboration.

Figure 4.1: Collaborative writing awareness information needed for synchronous writing

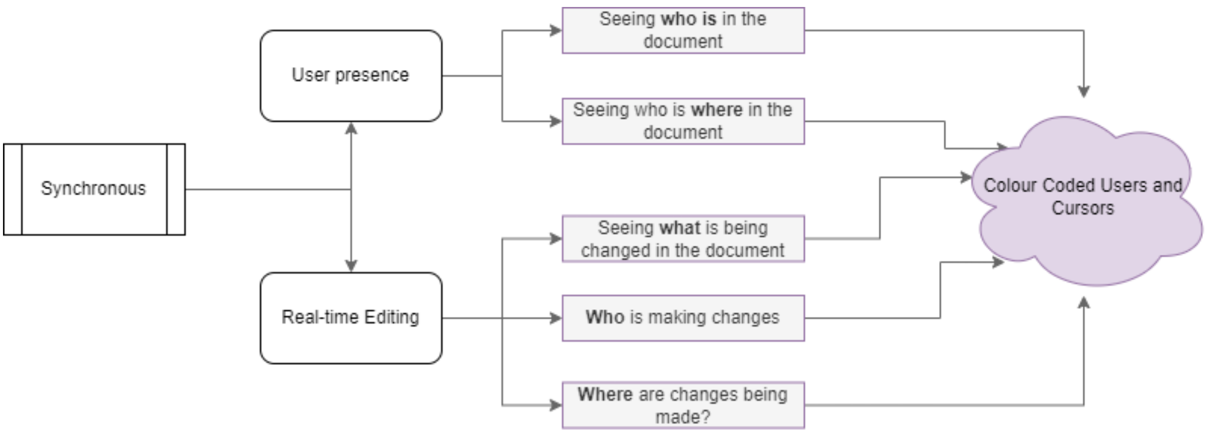
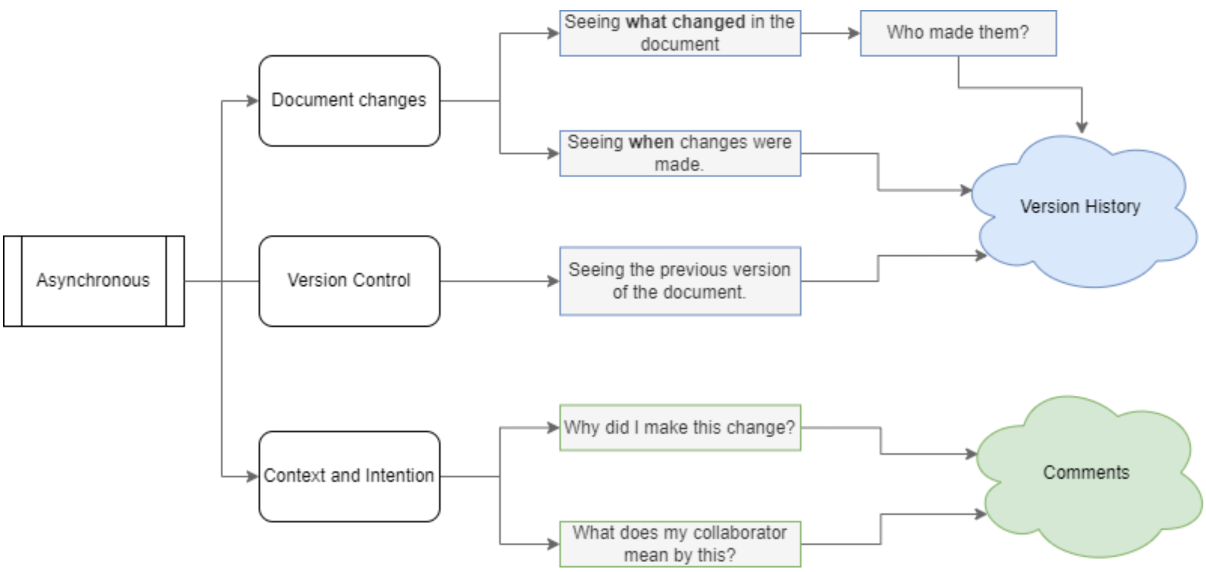
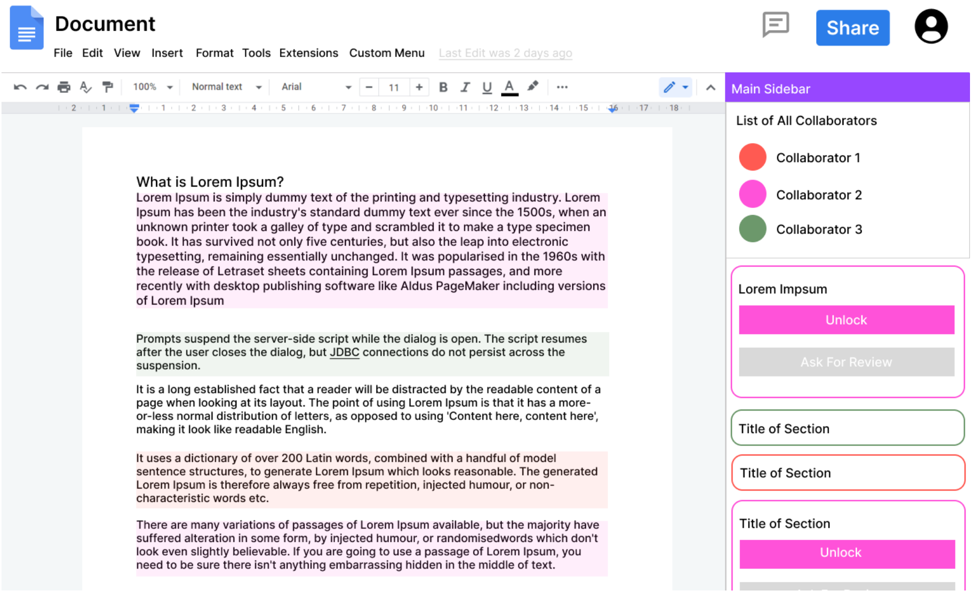



Figure 4.2: Collaborative writing awareness information needed for asynchronous writing




Another aspect about collaborative writing to consider is whether collaborators who are synchronously writing are able to communicate in real-time, i.e. are they working locally. Being able to communicate while collaboratively writing changes what collaborative awareness information needs to be provided to a team by the system. Teams that are working together in real-time are able to ask clarifying questions, provide detailed explanations about actions, allocate collaborative tasks and so on. Task allocation seems to be very important in collaborative writing. Olson at el. [45] describe that most students collaboratively writing an academic paper, seem to start with a synchronous writing section where they agree on the

Figure 4.3: Side A prototype wire-frame




content of the paper and then allocate team members parts to write. The approach to keep track of tasks differs, but the most common strategies seem to be writing a collaborators name next to the section assigned to them and/or highlighting sections with a different colour for each user.

Due to time constraints, I planned to first implement only a small selection of features to test out the design and functionality of CollabConnect. The decision about which features to implement were deduced from the formative study findings, as detailed in 6.

### 4.2.2 How to gather knowledge

The Google Docs interface already includes most of the necessary collaborative awareness information for a sighted user. I decided to leverage this functionality in CollabConnect, by extracting the needed information from the Google Docs interface directly. For example, by locating each user's cursor, I can determine who is in the document at any time and also where each collaborator is in the document.

Section 2.2 describes the limitations of the current design from a screen reader user perspective. Among other things, blind and visually impaired (BVI) collaborators may struggle to understand the changes made by sighted collaborators and have to resolve to ask them via other means of communication [19]. In their paper, the authors of CollabAlly [34] mention the idea of implementing a system that would capture spoken explanations and clarifications, mimicking how people collaborate when they can speak to each other in real-time. For example, sighted collaborators can provide context for their BVI collaborators by summarising the changes they made while writing their section or editing a paragraph. This would allow sighted collaborators to provide context for their BVI counterparts, summarising the changes they have made and making the collaboration process more inclusive.

To achieve this goal, I decide to design Side A of CollabConnect, so that it prompts sighted collaborators to provide additional information beyond what is currently captured by Google Docs. By asking specific questions about the changes they have made, we can distribute the labour of access more evenly and make the collaboration process more accessible for all team members.

### 4.2.3 Deciding the space and method

While I decided on the overall concept of CollabConnect, I had yet to design the user interfaces. These are the parts of the system that the users interact with to gain and give collaborative awareness. In this section I detail the flow of the interaction and information between an end user and the tool. I also explain how and when they would be presented to the users.

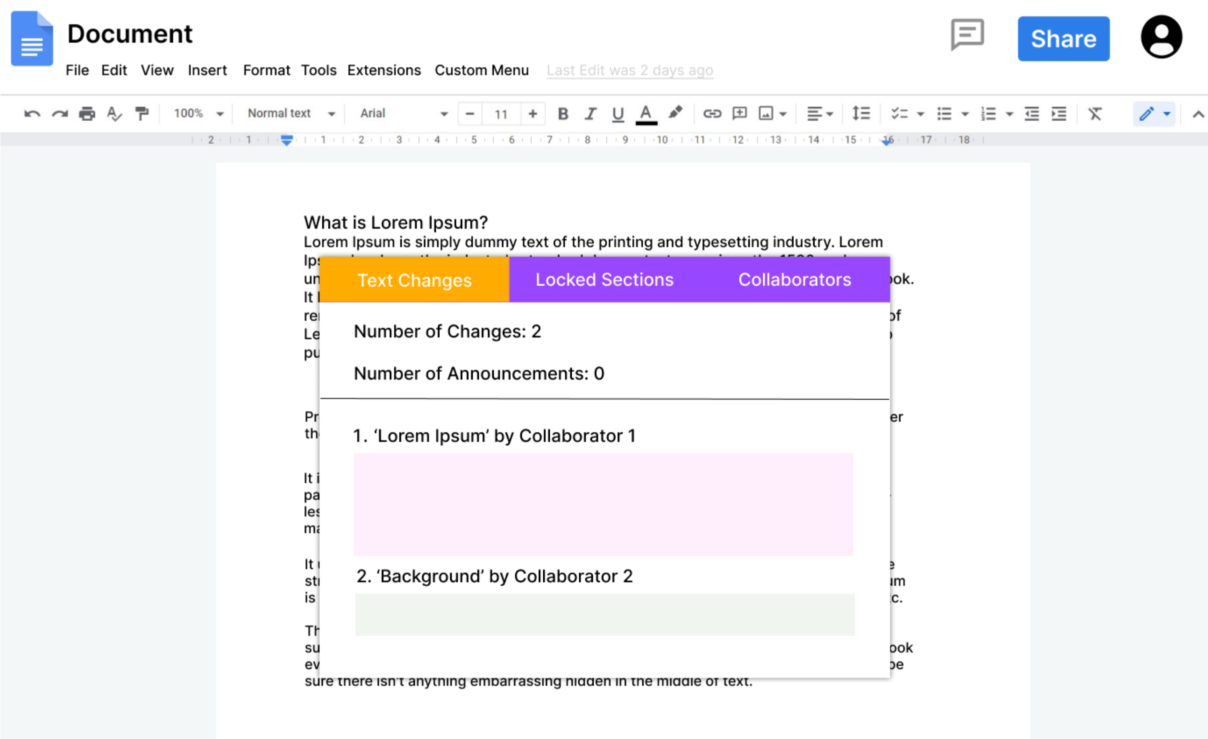
### Side A - UI for Sighted Collaborators

To support the sighted collaborators I decide to design Side A of CollabConnect as sidebar that holds the main elements and a couple of dialog boxes that open when triggered. The sidebar design provides a persistent and unobtrusive presence on the user's screen, which allows for quick access to collaborative features without disrupting the user's workflow. The popup windows, on the other hand, provide a more focused and immersive experience when interacting with specific collaborative features. BVI users have reported that in their experience, sighted collaborator forget to do what they ask of them or use accessible tools. I tried to find a solution in my design by having the sighted side of CollabConnect always open and present, so that the users are constantly reminded to use it. The prototype wire-frame do Side A can be viewed in 4.3.

### Side B - UI for Blind and Visually Impaired Collaborators

As for the design of Side B of CollabConnect, I chose to focus on creating a simplified and intuitive interface that is accessible to users with visual impairments. My design was informed and inspired by CollabAlly's design and guided by their design recommendation. The authors report on the summary dialog box to be accessible and welcomed by their study participants, so I decide to follow suit and design Side B as a popup dialog box. This design allows for on-demand access to information and can be implemented with a single keyboard command. I wanted the dialog to provide easy navigation and a clear, consistent layout. The interface includes a navigation bar at the top of the screen that allows users to easily access different sections of the software. The overall goal was to create an interface that is easy to navigate and use for individuals with visual impairments, while still providing a comprehensive overview of collaborative writing awareness information. Figure 4.4 is the prototype of Side B of CollabConnect.

