Developing accessible services: understanding current knowledge and areas for future support.

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Developing Accessible Services

Understanding Current Knowledge and Areas for Future Support

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ABSTRACT

When creating digital artefacts, it is important to ensure that the product being made is accessible to as much of the population as is possible. Many guidelines and supporting tools exist to assist reaching this goal. However, little is known about developers' understanding of accessible practice and the methods that are used to implement this. We present findings from an accessibility design workshop that was carried out with a mixture of 197 developers and digital technology students. We discuss perceptions of accessibility, techniques that are used when designing accessible products, and what areas of accessibility development participants believed were important. We show that there are gaps in the knowledge needed to develop accessible products despite the effort to promote accessible design. Our participants are themselves aware of where these gaps are and have suggested a number of areas where tools, techniques and guidance would improve their practice.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in accessibility**; *User studies*; *Accessibility systems and tools*; User centered design.

KEYWORDS

Accessibility, digital accessibility, web accessibility.

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1 INTRODUCTION

It is estimated that 22% of all people of all people in the UK have some form of disability [53]. This can include disabilities relating to mobility, mental health, memory, hearing, vision and learning. It is therefore imperative to create software and services that can be used by all people and to not solely focus only on designing for typical users. Tools and guidance to assist in the development of creating accessible products are now commonplace. Large companies such as Google [20], BBC [5], and Microsoft [34] all provide methods of accessibility best practice that have been made available to the general public. Whilst overall accessibility has been seen to have improved in recent years, it can be argued that some of this increase is related to the change in a technology itself rather than a change in developer attitude [47]. Care must be taken before presuming that overall awareness of accessibility best practice and implementation has increased.

The implementation of accessibility within a digital service can be based on many factors with this including the size of an organisation, the sector that an organisation works in, social willingness, and the complexity of the product being developed [30]. Accompanying this, there are many methods that can be used to assist in the adoption of accessible practice [60] with this including raising awareness of accessible policies and guidelines [8, 12], the development of tools to assist in accessible design [25], coordination with the disabled community [11], and conducting accessibility self assessment [15]. However, little is known about the resultant methods that developers use to implement accessibility based on the above.

In this paper we present findings from a workshop that was created to understand developers' current perceptions of accessibility and what methods they use to deal with accessibility challenges in their daily practice. We also examine what tools and assistance developers believe they require in the future to make their products more accessible and what techniques they perceive to be key for developing accessible services. In doing so we make the following contributions:

(1) The structure and framework for a workshop that can be used to evaluate designers/developers' understanding of accessible practice and also as a prompt to further discuss accessibility issues within an individual technology development domain [10],
(2) Our analysis from carrying out this workshop with 197 participants over a 1 year period where we discuss common perceptions of accessibility and how this is informing software design and development.

2 RELATED WORK

Defining Accessibility

Two models often used when discussing accessibility are the medical and social models of disability. The medical model states that people are disabled by the impairments that they have while the social model focuses on the principle that people are disabled by society and their surroundings [36]. A key factor in the social model of accessibility is the understanding that anyone can take part in an activity given the right circumstances [26]. Accessibility can also be thought of as encompassing Permanent, Temporary, and Situational Impairments that an individual may encounter [33]. When developing accessible applications care must be taken to understand the diverse contexts and needs that users may have [9]. Accessibility factors that can be considered when creating digital artefacts consist of the following aspects [54]:

(1) **User Impairments**, where barriers exist due to issues in body function or alteration in body structure.
(2) **Activity Limitations**, where barriers exist with difficulties in executing activities.
(3) **Participation Restrictions**, where problems exist in taking part in activities due to issues such as discrimination.
(4) **Environmental Factors**, where facilitators or barriers in the environment impact on the user.
(5) **Personal Factors**, where aspects such as motivation and self-esteem can influence an individual's participation.

An alternative to accessibility models that can be used to examine issues in this area lies in categories that can be used to group accessibility areas. Accessibility tool kits have been used to examine interaction and an example of this (taken from [1, 24]) is shown below.