Figure 4.4: Side B prototype wire-frame



# Chapter 5

# Formative Study

As detailed in section 2.2, current collaborative writing systems do not support screen reader users and are not designed to support effective collaboration in mixed-ability teams. To inform my research and the design of a better tool, I conducted a formative interview study. I decided to gather information from both visually impaired users and sighted users who have experience using Google Docs, or other similar tools, to perform collaborative writing tasks in a mixed-ability team. The interviews were semi-structured, but generally, all questions and topics discussed fall into four main categories:

- Experience with collaborative writing systems.
- Experience with collaborative writing in ability-diverse teams.
- General systems requirements for an accessible and usable collaborative writing system.
- What can sighted collaborators do to create access in an ability-diverse team.

## 5.1 Participants

Four participants took part in my interview study, out of which, three are blind. One of the three blind participants, Tom, was contacted through personal connection to my supervisor. Tom put me in contact with Shelly, who is his wife. The last participant, Ronnie, responded to my recruitment post on the Reddit sub forum for blind surveys. Even after extensive recruitment by sending emails, contacting the University of Bristol Disability Networking Society and posting on Reddit and other forums, nobody else contacted me about participation. I asked all three participants if I could reach out to a sighted collaborator they have worked with previously. Out of the three, I was only able to contact and schedule an interview with Riley, who has worked with Ronnie on a story they wrote together a couple of years ago.

Table 7.2 details some general background information about the four participants. Namely their self-reported visual ability, occupation and who they typically collaborate with and what screen reader they use. All participants have experience with collaborative writing in mixed ability teams, but Tom, Ronnie and Shelly have limited experience with Google Docs or Microsoft Word. Both Tom and Shelly experienced modern collaborative writing systems towards the later parts of their careers, when they reached higher positions in their respective work. Both have most experience collaborating with people who are junior to them, be it PhD students working on their research project or managers of local social work centres. Ronnie has some experience collaborating with peers for fun personal projects like creative writing.

## 5.2 Procedure

Days in advance, each participant received a Participant Information Sheet which explained the purpose of the study, collection of data and how to withdraw from the study. After reading the document, they were asked to sign a consent form. As three of the participants are blind, it was easier for them to give verbal consent at the beginning of the interview. All interviews were done remotely as audio calls through Microsoft Teams. The audio of each interview was recorded and a transcript was produced by the in-build transcription service of Microsoft teams. Subsequently, I reviewed each transcript against

| Name | Self-reported visual ability | Occupation | Collaborators | Screen reader |
|---|---|---|---|---|
| Tom | Blind | University Lecturer | PhD Students | JAWS |
| Ronnie | Blind | Freelance Artist | Clients, creative writing co-authors | JAWS, VoiceOver for iPhone |
| Shelly | Blind | Retired, Children's social worker | Colleagues | JAWS |
| Riley | Sighted | Teacher | Colleagues, creative writing co-authors | N/A |

Table 5.1: Details about participant of formative study

the audio recording and corrected any errors from the automatic service. Each interview lasted between 30 and 60 minutes and all blind participants were asked if they would be willing to participate in the following design evaluation study as well.

To best capture the complexities of the issue at hand and the varied experience of each participant, I opted to do in-depth semi-structured interviews. This allowed the interview to feel more like a conversation which led to unexpected topics and observations to arise. The interview was structured around four topics, detailed above. After gathering general background information, I asked each participant how collaborative writing fits into their professional or personal life. Each participant thoroughly described the most common type of collaborative writing situation they encounter, from what systems they use, who they are collaborating with, what they work on to what type of collaborative awareness information they seek out or provide. Additionally, they were asked about the usability and accessibility of specific collaborative awareness features that are commonly implemented in Google Docs or Microsoft Word (comments, track changes, version history, real-time editing features). I wanted to know what their idea of an accessible system would look like if they could design it. I specifically asked about what sighted collaborators can do or say, and what information they can provide to create more access for them when collaboratively writing. The interview concluded with a short description of CollabConnect, my prototype design and how it was intended to work to support mixed-ability collaboration. I asked for any feedback, opinions or suggestions.

In addition to all the questions above, Riley was asked about their experience as the sighted collaborator in a mixed-ability team. I asked him whether his normal workflow changed when working with Ronnie, and if he did any specific actions to support his blind collaborator. By interviewing a sighted collaborator, albeit only one, I was able to capture their perspectives and views of working in ability-diverse teams with respect to accessibility, something the previous works described in 2.2 were missing.

## 5.3 Data Analysis

To analyse the data from the semi-structured interviews, I used qualitative coding and thematic analysis. First, I prepared the transcripts by formatting and correcting any errors from the automatic transcription tool. Having to read through the transcripts multiple times allowed me to get familiar with the contents of each interview. Then, I used a mix of deductive and inductive open coding to identify concepts, patterns and common themes present in the content. I created a codebook with codes such as "Busy working environment", "Resistance to accept need for access" and "unfamiliar design". Some of the codes matched up to the themes Das et al. [19] identified in their formative study about mixed ability teams, for example "the social cost of accessibility", "need to be equal to sighted peers" and "breakdowns due to lack of an accessible system". I continuously and iteratively updated and refined the codebook as I analysed more data.

Next, I used thematic analysis coding to identify patterns and themes that emerged from the coded data. To ensure that the analysis was accurate and comprehensive, I compared data to data and data to themes in a process of iterative analysis. Informed by my research and findings from CollabAlly and Co11ab authors [34, 20, 19] I identified several overarching themes detailed in 5.4. The findings can be split into two categories; themes that pertain to the experience of collaborators in mixed-ability teams and accessible collaborative writing systems design requirements. The finalised codebook with themes, higher codes and lower codes can be inspected in full detail in Appendix A.

On one hand, these themes describe the common experience of blind collaborators and sighted collaborators when writing together. This allows us to gain a deeper understanding of all perspectives in an ability-diverse team and what role they play in creating access. On the other hand, from the data I was able to extract important features and system design recommendations that would suit the needs of my participants. To perform this data analysis I used Delve, a qualitative data analysis software.

## 5.4 Findings

I present the findings from the formative study interviews with blind and visually impaired participants, Ronnie, Tom and Shelly, and with one sighted participant, Riley. First, I grouped together the experiences of BVI collaborators when writing in a mixed ability group into four distinct categories. Then, I mention two observations from Riley from his time collaborating with Ronnie. Here are all the themes I identified about my participants experience when collaboratively writing in mixed-ability teams:

1. Inaccessible systems make BVI users feel unimportant and excluded.
2. In busy and competitive environments, inaccessible systems are seen as a burden.
3. Sighted collaborators lack understanding of accessibility needs and the invisible work done by BVI users.
4. BVI users are forced to create workarounds to fill gaps left by inaccessible systems.
5. Collaboration style and flow changes depending on who is involved in the collaboration.
6. Sighted collaborators make assumptions about the access needs of BVI collaborators.

Lastly, I combine all the themes to identify several high-level design requirements of an accessible collaborative writing system.

### 5.4.1 Themes and Observations by Blind and Visually Impaired Collaborators

**Inaccessible systems make BVI users feel unimportant and excluded**

Collaborative writing systems and their design do not reflect the actual needs of screen reader users, which has serious social consequences for those who use them. In regards to Google Docs accessibility shortcuts Ronnie said *" ... they were designed for people that don't have hands, ..., they were really unintuitive and made no sense and Google was basically forcing me to use key commands that are not like the normal ones you use with just like a word processing program."* Tom shared the same sentiment, which led him to not want to use Google Docs at all, saying *"And so that meant it was hard to remember how to use them. And so that, you know, made me minimise the amount I had to [work with Google Docs]."* Ronnie said that her first experience with Google Docs was so unpleasant, they never went back to using it. As discussed in 2.1 collaborative awareness is important for effective collaboration and is usually communicated with visual features like comments, track changes and real-time editing features. With regards to track changes, Tom said *"I can't say I'd greatly like it because I think probably a lot of the attraction in it is the visual appearance of it."*

The participants mentioned how collaborative writing system accessibility features are an afterthought in the design process and learning how to use them rather becomes another job for users to manage. Ronnie expressed their frustration by saying *"I mean like one issue I always have is just like why accessibility just needs to be built into things from the ground up, it always should have been."* As a result of inaccessible design, blind and visually impaired users may feel like their needs are not important or valued, leading to social consequences such as feeling left out and not thought of. When talking about systems that break down for screen reader users Shelly said *"Sometimes I write to companies when I'm in my frustration and say don't you want blind people's money?"*

Not only are screen reader users not able to effectively understand collaborative awareness information, they also have difficulties providing it. In the interview, Shelly came to the realisation that she has never attempted to use track changes and never even thought about doing it, saying *"... but I wouldn't be sending it back with track changes. So, I suppose that could have been problematic if I'd not been senior to them and it was more of a debate."* She added that she *" ... wouldn't have even known how to do it. I wouldn't even have tried. But obviously if I'd been a peer, I would have needed to have done that, wouldn't I? Wouldn't have just sent it back changed. I would have had to have learned a new skill, I suppose."* These consequences can result in individuals feeling like they are not equal participants in collaboration.

Overall, it is crucial for systems to consider the needs of screen reader users to ensure that everyone can participate and feel valued.

#### In busy and competitive environments, inaccessible systems are seen as a burden

All participants noted how important well designed systems were to support them in their busy work lives. In his own words, Tom said that *"Being efficient is really critical."* and that *"... you are usually in a hurry and you just want to get the job done quickly."* He expressed that when he encountered a collaborative writing feature he couldn't grasp quickly, he usually found a workaround that worked and was fast. He considers that maybe he could use the feature after spending extensive time learning how to use it, but he just did not have the time.

In competitive environments there is no room for mistakes, but inaccessible and unusable systems can lead to errors. Shelly's experience is very unique among the three participants, because she had access to work support. In her own words, she *"bought herself out of the problem"* of not being able to use collaborative writing systems effectively. *"But in the working environment I couldn't spend lots of time learning a lot of new commands because I actually had to do the job."* Instead, Shelly had a personal assistant (PA) with whom they developed a system of workarounds for working with documents, which she had to do on a daily basis. She said she decided to do this because as a social worker *"... it was too important to get wrong, I suppose."*

Blind and visually impaired people may have to hide their accessibility needs to fit in with the system, which can lead to further marginalisation. Moreover, such individuals may experience less efficiency in their work, leading to financial consequences such as unemployment and missed opportunities. When talking about how inaccessible writing systems cause BVI individuals to lose jobs Ronnie said *"... there's just a huge unemployment rate among the blind especially, and it's not because we can't do the job. We're just kind of not being allowed to try."* They further made their point by saying that even if the system breaks down for a blind employee, it is them who gets blamed for not being able to do the job and suffers the consequences. Shelly agreed with this sentiment by saying *"I would imagine the pressure to be able to be self-sufficient now as the visually impaired person in the workplace is greater than it's ever been."* .

Inaccessible systems can also prevent individuals with visual impairments from fully utilising their skills and expertise, which can further impact their work and career opportunities. In the beginning of her career Shelly expressed she was worried about being viewed as competent by saying *"I didn't want to be seen as not to be as competent and capable as my peers because it always felt as if you were just one step away from someone saying how can a blind person be a social worker?"*

#### Sighted collaborators lack understanding of accessibility needs and the invisible work done by BVI users

When working in mixed-ability groups, sighted collaborators often lack understanding or awareness of what creating accessibility entails. Ronnie experienced a lot of trouble working on a Google Docs document with multiple collaborators on a writing assignment for university. Even after explaining their needs, their peers would all use different fonts and colour and change things in a way that they found to be hindering their ability to finish the assignment. They explain their collaborator's actions by saying that *"they didn't necessarily care. Which ... is something that comes up a lot as far as working collaboratively with people. They just forget that you're blind and they don't care. And some days you have it in you to, like, remind them and some days you don't. So, it could just be a strain on the disabled persons and just to constantly make people aware that like, hey, I'm right here."* In this specific situation, Ronnie had to drop out of finishing the assignment and find a replacement for themselves for the project.

Additionally, the use of assistive technologies like screen readers may slow down certain tasks, which sighted collaborators may not realise. Shelly described a situation where she would receive a spreadsheet with loads of different tabs and data minutes before a meeting pertaining to that spreadsheet. She had to communicate her needs by explaining multiple times that it takes her time to get a high-level overview, because a screen reader takes it cell by cell, which is time consuming. Shelly ponders that she probably was able to get this request met by being the most senior person in the room. She said *"but when you're the senior person in the room, you can say, actually I need this the day before. So, I suppose that could have been problematic if I'd not been senior to them and it was more of a debate."*

Moreover, there seems to be resistance from some sighted collaborators to accept the need for accessibility accommodations. For instance, in a situation where she was working as a consultant in a different work environment, Shelly had to fight for her assistive technology to be installed on their machines.

Shelly notes that this kind of attitude can create significant challenges and *" makes you almost hide the difficulties rather than be outspoken about them."*

#### BVI users are forced to create workarounds to fill gaps left by inaccessible systems

BVI users often face significant challenges due to inaccessible systems, which leave gaps that they fill by developing workarounds. These challenges can include breakdowns when accessing information, difficulty communicating with sighted colleagues, or struggling to use inaccessible software.