- **Visual**: Relates to blindness, visual impairment, and Colour Vision Deficiency.
- **Cognitive**: Relating to issues of memory, fluid intelligence, attention and emotivness.
- **Physical**: Relating to fine and gross motor skills.
- **Communication**: Relating to issues of hearing, talking, reading, and expression.
- **Emotional**: Relating to issues of anger and despair.
- **Intersectional**: Relating to where issues intersect.

It is unclear to what extent developers understand the various accessibility areas that exist and what challenges these areas then create. This motivates our initial inquiry in this work where we attempt to discover **RQ1: What is the developer awareness of permanent, temporary, and situational accessibility challenges?**

Current Methods of Implementing Accessibility

It is estimated that 2.5% of CS faculty staff and 50% of institutions teach accessibility in the United States [50]. Whilst accessibility is most commonly taught within specific modules/courses it can can also be fully integrated throughout the CS curriculum and not taught as a separate topic but instead maintain a presence in all aspects of teaching [58].

A common method that is used within the teaching of accessibility is to promote empathy in developers [21]. For example, having students use screen reader software has been used as a method to increase the appreciation of web accessibility [14]. However, it has been shown that exposing developers to the specific challenges that people with disabilities face does not give developers enough knowledge to address accessibility barriers and that education must include more than just this single aspect [32]. Issues exist in the approaches that can be used to incorporate accessible topics, the sharing and development of resources, and the overall assessment of accessibility [45].

Many tools exist that assist developers in assessing the accessibility of applications [27, 39] but the usage of these tools applies a retrospective look towards an application and does not promote accessible thinking from the beginning. This model is echoed within online courses that teach accessibility where a focus is placed on the evaluation of accessibility rather than the implementation of accessible methods [19]. It is possible to alter web editors' software to give developers empathy information to assist with developing accessible sites. However this method places a focus on understanding accessibility issues rather than guidance on methods that can be used to solve them [38]. A key issue in the teaching of accessibility is in a perceived lack of techniques that can be used [59] and it is a common challenge to hire developers that have the accessibility knowledge and experience that is needed to build inclusive products and services [29].

An issue exists in not knowing the techniques that developers use to create accessible products. Developers may understand what makes a product accessible but not how this can be achieved. This acts as motivation for our second research question in this work where we attempt to understand **RQ2: What techniques are used by current developers when creating accessible applications and what information do these developers perceive that they require to improve their practice?**

Importance and Difficulty in Current Practice

Accessibility can encompass technical, operational and psychological aspects within artefact design [4]. This complexity creates a difficulty in accurately determining if a given system is accessible or not. Additionally, the testing of systems to determine whether a given accessibility level has been met can lead to different outcomes between accessibility auditors due to the complexity of accessibility guidance [6]. The *A, AA* and *AAA* categorisation used within WCAG 2.1 [8] places the most important accessibility features within the *A* category and labels these as essential. *AA* and *AAA* levels, whilst still important, are often viewed as additions. The accessibility of websites (when measured at a WCAG 2.0 *A* standard), for example, has been shown to have improved over time with the biggest improvements being seen in governmental sites but it is not known whether these changes are down to an increased *want* for accessibility [49] or simply better developer tools and coding practice [23].

Game developers often place a level of importance in implementing accessibility features that would be used by the largest group of users [43]. The Able Gamers Accessibility Guide uses a *good, better, best* model to describe how accessibility can be implemented [18]. For example, when examining visual game accessibility it is suggested that "changable text colour and font size" are Level 1 (Good) tools, "customised fonts and UI recolouring options" are Level 2 (Better) options, and "speed adjustments and text to speech input" are Level 3 (best) components. This is very similar to the approach taken in Hamilton's Games Accessibility Guidelines [22] where guidance is categorised into *basic, intermediate, and advanced* categories. In this example the focus is placed on difficulty of implementation rather than importance.