All participants described situations where they utilised other means of communication, be it email or Discord chats, to be able to effectively write collaboratively. Tom mentions scenarios where collaborative writing becomes just sending passages over email. Shelly was in constant communication with her PA and would send over documents she received with changes. Oftentimes, changes would be highlighted or marked visually in a different way, which Shelly could not perceive. Her PA would go over the document and send her back a high-level overview of all the changes.

Other tasks of Shelly's PA included preparing documents Shelly received and formatting them in a way that she could understand. For example, when she received a document with track changes, her PA would go over it in advance and mark out with three asterisks (***) where each track change was. Later, Shelly could just search through the document to find each track change easily. As Shelly is blind and her PA was sighted, I consider them a mixed-ability team. She concludes that over the years they developed a very effective way of collaborating. She said *"We worked, you know, for years together. So, we got very, very quick at it."* This agrees with the theory that accessibility emerges from team practises over time [19]. Even though they worked well together, her need for this workaround stemmed from the systems she had to use not being accessible to her. She said that working with documents *"... did require some sighted assistance there, which I'd have preferred that it didn't."*

Similarly, Tom leaves comments inline, rather than using the in-build commenting feature. He marks it out with three asterisks so it's visually distinguishable from document text. When asked about using the inbuilt commenting feature, Tom did not know such a thing existed and how it worked.

When working with Google Docs, Ronnie prefers not to use a screen reader. They say that they just never got the grasp of it and would not be able to use it effectively. Instead, Ronnie developed a workaround, a technique they call 'eyeballing'. They use their remaining vision to zoom in very closely on a huge monitor. This process take a long time and is still not ideal. Only being able to perceive a small part of the screen at a time makes Ronnie struggle with knowing what they do not know and finding that information.

These workarounds and external assistance can be time-consuming and add an extra burden to the work of BVI users, highlighting the importance of accessible design to avoid these issues. *"I'd like as a visually impaired person, just to do my job in the software and the technology to support me to do my job, not to become the job, to do the job."* Shelly remarked at the end of our interview.

### 5.4.2 Observations by Sighted Collaborator

Riley is a teacher who frequently collaborates with a variety of people, from his young students, to colleagues and online friends. He met Ronnie because of a common interest and they decided to work together on a writing project. He described their collaboration as beta reading, which involved looking over others' work, offering edits and making suggestions and constructive criticism. Riley has previous experience in beta reading and mentioned that he does it often in different systems, but mainly uses Google Docs.

#### Collaboration style and flow changes depending on who is involved in the collaboration

When asked about how they went about doing beta reading and what it involved Riley mentioned that he generally changes the way he collaborates based on who he is collaborating with. These changes were in several different spaces and included changing what information to provide, how much and how. For example, when doing beta reading with younger people he would specifically choose not to give too much feedback, as collaborators would shut down quicker. With Ronnie, he was careful about the way he provided certain information and how he went about sharing it. In his own words, collaborating with Ronnie was a *" . . . combination of me being on Discord, giving them a general summary of what I did, like what I don't like, as well as some general reasons behind some of the comments that I made."* He said that for larger changes he would leave comments, but with smaller things that needed to be corrected, like typos, he would just go ahead and make the changes as they trusted each other's judgement. During their writing Ronnie would often ask to change font sizes and spread things out in the document, so they could navigate easier. Riley would always say yes to such requirements saying *"You know, we can always change the font later. There's nothing to worry about."*

Riley's experience suggests that sighted collaborators change their formal work to fit with the workflow of a blind and visually impaired collaborators.

**Sighted collaborators make assumptions about the access needs of BVI collaborators**

When collaboratively writing, Riley often highlights text to, for example, point out a tense problem or a repeating verb. With Ronnie, he would avoid highlighting text, as he thought they would find it too overwhelming. If he did highlight a section, he would make sure to select a larger section so Ronnie could find it easier (Ronnie has some remaining vision left). When asked about what made him think that this would work better than what he does usually, Riley said *"As far as I can tell, like it's never been a problem, so I could have been wrong with the whole highlighting thing, now that I think about it. "* Riley realised that he simply assumed what Ronnie's access needs were and because they did not say anything about it, assumed that he was doing it right.

### 5.4.3 Accessible Collaborative Writing System Requirements

This section outlines the five requirements of what a collaborative writing system should implement to be accessible for blind and visually impaired users. I identified these after analysing the interview data and concluding the thematic analysis. In the interview, in addition to describing their experience in ability-diverse teams, the participants described their ideas of what a good collaborative writing system would be like for them. I deduced these requirements from the six themes described in the section before and directly from participant answers about specific collaborative feature descriptions. By implementing these requirements, collaborative writing systems can become more accessible and efficient, and facilitate effective communication and collaboration among all team members. The five requirements are:

- **Systems that are fast and effective:** Accessible collaborative writing systems must be designed with features that make collaboration fast, intuitive to navigate and allow for effective collaboration.
- **Systems that are easy to pick up:** Accessible collaborative writing systems must be designed to be screen reader user-friendly, easy to learn to operate, ensuring that BVI users can quickly adapt to and effectively use the system.
- **Systems that work similarly to other assistive technology tools:** Accessible collaborative writing systems must implement workflows common for BVI users, for example, they should use similar shortcuts to screen readers. Additionally, they should be designed to work seamlessly with other assistive technology tools like screen readers and braille displays ensuring a cohesive user experience.
- **Systems that make collaborators participate with creating and accessing collaborative awareness information:** Accessible systems should include features such as comments and track changes that are designed for BVI users to use so they can participate in creating contextual awareness information.
- **Systems that distribute the labour of access:** Accessible systems should be designed to minimise the burden of creating access, by distributing said labour on the whole team and embedding features throughout the system designed to prompt sighted users to provide collaborative awareness information.

# Chapter 6

# System Design and Development

Following the prototype design and concluding the formative study, I developed CollabConnect. In this section I detail the systems architecture and changes made to improve the initial prototype. Importantly, I introduce the two sides, Side A and Side B that make up CollabConnect. I explain which collaborative awareness information I am providing to the mixed-ability team and how each collaborator takes part in creating access. In detail, I explain the exchange of information between the sides and how this design solves the main issues of inaccessibility of collaborative writing systems. Finally, I reflect on how well this design adheres to the design requirements I introduced in section 5.4.3.

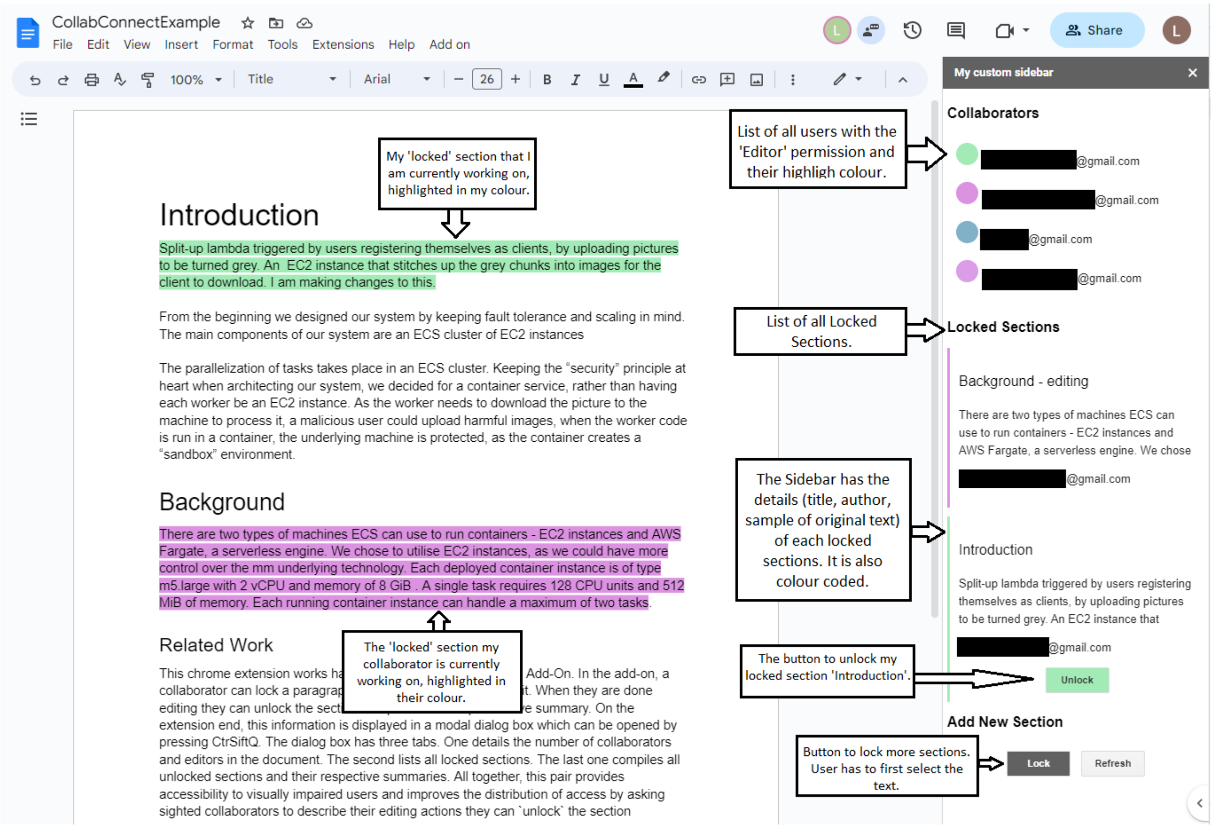
## 6.1 System Overview

I decided to implement CollabConnect so that it would support both sighted and blind collaborators in their attempts to share and perceive collaborative awareness information. From the formative study, I deduced that most collaborative awareness information is equally important to facilitate effective collaboration. Therefore I decide to start with implementing the basic features of a collaborative writing system. That is, I wanted my tool to be able to give answers about who was in the document, what they are working on and what they have done. In addition, with the contribution from the sighted collaborators, I was able to provide the intention and explanation of action to the BVI user. I designed the tool to support remote collaboration, so that users can fully gain collaborative awareness even without being able to communicate in real-time.

When using CollabConnect, the sighted users are all assigned a pastel colour the moment they become Editors in a document. Their colour can be viewed in the main Sidebar. Along with listing all collaborators, the Sidebar also lists all 'Locked Sections'. These locked sections are highlighted paragraphs of text in the document. A collaborator can lock one section at a time and that section is highlighted in their colours. The paragraphs are not actually locked, as in, anybody with editing rights can access that section and make changes to it. The purpose of these locked sections are mainly to visually communicate the separation of work between sighted collaborators. Additionally, when a user locks a section, they must give it a title. This information is then presented to other users, in the Sidebar for the sighted collaborator and in the Summary Dialog Box for the BVI collaborators. The Sidebar list of 'Locked Sections' cards includes the title of each section, who is the author and the first few words of the original text they locked. If the user is the author of a section, they also have access to the 'Unlock' button. When they are done writing, editing or working on their section, a user can unlock the section by providing a summary of their changes. Each locked section is also colour coded in their author's colour.

On the other side, the only interface the BVI collaborators interact with is a pop up summary dialog box. This popup has three tabs; Collaborators, Locked Sections and Text Changes. Each tab provides the corresponding collaborative writing information to the user by listing all collaborators and current editors, all locked sections and their details and all text changes and their summaries respectively. In addition to providing details about each piece of information, the dialog box gives a summary about the amount of each information. This allows the BVI collaborators to gain a high-level overview of the current state of the document at any time. The Dialog box is opened with a single keyboard command and it is screen reader compatible, as users can navigate through it by pressing 'Tab' and 'Shift+Tab'. This simple design allows user to seek collaborative awareness information on-demand.

Figure 6.1: CollabConnect Side A main interface - Sidebar




# 6.2 System Design

## 6.2.1 Side A

As described above, the main interface of Side A of CollabConnect is a sidebar. This decision was detailed in the prototype design section. After evaluating the interviews I concluded that a sidebar and pop up dialog boxes are the perfect design choice for the sighted side of CollabConnect. To reiterate, the Sidebar stays open in the right hand side of the web page, and lists all necessary collaborative awareness information. By having the colour coded collaborators, editors can deduce who is the author of what section. The Sidebar further provides more detail about each section in a list. The two main features - locking and unlocking of a section are done through buttons that are in the sidebar. This design groups the functionality of Side A of CollabConnect into one place so the user has all the features in one place. Additionally, by having an unobtrusive persistent sidebar open at all times, sighted collaborators are reminded of the tool and its functionality, so they are less likely to forget to use it. The main features of Side A of CollabConnect aim to provide the information about who are the collaborators of a document, what they are working on at any moment. Figure 6.1 shows the main user interface for Side A. Figures 6.2 and 6.3 show the two dialog boxes used for locking and unlocking sections.

### Collaborators

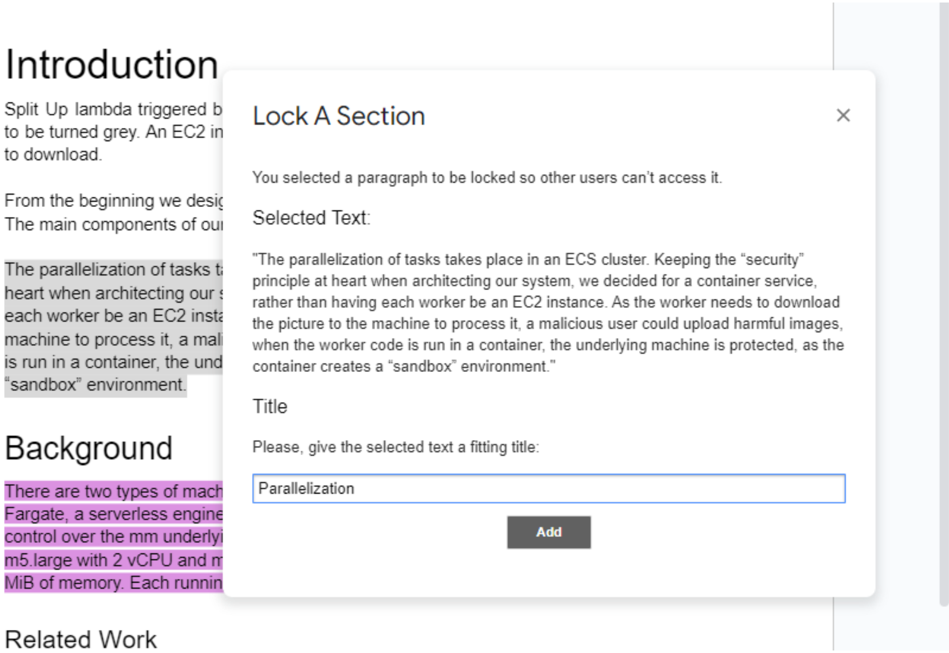
The Collaborator List is the first feature in the CollabConnect sidebar. This feature lists all users with the 'Editor' permission, even if they are not currently in the document. This is different to the collaborator icons that are located in the top-right of Google Docs, as they appear only when users are in the document at the same time. These users also do not have to be logged in to access the document, so they can be anonymous collaborators. The CollabConnect Collaborator List has the actual email addresses of each editor. This feature answers collaborative awareness questions about who is in the document and who they actually are.

Next to each email address is a small circle the colour that was randomly generated for the collaborator. This colour gets assigned to each user the moment they join the document as an editor. The colours are pastel and light, as they are used to highlight the 'Locked Sections' so the black text needs to be readable with the colour set as its background. In Side A of CollabConnect, this collaborator colour is used to indicate the authorship of other information. In addition to the highlighted sections in the document, the Locked Section List in the sidebar is also colour coded.

### Locking

The third section of the Sidebar is ‘Add New Section’, which can be seen in the bottom-right of 6.1. It features two buttons, ‘Lock’ and ‘Refresh’. Pressing the latter refreshes the contents of the Sidebar. The former is used to lock a section. A user may only lock one section at a time. If they do not have any locked sections, they can select the paragraph or piece of text they wish to lock. After selecting the text, the user should press the ‘Lock’ button.

Figure 6.2: CollabConnect Side A ’Locking’ dialog.



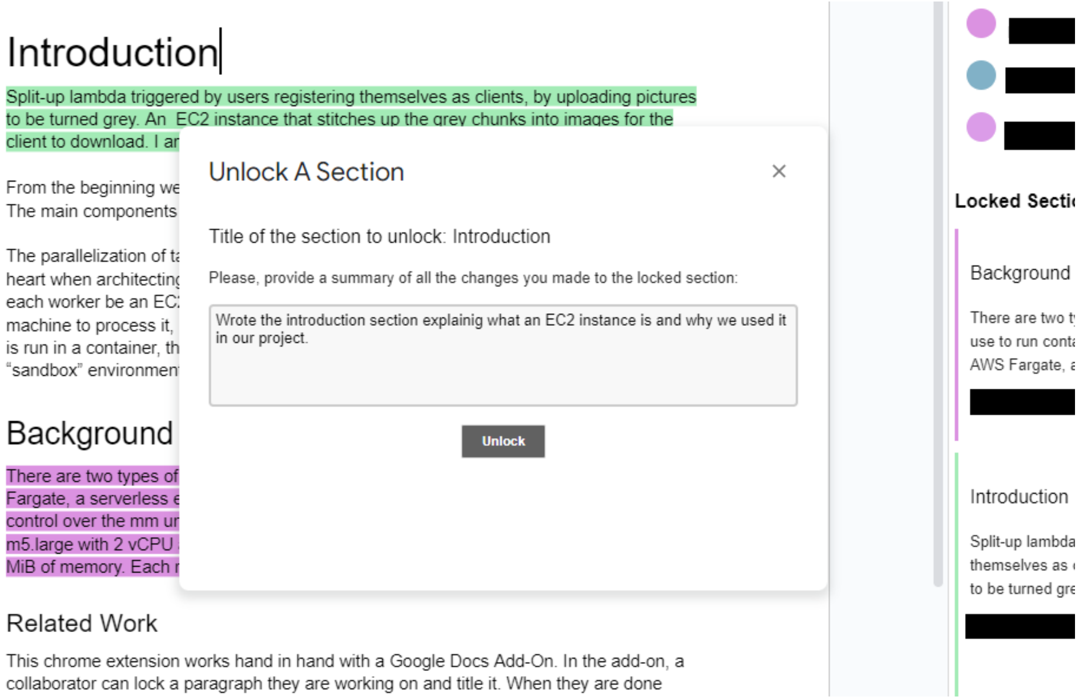

As a result, the ‘Lock A Section’ dialog pop up appears on the screen, as illustrated in figure 6.2. Here, the user can review the text they have selected and proceed to give the section a fitting and descriptive title. This title needs to be unique, so no other locked section can have the same title. After choosing an appropriate title and pressing ‘Add’, the selected text gets highlighted the user’s colour and the newly created Locked Section card gets added to the list in the sidebar. Now, the user can work on their locked section.

In a collaborative environment, this functionality allows for all collaborators to visually mark what they are working on. Oftentimes, when collaboratively writing in groups, co-authors deploy a divide-and-conquer strategy, where each person has tasks to accomplish on their own - typically writing a section of the whole document. Typically, teams assign tasks by highlighting sections, writing names next to headers and keeping a task list in a different system. CollabConnect’s locking feature allows for users to apply this strategy and provides additional support for implementing it which is not native to Google Docs. This feature helps answer collaborative awareness questions about knowing what collaborators are working on.

### Unlocking

Each Locked Section card has an ‘Unlock’ button as seen in 6.1. This button is only available to the author of a Locked Section. A user can unlock a section at any time. After pressing the ‘Unlock’ button, the second dialog, the ‘Unlock a Section’ box, pops up. Figure 6.3 shows an example of a user unlocking their section with the title ‘Introduction’. In the dialog box, they are prompted to provide a summary of the changes made to the locked section. The user is not allowed to unlock a section without writing in this summary box. After writing the summary, the user can press the ‘Unlock’ button. The unlocking process changes the background of the highlighted section back to transparent, to visually indicate that the user is no longer working on this section. The corresponding Locked Section card also disappear from the Locked Section List in the sidebar.

Figure 6.3: CollabConnect Side A 'Unlocking' dialog.




### 6.2.2 Side B

Blind and visually impaired collaborators access my tool by installing the CollabConnect chrome extension from the Google Web Store. After installing it and opening a Google Docs document which has the appropriate App Scripts attached (for the Google Docs Add-on to run), the users can press 'Ctrl+Shift+Q' on their keyboard. A dialog box appears on top of the web page. The dialog has three tabs in its navigation bar; Collaborators, Locked Sections and Text Sections. Pressing each tab will render the appropriate collaborative awareness information pertaining to each section. Side B of CollabConnect was designed to provide on-demand high-level overview as well as detailed information about who is in a document, what they are working on and what changes they have made to BVI users.

#### Collaborators

After accessing Side B of CollabConnect, the 'Collaborator' tab is opened (Figure 6.4). Here, in the top section, the user can learn how many collaborators are currently in the document and who they are. Further down, the user is also provided with the full list of all users who have the 'Editor' permission to the document at hand. Similarly to the Collaborator feature of Side A, this tab gives the user access to information about who is in the document and who they are.

#### Locked Sections

A user can navigate to the next tab, named 'Locked Sections', by pressing the button in the navigation bar or tabbing into it. Here, the information sighted collaborators provide in Side A of CollabConnect is used to communicate awareness about collaboration to the BVI collaborators. As shown in Figure 6.5, on the top of the dialog, a user can read or listen to how many locked sections there are currently in the document. Navigating further down, the dialog has a list of locked sections where each locked section has a card, similar to the list in Side A. In a list, the title, the author, along with the locked section original text is provided for the BVI user to access. This feature was designed to give blind users the ability to be able to know who is working on what in a shared document.

Figure 6.4: CollabConnect Side B 'Collaborators' tab. In the modal dialog, there are two lists of collaborators. First list shows the current collaborators in the document and the second is the list of all Editors.

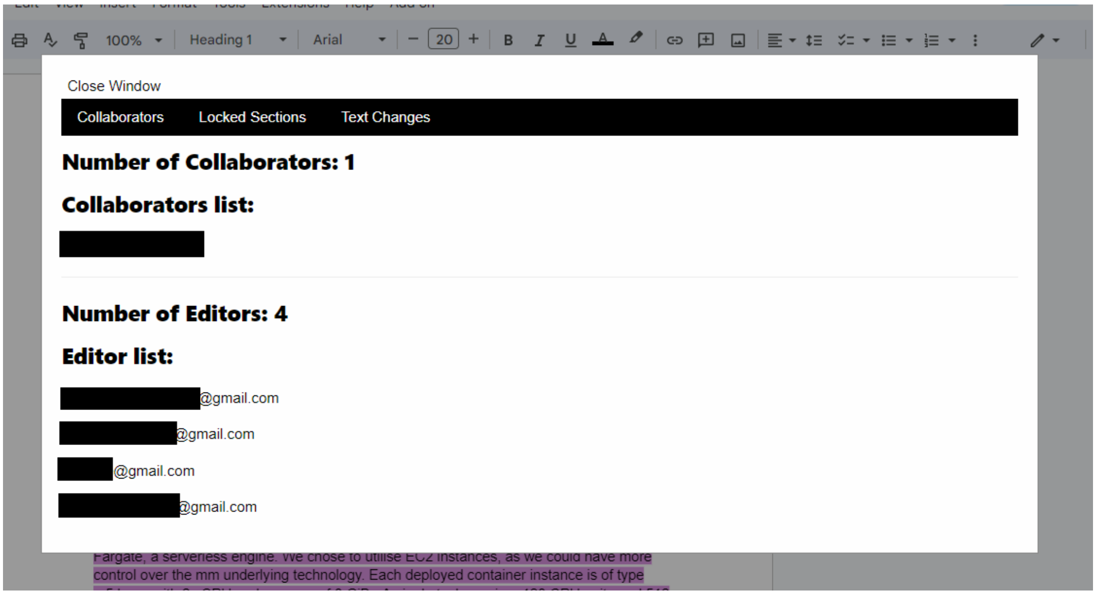
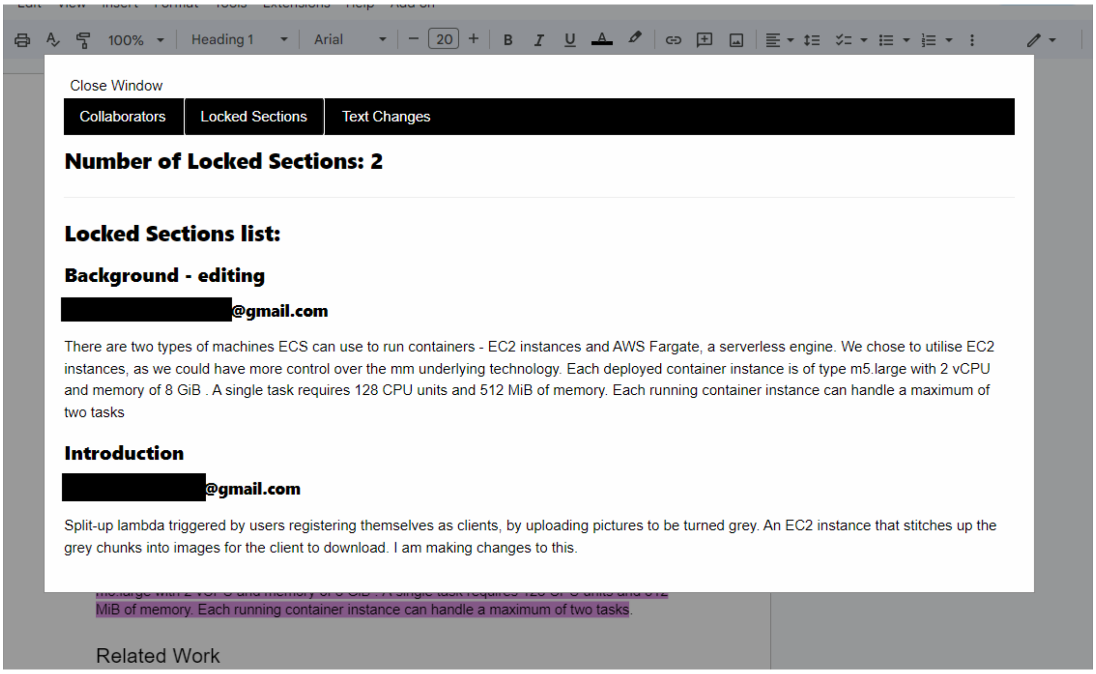



Figure 6.5: CollabConnect Side B 'Locked Secitons' tab. In the modal dialog, there is an example of two locked sections, showing the title and the author of each section.

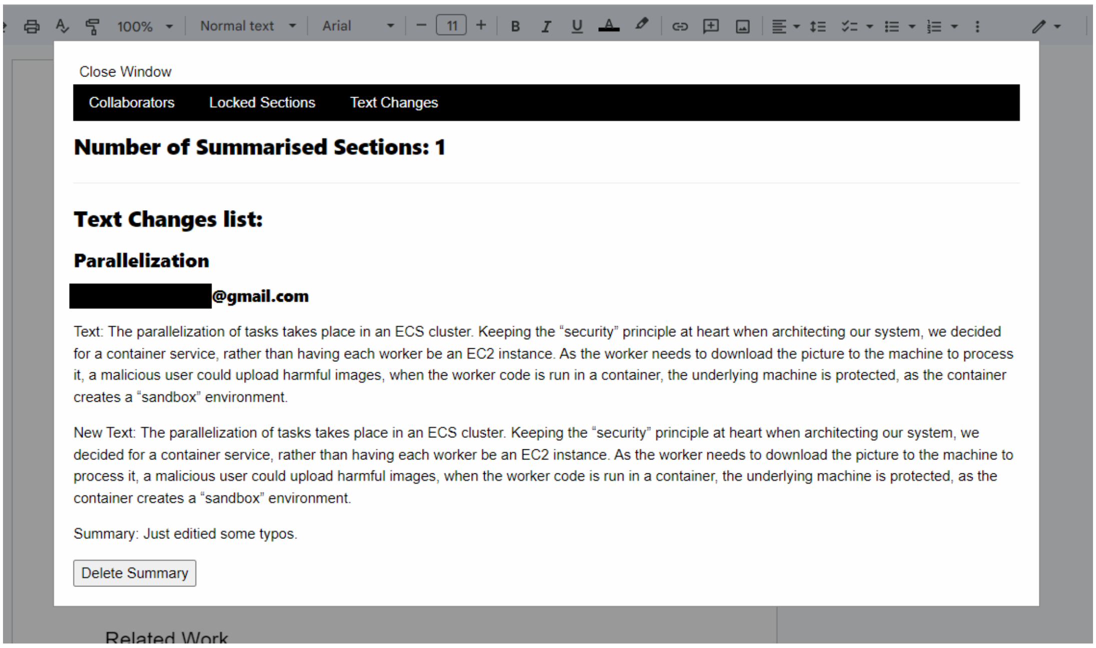



### Text Changes

The last tab in the navigation menu of Side B belongs to 'Text Changes' (Figure 6.6). The information is organised in the same way as in 'Locked Sections', with the number of summarised sections on the top of the modal and a detailed list of each text change underneath. For a text change, the title, the author, the original text and the new text (when the collaborator unlocked it) is given. Additionally, the summary the sighted collaborator had to submit when unlocking a section is given as well. This allows the BVI user to identify changes in two different ways. They can either listen to the old and new version of the paragraph and try to find differences, or they can choose to rely on the information provided by their collaborator to get a summary and or explanations of the changes made.

Each text change card element has a 'Delete Summary' button. By pressing this button, the user

Figure 6.6: CollabConnect Side B 'Text Changes' tab. In the modal dialog, these is an example of one summarised section, showing the original text, the new text and the summary of changes.




deletes the text change card so it no longer appears in the tab. The user is the one to control what text changes information they view. This is different to the Locked Sections design, where a user can only access information that is currently available and will have the information until the author of the locked section decides to unlock it.

This feature was designed to provide collaborative awareness information to BVI collaborators, namely the artefact history and action history elements (Table 2.1). These awareness elements try to answer questions such as; how did this happen and how did it come to this state? Additionally, the summary of changes as given by the sighted collaborator can be compared to how people explain and summarise their actions when being able to talk while collaboratively writing.

## 6.3 System Implementation

From a technical perspective, CollabConnect has four main parts; the google docs add-on, the chrome extension, the backend that makes API calls to the database, and the database itself. Figure 6.7 shows how all four components are connected. The following section will detail the technical information of each component, how they are utilised in my tool and why I have decided to go for this technology.

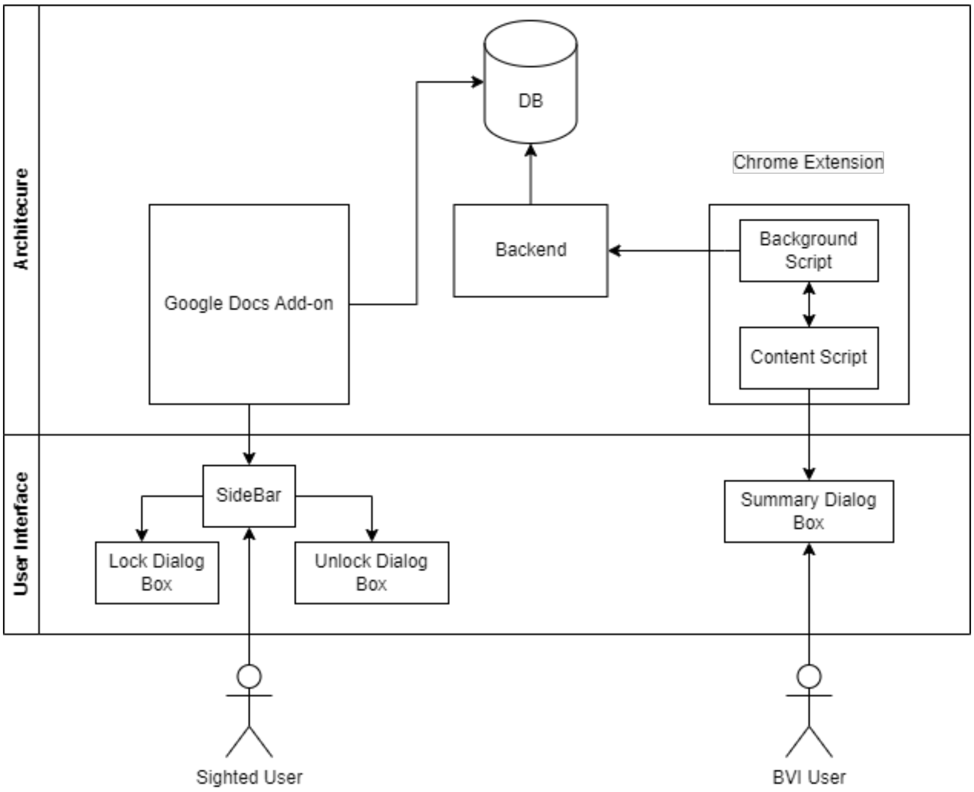
### 6.3.1 Google Docs Editor Add-on

I developed CollabConnect to work with Google Docs (see 4.1). The multiple different ways to extend the Google Docs interface are detailed in Chapter 3. I decided to implement Side A of CollabConnect as a bounded Editor Add-on script for the following reasons. A bounded script has the ability to add UI components, sidebar and popup modal dialogs to the Google Docs interface. This was necessary, as these components make up the main user interface of CollabConnect Side A. Additionally, knowing that publishing would take a long time (see 3.1) and the limited time frame for developing this project, I opted to develop CollabConnect as a bounded script under a Cloud Project, instead of publishing the Editor Add-on. To share CollabConenct for testing purposes I would add users to my Cloud Project to give them the correct permissions to access the add-on.

### 6.3.2 Chrome Extension

To develop an interface that a blind or visually impaired screen reader user would interact with, I had two requirements. Firstly, I wanted to be able to get high level insights about the web page, for example cursor locations. An App Script project can only access the information about the document, not the whole

Figure 6.7: Architecture diagram of CollabConnect, showing how Google Docs Add-on (Side A), Chrome Extension (Side B), the CloudSQL database and the backend are connected.




web page. Secondly, the interface must be easy to use with a screen reader. Because of these restrictions, I was forced to consider a different solution to develop Side B of CollabConnect. Inspired by CollabAlly developers, who made their tool as an extension, I decided to implement this side of CollabConnect as a Chrome Extension.

The CollabConnect Chrome Extension developed for this project is made out of a manifest file, a service worker called ‘background’, a content script called ‘content’ and a HTML page in the form of a popup. A service worker is a script that runs in the background and listens for and handles browser events. In this project, the service worker listens for the user pressing a predefined keyboard shortcut (Ctrl + Shift + Q) and if it sends a message to the content script to open up the dialog popup box. Additionally, the service worker handles all communication with the backend and handles retrieving and updating data from the database. The published version of the extension is available to install at https://chrome.google.com/webstore/detail/collabconnect/hahbhgbihpedbknldpiombgemcgfojko.

### 6.3.3 Database

To coordinate and organise the exchange of information between the two sides of CollabConnect, I decided to utilise a relational database. The main functionality of the database would be to store information pertaining to a document, specifically locked sections and their text, title, author and in the case of an unlocked section the new next and the summary. I chose to use a cloud stored database, specifically Cloud SQL, as it was hosted on Google Cloud Platform (GCP) and I could connect it to the same Google Cloud Project and its permissions.

### 6.3.4 Backend

The chrome extension side also retrieves and updates the information in the database. The service worker of the extension is able to perform a few simple fetch API calls to the backend deployed in the cloud. The backend is built with the Express.js framework. This backend is implemented as a Cloud Run instance which handles all the calls to the Cloud SQL database.

## 6.4 System Accessibility

### 6.4.1 Accessible Design for Modal Dialog

Inspired by the design of ColabAlly, I implemented the user interface of Side B of CollabConnect as a singular dialog box with three sections. I followed the APG pattern for making a dialog box, called the 'Dialog (Modal) Pattern' [30]. The dialog is a window overlay which is positioned over the Google Docs web page, opened by a keyboard command. To comply with the APG pattern, the element which serves as the dialog has the ARIA role of 'dialog'. Once opened, the focus is set to the most appropriate element, which is the 'Collaborator' button in the navigation menu. The user can move between focusable elements by pressing 'Tab' to go forward and 'Tab+Shift' to go backwards. It can be closed by pressing the 'Close Button' or clicking anywhere outside the dialog box.

#### Testing for Screen Reader Accessibility

After developing the extension I wanted to test how well I incorporated the accessibility recommendations and whether screen reader users would be able to use CollabConnect. To do this, I downloaded JAWS, a widely used Windows screen reader. Using a screen reader with my tool allowed me to identify and correct accessibility mistakes, such as HTML elements without appropriate tags and incorrect tab sequences. However, as a novice screen reader user who is sighted, I missed certain accessibility issues with CollabConnect, as detailed in 7.4. This brings to attention the need to test accessibility features with the actual end users, as they can more appropriately judge the usability of the design.

### 6.4.2 Revisiting System Requirements

I concluded the section 5.4.3 by listing five system requirements for an accessible collaborative writing tool, as informed by the formative study findings. Here, I revisit the requirements and detail how CollabConnect adheres to them to accomplish accessibility for ability-diverse teams.

- **Systems that are fast and effective:** Users that interact with either side of CollabConnect are presented with collaborative awareness information catered to make their collaboration faster and more effective. They can access this necessary information in a few simple intuitive steps (one keyboard command or a glance to the sidebar).
- **Systems that are easy to pick up:** CollabConnect was designed to be screen reader user-friendly and easy to learn to operate. Side B of CollabConnect is implemented following a design pattern for a modal dialog made by ARIA APG. following this pattern ensured that BVI users can quickly adapt to the system. CollabConnect uses only one additional keyboard shortcut, which makes it easy to pick up and solves the steep learning curve problem of Google Docs accessibility features.
- **Systems that work similarly to other assistive technology tools:** Using the APG modal dialog pattern allowed for the system to implement workflows common to BVI users. They can use their screen reader to navigate the dialog box in the same way they would navigate any other web page.
- **Systems that make collaborators participate with creating and accessing collaborative awareness information:** The main features of Side A of CollabConnect aim to provide the information about who are the collaborators of a document, what they are working on at any moment and what changes they have made. Side B of CollabConnect was designed to provide on-demand high-level overview of collaborative awareness information as well as detailed information about who is a in document, what they are working on and what changes they have made to screen reader users.
- **Systems that distribute the labour of access:** In addition to visually diving writing and editing tasks, the sighted collaborators can provide additional collaborative awareness information by titling and summarising their locked sections. This makes them responsible for creating access for their BVI collaborators. CollabConnect distributes the labour of creating access by implementing these features into the workflow of using the system.

# Chapter 7

# Design Evaluation

After creating a CollabConnect, I conducted a design evaluation user study to obtain feedback on it's design and usability. In addition, I wanted to gain insight into whether CollabConenct achieved its goals, proposed in 4.1.2. A such, I designed the study to allow me to answer two research questions:

> *RQ 1: Does CollabConnect provide BVI users ways to gain collaborative awareness information?*

> *RQ 2: Can sighted collaborators use CollabConnect to join in the labour of creating access in a helpful way?*

The study, as composed of three parts, the pre-observation study questionnaire, the observation study and the post-observation study questionnaire. The observation study was audio recorded to allow for analysis of workflows and approaches when seeking collaborative awareness information.

## 7.1 Participants

Four participants took part in this study. Two of these participants were female, one male, and one was non-binary. I reached out to all blind and visually impaired participants from the interview study. Ronnie and Tom agreed to take part in testing the tool I developed. I paired both with sighted collaborators, who I found through convenience sampling. Violet and Petra are both university students and perform collaborative writing tasks often. All necessary participant information can be found in Table 7.2.

## 7.2 Procedure

I divided the study into three parts; the pre-observation questionnaire, the observation study and the post-observation study questionnaire. The pre-observation study questionnaire was designed to record how each participant viewed and ranked specific collaborative writing information and what were their typical ways of doing collaborative writing. The observation study required participants to undertake two collaborative writing tasks. Participants worked together in pairs of one sighted and one BVI user. After the observation study, participants were asked to complete a questionnaire about their experience using the system. Both questionnaires were given to the sighted participants in the form of an online form. As for the BVI participants, instead of sending them the form I decided to ask them the same questions and record their answers for them, in a style similar to a structured interview. I made this decision as I knew completing the questionnaire would take longer and the study was already estimated to be longer than 1.5 hours. The observation study was recorded to allow for analysis of workflows and approaches when seeking collaborative awareness information.

### 7.2.1 Pre-observation Study Questionnaire

To answer my first research questions, I first had to gather information about how my study participants gain collaborative awareness information when in normal situations. I designed several questions which can be separated into two categories. First, I asked them to rank the importance of having five different types of collaborative awareness information for effective collaboration. The questions are Likert style

| Name | Self-reported visual ability | Occupation | Collaborators | Screen reader |
|---|---|---|---|---|
| Tom | Blind | University Lecturer | PhD Students | JAWS |
| Ronnie | Blind | Freelance Artist | Clients, creative writing co-authors | JAWS, VoiceOver for iPhone |
| Violet | Sighted | University student | Other students | N/A |
| Petra | Sighted | University student | Other students | N/A |

Table 7.1: Details about participant of Design Evaluation Study

questions, with the scale of 1, meaning "strongly disagree", to 5, which stood for "strongly agree". The participants were asked to the following questions:

- On a scale of 1- 5 please rate 5 different collaborative awareness information in regards to how important each is to help with effective and productive collaborative writing. When collaboratively writing in a shared document ...
  1. ... knowing who is in the document at any time is important.
  2. ... knowing who is working on what is important.
  3. ... knowing what a collaborator has worked on is important.
  4. ... knowing what changes a collaborator has made is important.
  5. ... getting a high-level overview of collaborative information (who is in the document, what they are working on or what they have worked on, what changes they made) is important.

Secondly, I asked the participants to describe in their own words their typical ways of getting or knowing that collaborative awareness information. I asked the following set of questions:

- Please describe how you usually know that collaborative awareness information from the collaborative writing system that you use. If you don't know that information at any point and need it to perform a task, please describe how you would go about getting/finding that information.
  1. How do you know who is in a document?
  2. How do you know who is working on what at any time?
  3. How do you know what a collaborator has worked on?
  4. How do you know what changes they have made?
  5. How do you get a high-level overview of collaborative information/current state of a document?

### 7.2.2 Observation Study

#### Training

Before the study I conducted a one-on-one training session with each of the participants. I prepared a training document with several paragraphs. I instructed participants on how to access the tool, explained the basic functionality and features and what they were designed to do. As part of the training, I would ask them questions about the current state of the document while making changes (adding locked sections, unlocking sections) to make sure they understood the correct usage of the tool and knew where to seek appropriate information to answer my questions. All together, the training took around 15 minutes for the sighted participants and around 30 minutes for the blind participant.

#### Situation Description

I started the observation study by providing the participants with a brief description of the situation I designed for the study. I wanted to test CollabConnect as a collaboration tool in a situation where a mixed ability team synchronously edits a shared document. The situation description I designed and read to the participants is as follows:

”You are working in a mixed ability team on an assignment. You were given a topic “Countries in the UK” and told to write an introduction paragraph and a paragraph about each country. With your teammates you decided beforehand on who is writing which paragraph. You have also agreed to read over each other’s work, correct any grammatical mistakes and add a sentence about your personal opinion about each country. You are working on this assignment remotely, so you cannot communicate verbally with the other collaborators.”

| Group | Introduction | England | Scotland | Northern Ireland | Wales |
|---|---|---|---|---|---|
| Violet, Ronnie, Author | Author | Ronnie | Violet | Author | Violet |
| Petra, Tom, Author | Author | Author | Tom | Petra | Petra |

Table 7.2: Detailed task allocation for Task 1 for Design Evaluation Study

Upon entering the study document (Figure 7.1) the Introduction was already written and the other section I, the author, was responsible to write, Northern Ireland or England, was in a ‘Locked’ state. Going from Task 1 to Task 2, I unlocked this section. I did not talk to the participants while solving the tasks. Instead, I instructed them to verbally explain all their actions, decisions and thinking processes. As these calls were recorded, I could go back and examine their verbal explanations to conduct analysis. The participants were also aware that the goal of the study was to observe how they use CollabConnect to write collaboratively, not how well or fast they can write about the countries of the UK.

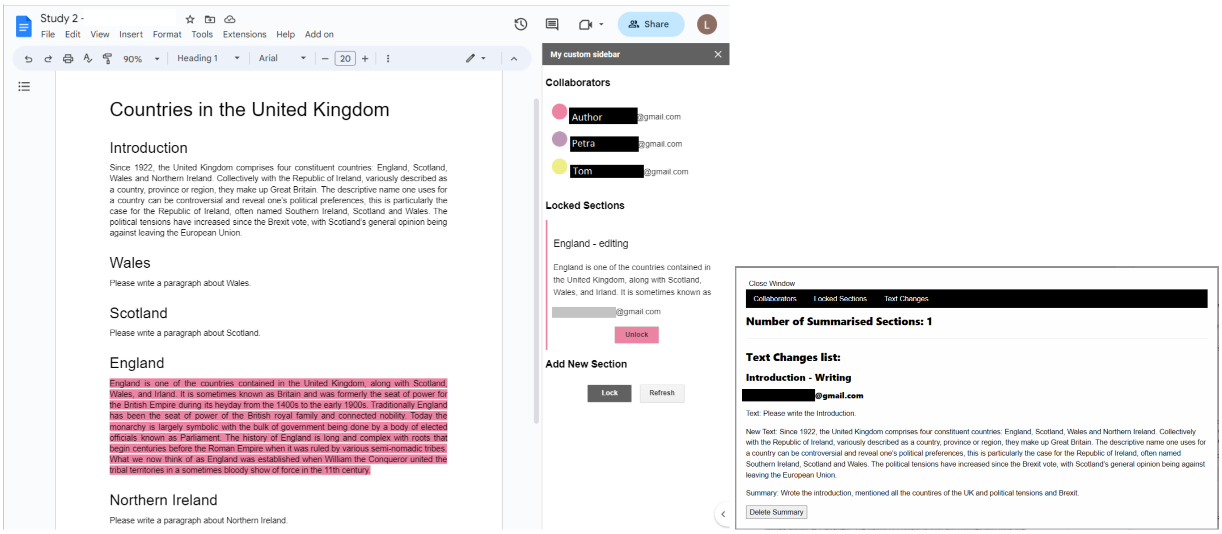



Figure 7.1: What the study document looked like before the beginning of the study with Tom and Petra.

### Task 1

All tasks were communicated to the participants verbally. When the observations study started I was on two separate online calls, one with each collaborator. This means the participants could not hear each other, their only communication was through the shared document and CollabConnect. The first task was a writing task. The collaborator was asked to write about the section they were responsible for, as detailed in Table 7.2. The task description, in its exact wordings, is as follows:

“Write a paragraph about ... (insert country from Table 7.2). Share any general information you know and any personal experiences you have with the country.“

### Task 2

The second task was an editing task. I asked the participant to edit the section their other collaborator (not me) has most recently finished working on. The task read to the participants was:

“Your collaborator has asked you to go over what they have most recently written and check for any mistakes they made. You should also add a sentence or two about your personal experience, memory or opinion about the country.”

**During the Study**

I prepared a set of questions that I asked the participants after they finished each task. The participants informed me about completing the tasks verbally or by writing in the chat of the online meeting. After they did, I would join their call and ask them the following:

1. How many collaborators are in the document currently?
2. Can you name all collaborators?
3. Is anybody currently working on their paragraph?
4. Has anybody already finished writing their sections?
5. If yes, What did they do?

This was to observe their ability to assess the current state of a document and seek out collaborative awareness information when prompted. These questions w derived from Gutwin and Greenberg's framework for workspace awareness [28].

### 7.2.3 Post-observation Study Questionnaire

After finishing the observation study, the sighted participant was sent a Google Forms questionnaire to share their feedback on the experience. I conducted a structured interview with the BVI participants, asking them the same questions in the same order. The questionnaire included a combination of scale, and open-ended questions, aimed at assessing their thoughts on the design and usability of the system developed. The questions can be divided into two categories, questions about the tool and about the tasks.

- Tool Specific Questions:
  1. Least favourite feature of the tool.
  2. Most favourite feature of the tool.
  3. How would you rate your overall experience when using the tool?
  4. Do you have any suggestions for the design of the system?
  5. Would you consider using CollabConnect again?what they are working on or what they have
  6. Did the tool change your typical workflows of getting collaborative information?
  7. Describe any way that your workflows of getting collaborative awareness information differed from what you do typically.
- Task Specific Questions
  1. What was your general approach for solving Task 1/2?
  2. Did you encounter any issues when solving Task 1/2?
  3. When doing similar things on collaborative writing systems, would you say your experience was worse/better/the same as when using the tool?

## 7.3 Data Analysis

Through audio recordings of all sessions, I transcribed and analysed observational data alongside questionnaire responses. Using a qualitative coding approach, I identified themes that emerged from the data, particularly in relation to participants' reactions to the design features CollabConnect. The aim of this study was to gain insight into how participants perceive CollabConnect in the context of creating access and how such technology can transform collaborative work and distribute the labour of access. Rather than focusing on task performance, this analysis aimed to explore the participants' subjective experiences and perceptions.

## 7.4 Findings

In this section, I present the findings of the design evaluation study. I collected data at all three stages of the study and I organised the findings into two sections. Firstly, I discuss the results from the pre-study questionnaire. Then, I combined the findings with observational data from the study and the qualitative data from the post-observation study questionnaire. Here, I present the results organised according to design features, as they emerged from the analysis. Lastly, I present the design suggestions from the participants and their overall experience with CollabConenct.

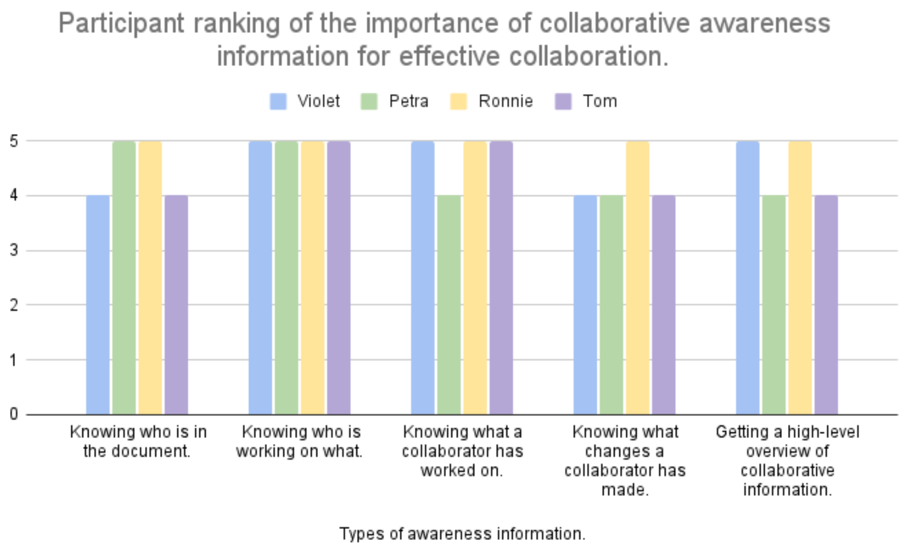
### 7.4.1 Pre-observation Study Questionnaire Results

Overall, the participants ranked all five collaborative awareness information as very important, giving an average score of 4.5 to knowing who is in the document, what a collaborator has worked on and getting a high level overview of collaborative information. Knowing what changes a collaborator has made received an average score of 4.25. Knowing who is working on what was ranked the highest, with all participants giving it a 5. Individual ranking can be found in Figure 7.2. This suggests that I chose important awareness information in my design of CollabConnect. Participants mentioned other features that they also find important for effective collaboration, such as leaving comments and knowing who is leaving and entering the document in real-time. An area of future improvement would be to add the functionality of collaborator announcements to facilitate real-time updates, like the ones the authors of Co11ab and CollabAlly implemented in their systems [20, 34].

When asked about how they usually get these types of information, there was an apparent difference between the sighted and blind participants. The sighted participants, Violet and Petra, had a precise and easy way of knowing who is doing what and where in the document. They described how they make use of visual features such as colour coded cursors and icons, version history or comments. Petra said that she gets a high level overview of the document by doing *"... quick scroll through the document to see who is working on what."*

On the contrary, Ronnie and Tom expressed that they usually have no way of knowing who is doing what and where in the document and what changes have been made. Ronnie said that knowing who is working on what *"... tends to be a surprise ... like the text that I'm working on is suddenly moving."* Most of the time, the BVI participants developed workarounds for having collaborative awareness information. This phenomenon is also explained in 5.4.

Figure 7.2: Participant ranking of the importance of collaborative awareness information for effective collaboration



### 7.4.2 Observation Study and Post-Study Questionnaire Results

#### Task 1

Immediately after having access to the document, even before I managed to explain the task to the blind participants, Tom and Ronnie opened the modal dialog to get a sense of the state of the document. After they received the task, they proceeded to find the heading of the appropriate section and started working. Ronnie said that they solved the task in a way that is *"pretty standard for how I would do it."*. Tom shared the same sentiment and said *"If I was writing a paragraph, the process would be broadly the same. I'd have to find where I wanted to be in the document to write whatever I was gonna write, and then I'd write it."*

However, Tom had some issue with the cursor working differently in Google Docs then what he was used to, which made him initially confused about how to navigate the document. Similarly, he had issues moving from the dialog box to the body of the document with his screen reader. He said: *"Certainly for a time I thought you could go from the various things in the tool, .... if you keep tabbing, you'd end up back in the document. And also yeah, I wasn't sure for some time whether I could just escape back into the document or whether just clicking on close that window would take me into the document."* After he finished his first task I made sure to properly explain how to close the dialog and move back to the document. Ronnie expressed that usually, they would keep the task definition written down somewhere near them, so they can refer back to it easily, as they struggle with remembering specific details of the task definition.

After the tasks, when I was asking the questions described in 7.2.2, both Tom and Ronnie initially struggled to know where to look in the tool to find the answers. They were mainly confused about how to know what people are working on, as they did not realise that the 'Locked Sessions' tab holds that current information of the sighted user.

Both Violet and Petra easily utilised the tool to lock and unlock the sections they were working on. The general approach for the two of them was to read the document, lock the section of text and explain what they are working on by giving it an appropriate title (e.g. "Wales - writing"). Then after finishing writing the section they unlocked it and explained what changes they have made in the summary.

After the first task, when I asked Violet and Petra about who was writing what, they tried to seek that information by looking at the sidebar or at the colour-coded cursors. However, the blind and visually impaired collaborators do not have the functionality of adding a locked section and, thus, unlocking it. This shows a substantial hole in the design, as both sides do not have equal access to information and are not able to participate in the collaborative tool in the same way. In the questionnaire, Violet noted that her least favourite feature of the tool was that she *"... didn't get any overviews of the work done by other collaborators."*

#### Task 2

The second task, where I asked the participants to edit each other's most recent work, went smoothly with the collaborators successfully finishing without any major problems. The sighted collaborators Violet and Petra deployed a very similar approach to solving the second task, where they highlighted the appropriate section and started making edits and adding sentences. Once done, they unlocked the section and wrote a description about what they had done. In the questionnaire, Petra noted that from her experience, sometimes she is editing a section with multiple collaborators at the same time and was not sure if CollabConnect would be any useful in that situation.

Ronnie and Tom both started the task by looking at the 'Text changes' to identify what was the most recent paragraph their collaborator had worked on. Here, Ronnie expressed their desire to have the card for each summary section include a timestamp. They said that since there are multiple sections authored by different collaborators, they would prefer to have a way to look at the most recent one.

Neither Tom or Ronnie paid much attention to the delete button under each summary, so all summarised sections in the 'Text Changes' stayed there. The lack of time stamps and deleting the sections is evident in Figure 7.3, which shows the state of the document and CollabConnect after Tom and Petra finished the second task.

#### The Process of Locking and Unlocking

Violet had a lot of thoughts about the locking and unlocking process. She said the way of getting collaborative awareness information changed when using the tool. She explained by saying *"I was looking if any of the sections are 'locked' by a collaborator. I also had to actively make other collaborators know*

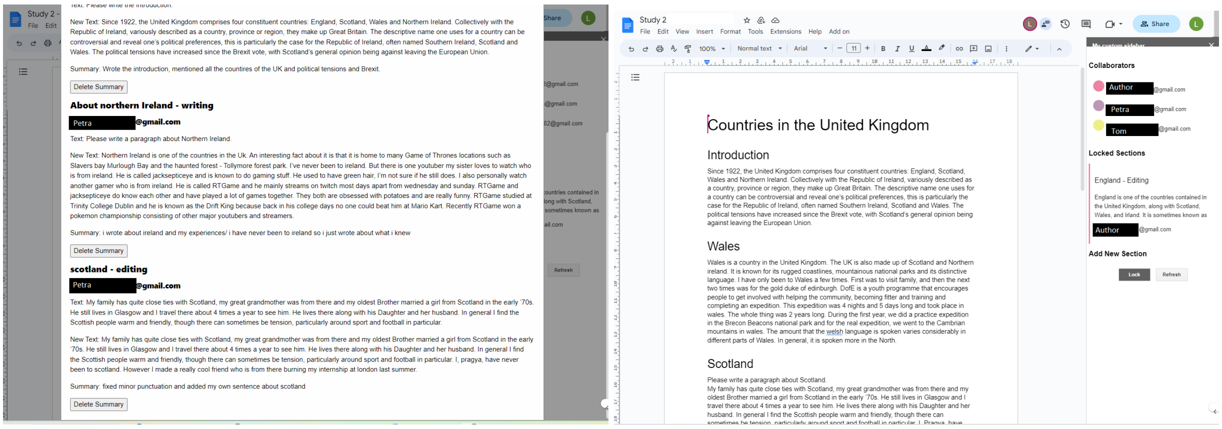



Figure 7.3: The study document after the study with Tom and Petra.

*where in the document I'm working and what changes I've made."* When writing her paragraph about Wales, Violet liked the process of locking the section she was working on, as *"Locking the section of text made it very clear and I wasn't worried that someone is going to edit it while I am still working on it."* According to her, this feature made her collaborative writing experience better overall. She also noted that while locking sections seemed like an extra step at first, it ultimately made her more focused on the task at hand.

Ronnie expressed some concerns regarding the tools reliance on able-bodied and sighted collaborators to manually update it. They said *"When sighted people have to do something extra for a disabled person, it's very easy for them to just forget and not understand how important it may be to a collaborator. That does result in really important information being missing."* Ronnie emphasised the importance of ensuring that the tool does not add more work for disabled collaborators, like having to ask and remind sighted collaborators to use the tool. To solve this, Ronnie suggested the use of an automated system to reduce the chances of sighted collaborators forgetting to update it. Tom pointed out the same concern, *"Obviously with the summaries, you rely on people actually putting them in and accurately describing what they've done."* However, as he was never able to get any type of overview of changes, he still viewed this feature as an improvement. Tom suggested: *"You might, ..., consider almost forcing an author to write some kind of summary when they've completed editing to avoid the possibility somebody just comes out and doesn't bother."*

### Locked Sections and Text Changes

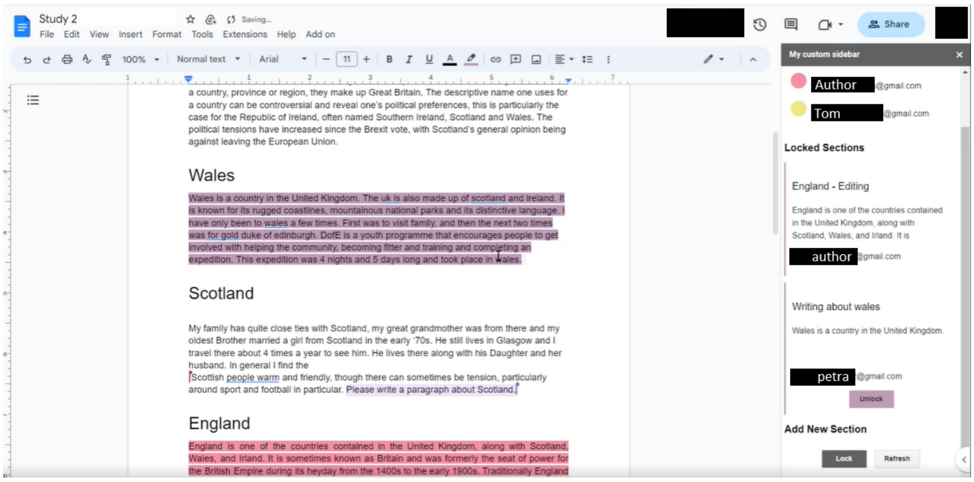
Petra had some difficulty with the colour of the highlighting, saying that *"sometimes the colour it chose was kind of hard to read."* The system assigned her a purple colour, as seen in Figure 7.4, which made the black text hard to read. She suggested that locking sections should be available to her visually impaired collaborator as well, saying *"When asked who was working on things, I subconsciously started looking for the chunks of highlighted text, so I got confused when I couldn't see Tom's section."* Violet expressed the same sentiment, saying she would appreciate all collaborators to have the ability to lock and unlock sections.

Petra particularly liked the sidebar that displayed all the locked sections, saying it was her favourite feature. Ronnie appreciated the 'Locked Sections' tab, but suggested that it could be improved by updating more automatically, saying *"Like somebody is working on this and if it were able to like update more automatically, that would be an incredible thing because you could just watch the 'Locked' tab and then see whatever somebody was working on disappear."* Ronnie also liked the basics of the 'Text Changes' log (list), but suggested adding timestamps to track changes.

### Collaborators

Ronnie liked the feature that allowed them to see who else was in the document, saying they were able to quickly navigate to the dialog and open the Collaborators section. When asked about how they identified collaborators' presence, Ronnie said *"Thankfully there is just ... the first pane just shows you who's there right now and who has access in general, which is really good to know."* This feature provided them with valuable information about who was actively working on the document and who had Editor access.

Figure 7.4: The study document during Tom's and Petra's observation study. Petra was allocated the purple colour and was working on the Wales section




### Terminology

The BVI participants expressed confusion with the terminology used for certain features of the tool, mainly the names for each tab in the summary dialog box. Tom noted that there was some confusion around the list of editors and what it meant. They said, *"Does that mean they're editing the document right now, or does it just mean they've got editing rights to the document?"* This highlights the importance of clear and concise terminology that is easily understandable for all users, especially those who may be using assistive technology. Ronnie would also get confused from time to time about the meaning of 'Locked Sections' and 'Text Changes'. However when asked about more appropriate names for each feature, they admitted that the current names were probably the best fit to convey their functionality. Ronnie noted that learning the terminology for assistive technology is a necessary step for blind users. They said, *"part of what you have to do as a blind person is take some time to learn what things mean and in what context."* While it may be challenging to find universally understandable terms for certain features, it is important to strive for clarity and consistency to minimise confusion and increase accessibility for all users.

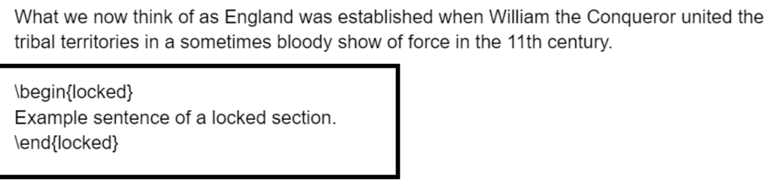
### Design Suggestions

Violet suggested that it would be helpful to know if other collaborators have already seen or listened to her changes. This feedback suggests incorporating some kind of notification system or status indicators of the progress. This feature could help ensure that all members are on the same page and that everyone is aware of the updates made to the document, reducing the risk of confusion and miscommunication.

Petra suggested that highlighting sections being worked on by visually impaired users would improve the collaborative experience. She said that *"When asked who was working on things, I subconsciously started looking for the chunks of highlighted text, so I got confused when I couldn't see Tom's section"*. This feedback suggests that implementing a clear visual indicator of which sections are being worked on by each collaborator could help sighted collaborators better understand the progress of a project and avoid confusion. Tom shared the sentiment and expressed his desire to also be able to participate in creating collaborative awareness by locking sections for his collaborators. Tom gave a specific design suggestion, saying that BVI collaborators can mark out a Locked Section by leaving an inline starting command and ending command. This is similar to how latex commands work. An example of how this could work in Google Docs can be seen in Figure 7.5. In his opinion, this design is intuitive for screen reader users, mainly for people who remember older versions of word processors, which were also operated with inline commands.

Ronnie suggested that having access to individual notes or messages within the system from collaborators would be useful. By having a built-in messaging system, team members can quickly and easily communicate important updates or questions about the project, streamlining the collaboration process and improving productivity. This feature can also be especially beneficial for visually impaired users who may find it challenging to navigate external messaging platforms.

Figure 7.5: An example of how inline commands for locking a section could look like in Google Docs




**Overall Experience**

On a scale of 1 to 5, all participants gave CollabConnect and their experience using it a rating of 4. All participants were positive about the tool, with Petra and Violet both expressing willingness to use it again in the future. Ronnie expressed her positive opinion by saying *"Knowing what's been changed, when and where, and knowing who's working on what thing and when they're doing it ..., I feel like both of those sections are good for the whole team."* Tom also indicated that he would use the tool again if he knew it was robust and he could continue to have access to it. Additionally, Tom appreciated that the tool was built around Google Docs, which he felt was a valuable system to know and use for collaborative work. Overall, the participants' positive ratings and feedback suggest that the tool was effective in facilitating collaboration and communication among the team.

### 7.4.3 Discussion

**Does CollabConnect provide BVI users ways to gain collaborative awareness information?**

Based on the findings from the Design Evaluation study, it can be concluded that CollabConnect does provide ways for BVI users to gain collaborative awareness information. Participants in the study expressed that they found the Collaborators, Locked Sections and Text Changes to be helpful in providing real-time on-demand information on who was editing the document and what changes were being made. The ability to access summaries of changes made by collaborators was especially mentioned as a great addition to having collaborative awareness. However, some participants expressed confusion with the terminology of certain features and the lack of clear information regarding who has already reviewed changes made to the document. This could be avoided or corrected by involving the input of BVI users in the design from the beginning. The importance of developing accessible systems with BVI users is also stressed in the interdependence framework for creating assistive technology [8]. For example, the CollabAlly system was designed in a series of co-design session with a blind co-author who has an extensive history with collaborative writing systems [34].

Additionally, some participants felt that the tool could benefit from individual notes or messages within the system to streamline communication between collaborators. This is behaviour was also documented by Wang at el. in a paper exploring why people tend to not work collaboratively [58]. One of the reason introduced was that collaborators use a separate private writing space to work on prepare their sections as they do not want their writing process visible to other co-authors for various reasons.

Both sighted and BVI participants expressed the desire to have the blind collaborators have the ability to use the locking and unlocking feature. This shows a substantial hole in the design, as both sides do not have equal access to information and are not able to participate in the collaborative tool in the same way. I present the same sentiment about BVI users being equal participants in creating collaborative awareness in my findings from the formative study 5.4.

This feedback suggests that there may be room for improvement in terms of providing blind and visually impaired collaborators with ways to gain and produce collaborative awareness information in a more accessible and intuitive way. Therefore, it may be worth further exploring how CollabConnect can be improved to better support both sighted and BVI collaborators. Overall, even with these shortcomings, CollabConnect was found to be a promising tool for facilitating collaborative awareness for BVI users.

**Can sighted collaborators use CollabConnect to join in the labour of creating access in a helpful way?**

The results presented in 7.4 suggest that CollabConnect made a substantial attempt to distribute the labour of access to facilitate collaborative writing awareness. The information given by the sighted participants was helpful, but BVI participants voiced their issues and concerns with the concept of this information being reliant on sighted collaborators. Ronnie highlighted the potential for important information to be missed when sighted collaborators forget to include it, while Tom acknowledged the reliance on people to accurately describe their work. In order to mitigate this issue, Tom suggested the idea of forcing authors to write summaries when they complete their editing, although he admitted that this approach may be seen as overbearing. Even with these concerns, Tom and Ronnie admitted that having the summaries and locked sections gave them awareness of collaborator activity they normally do not have access to. Sighted collaborators are not aware of the invisible labour of BVI people and that in turn makes BVI users not able to trust that they would use an accessibility tool. This suggests that there are larger and deeper issues with views on accessibility and the invisible work of BVI collaborators that this short study was not able to address.

In this project, my goal was to explore if this additional information given to the BVI user was helpful, which has proven to be true. However, the information was only helpful because Violet and Petra did use the tool to lock and unlock the section. In a mixed-ability team, if the sighted collaborator chose not to use these features or write random letters to be able to lock and unlock instead of an actual title and summary, CollabConnect would immediately become useless.

A lot of accessibility tools and solutions rely on sighted people's input. For example, one of the most basic things people can do to improve screen reader accessibility (when creating documents or making web pages) to visual media is providing alt text to images. However, even this gets overlooked and most people do not add it [10]. To solve this, researchers have been exploring automatically generated alt text, mainly for social media [62]. This could suggest that one way to solve the accessibility issues of collaborative writing systems is to completely rid the tool of any reliance on sighted collaborators. However, this goes against the notion of accessibility being a collaborative effort of the whole ability-diverse team as explained by Das et al. [19] and Wang and Piper[59].

Not only are there concerns with how willing sighted people are to create access, but there is distrust against big corporations, such as Google, who develop the most popular collaborative writing systems. When I explained that in CollabConnect, sighted collaborators had to use the locking and unlocking feature, Ronnie still felt like such a system would never actually be developed by Google, as they do not care about their blind customers. Because as it is currently, Google has added accessibility features to Google Docs, but they're not usable nor accessible [19]. Why should we think that they would be willing to make their accessibility features actually usable? This reveals bigger questions about accessibility system design and responsibility on developers and companies to not only make software that meets the basic definition of accessibility, but develop with the actual needs of the end users.

# Chapter 8

# Conclusion

The aim of this project was to explore accessibility issues in collaborative writing and to design, develop, and evaluate a solution to support collaboration between visually impaired and sighted users.

## 8.1 Main Contributions

Firstly, I conducted an interview study with both sighted and BVI users about their experience with writing in mixed-ability teams. From the findings I identified several observations about the participant experience from both the sighted and BVCI collaborators. In addition, I developed design requirements for accessible writing systems. The findings from the formative study and the evaluation of the context of the current state of collaborative writing systems revealed many issues that blind and visually impaired users face. Namely, I identified two main problems,

1. Collaborative writing systems are inaccessible and unusable for screen-reader users.
2. Blind and visually impaired users have the sole burden of creating access.

To address this, I developed CollabConnect, a collaborative writing tool that works on top of Google Docs that presents collaborative awareness information to BVI users in a more accessible way. In addition, the tool makes sighted collaborators participate in creating access for their collaborators by changing how they collaboratively write in a way that provides additional awareness to BVI users. To assess how well CollabConnect solves the proposed issues, I conducted a design evaluation study. The study was composed of three parts; the observation study and pre- and post-observation study questionnaire. The data collected from all three stages of the study was analysed to answer two research questions:

1. Does CollabConnect provide BVI users ways to gain collaborative awareness information?
2. Can sighted collaborators use CollabConnect to join in the labour of creating access in a helpful way?

The findings conclude that CollabConnect was helpful in distributing labour and facilitating collaborative writing awareness, however there are deeper issues with views on accessibility and the invisible work of BVI collaborators that the study was not able to address. Specifically, there is a lack of belief that collaborators would use accessible tools and BVI user's distrust against big corporations like Google to develop accessible systems that meet the actual needs of end users. Overall, the findings of this project have important implications for improving accessibility in collaborative writing and can contribute to the need to design systems that give a more equal distribution of the labour of access among team members with different abilities.

## 8.2 Limitations

The development of this project was severely limited by time and resources. Here, I present several problems I found with my work, which was caused in part by the limited time and resources, but also my own design decisions.

Firstly, I wished to have interviewed more sighted collaborators who have experience working with blind collaborators. Only being able to interview one person led the inability to study their experience in depth, analyse general themes across a more diverse population sample and make appropriate design choices to better support their needs in CollabConnect. Whatever decisions I made that were influenced by the interview with the sighted participant made that decision skewed towards their opinion. Similarly, when conducting the design evaluation study, I had to pair the BVI participants with the sighted participants. Before, in 2.3, I explained the idea that accessibility stems from team practices overtime. However, when testing the tool, the ability-diverse team was made of complete strangers who were collaborating for the first time.

I mention that highlighting sections for the sighted collaborators is a way to employ the divide-and-conquer strategy to solve collaborative writing tasks. By designing it in this way, I limited the usability of my tool to a certain type of task, where only one person at a time is editing a paragraph. However, there are situations in collaborative work where multiple people work on a section at the same time. In situations like this, my tool would not be able to support such collaboration.

One of the major problems with CollabConnect, as mentioned in 7.4 is the lack of support for BVI users to create additional collaborative awareness for their collaborators. In hindsight, this seems like a big oversight. When designing the system, I focused too much on providing information for blind and visually impaired collaborators and making sure to implement an equal access to information model. Rather, I could have also implemented features that include BVI users in both the process of receiving and creating collaborative awareness.

## 8.3 Future Work

To improve CollabConnect and further explore the research behind accessible writing systems and the distribution of the labour of access, I propose several areas for potential future work.

Firstly, the existing features of CollabConnect could be refined based on the feedback received from participants in the design evaluation study. For example, the terminology of certain features could be made clearer, and additional information could be provided to indicate who has already reviewed changes made to the document. Additionally, the tool could be modified to allow blind collaborators to use the locking and unlocking feature, ensuring that both sighted and BVI collaborators have equal access to information and can participate in the collaborative tool in the same way. Furthermore, I could explore adding features to support different types of collaborative awareness information, such as real-time notifications, to streamline communication between collaborators. This could help to further improve the collaborative process and enhance the accessibility of the tool.

To gain a deeper understanding of what type of features should be added, I want to involve a mixed-ability team to co-design the next iteration of the tool to improve its accessibility and usability. By including both BVI and sighted collaborators in the design and development process, we can create a more inclusive and accessible tool that meets the needs of all users. It would be beneficial to conduct more interviews and usability studies with sighted collaborators to further refine and improve the tool. The feedback from sighted participants in the previous studies suggested that there may be room for improvement in terms of making the tool more intuitive and accessible to users who are not blind or visually impaired. By conducting additional research with sighted collaborators, I could gain further insights into their needs and perspectives, and use this information to refine CollabConnect.

In addition, I can conduct naturalistic longitudinal studies to examine how ability-diverse teams utilise the tool to create access and write collaboratively. This type of study could help to identify any potential issues that may arise with long-term use of the tool and provide valuable insights into how the tool could be further improved. This would allow for accessibility to develop through the participant's time and effort spent working together to collaborative write as a mixed-ability team.

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# Appendix A

# Coding Scheme from Formative Study Analysis

| Themes | Higher Codes | Lower Codes |
|---|---|---|
| Inaccessible systems make BVI users feel unimportant and excluded. | Accessibility features not reflecting the actual need of BVI users | Accessibility is an afterthought |
| | | Unfamiliar design - shortcuts |
| | | Not designed for the needs for screen readers |
| | | Anything but Google Docs |
| | BVI users are frustrated | Frustration |
| | Loosing collaborative aspect because of unability to access it | Not being able to utilise CA features |
| | Technology progresses, but accessibility regresses | Technology changes and BVI users need to relearn |
| | | Every system is different and accessibility is applied at different levels |
| | | Scale it down and meet BVI users where they at |
| | | Not being able to access certain information |
| | Unequal Participants | One has to work for accessibility |
| | | Not part of the job description |
| | Bad design has consequences | Limits choice |
| In busy and competitive environments, inaccessible systems are seen as a burden. | Busy working environment | Need for speed |
| | | Learning takes time and effort |
| | | Need time |
| | | Takes time to get good at using a feature |
| | Competitive environment | Need to be equal to sighted peers |
| | | No room for mistakes |
| | The social cost of accessibility | Need to hide 'invisible' work to seem competent |
| | | Not feeling like a person has the 'authority' to ask for access |
| | | Need to be equal to sighted peers |

| Themes | Higher Codes | Lower Codes |
| --- | --- | --- |
| | Loosing work/opportunity due to inaccessible design | Unemployment |
| Sighted collaborators lack understanding of accessibility needs and the invisible work done by BVI users. | Sighted collaborators do not understand or are willing to listen | Collaborators not realising what their choices mean to others with different ability |
| | | Resistance to accept need for access |
| | Invisible labour | Blame falls on BVI person |
| | Lack of Support | Need for good support, because things aren't accessible |
| | Asking for access | Seniority = power and value |
| | | Need to comply |
| BVI users are forced to create workarounds to fill gaps left by inaccessible systems. | Gaps left by inaccessible systems | Speech-audio being ovewhelming |
| | | Designed to be helpful visually |
| | Accessibility emerged from practices over time | PA filling the gaps of technology/people |
| | Developed workarounds | Workaround for seeing text changes |
| | | Remember versions of document to recognize changes |
| | | Workaround for working with comments |
| | | Summarizing changes |
| | | Leaving inline commnets |
| | | Filling the gaps with PA |
| | | Other means of communication to give feedbacck |
| | Important CA for effective collaboration | The need for a high level overview of CA |
| | | Avoiding concurrent edits |
| | | Working with documents |
| | | Knowing who are your collaborators |
| | | Track changes |
| | | Leaving comments or feedback |
| | | Editing text |
| | | Context |
| | Knowing what you don't know | |
| | Gaps left by assistive technology | Not being able to see/recognize text changes |
| | Gaps left by screen readers | |
| | Breakdowns due to lack of communication or good system | |