This motivates our final research question in this work where we investigate **RQ3: What methods of implementing accessibility do developers perceive to be important and is this related to the perceived difficulty of implementing these aspects?**

3 A WORKSHOP ON DESIGNING FOR ACCESSIBILITY

We present a workshop entitled *Designing for Accessibility*. This workshop was designed to act as a stimulus to prompt developers to discuss accessibility challenges that exist when developing digital services. The purpose of this workshop is to highlight the different accessibility challenges that exist when creating digital artefacts. Digital services are varied, and include web applications; mobile apps; desktop software packages; video games; and more. Accessibility is important in all of these areas and we therefore designed this workshop to be technology independent. Whilst this has the negative effect of decreasing the number of specific methods that can be used for a given digital platform it has the benefit of increasing the potential breadth of the data collected. The workshop is split into three different activities and features tasks that allow participants to explore what is meant by accessibility, to reflect on their own methods for creating accessible products and services, and then to look to the future for what additional support they require in order to improve accessibility further. The overall aims of the workshop are based on our previously defined research questions and are:

(1) To understand what participants' perceptions of accessibility areas are.
(2) To interpret participants' awareness of designing for accessibility issues.
(3) To learn what participants' beliefs are surrounding the importance of accessibility.

Workshop Activities

Activity 1 - Permanent, Temporary, and Situational Impairments. The first activity in the workshop is designed to allow participants to broaden their current understanding of what constitutes an accessibility challenge. This was accomplished through evaluating accessibility issues that are permanent, those that are temporary, and those that are situational. Participants were asked to come up with sample scenarios for each of these areas and to then complete a grid that references accessibility categories. This encourages participants to think about accessibility challenges in a more inclusive sense and situates the problems associated with these in a context that is relevant on a day to day basis. Figure 1 (Left) shows a completed grid that was developed by a participant during one of the workshop sessions. In this activity, we aim to examine what similarities (if any) exist between permanent, temporary, and situational accessibility challenges that participants discuss. We attempt to discover if the challenges that participants discuss surrounding situational accessibility issues match up with the challenges faced by people with disabilities.

Participants are prompted to discuss the different areas that they had described with other participants in the workshop and to expand on their definitions if they felt it was necessary. We use the technique of participants writing their initial thoughts on paper to assist in getting participants to

then discuss issues [40] and also to assist in later analysing participant views. Once participants had written down their initial thoughts on paper they participated in a round table discussion where they were encouraged to compare and contrast their thoughts with others in the workshop. In order to assist participants in coming up with items for each of the accessibility areas, descriptions were provided to allow participants to more easily reflect on individual aspects. We have previously covered these descriptions within the Related Work (Defining Accessibility) part of this paper.

Activity 2 - Current Awareness of Accessibility. The second workshop activity was designed to encourage participants to explore their current awareness of accessibility issues and what methods can be employed to solve them. These methods might include education, policy and legislative requirements, or the development of technical tools. Participants were first asked what user requirements they knew about that are necessary to create accessible digital products for each of the previously described accessibility areas, and then where they learned about these requirements. Participants were also asked how they currently deal with creating digital products that resolve their identified accessibility issues and what gaps, if any, they were aware of in their knowledge that impacted on their ability to do this. Finally participants were asked to suggest ideas for what they would require in order to improve their practice in each of the different accessibility areas. This final question was kept open to give participants the ability to suggest a wide range of ideas and to not pigeonhole them into a specific area (e.g. additional guidelines or development tools). This activity was carried out in a similar fashion to that of Activity 1 where participants were first given a matrix worksheet to fill in and were then asked to discuss their ideas and opinions with others in the workshop. An example of a completed matrix sheet is shown in Figure 1 (Center).

Activity 3 - Developing Core 'Problem Areas' and Solutions. In the third workshop activity, workshop attendees were asked to pick one of the six accessibility challenge areas they have identified to analyse more deeply. At this stage participants began by evaluating their previous matrices and are then asked to pick three activities related to an individual research challenge area that are:

(1) Currently implementable by everyone.
(2) Implemented by some people.
(3) Not implemented, or not capable of being implemented.

These activities were then written on a traffic light (i.e. red, yellow green) colour coded post it notes showing what category they belong to. Alternative labelling systems were given to participants that could not easily tell the difference between the colours provided. This created a total of 9 post it notes (3 activities x 3 implementation prevalence categories) per workshop group. In the final part of the workshop participants were asked to place their post-it notes onto an implementation graph to visually show how easy/difficult items are to implement, and how important these are. Participants were asked to reflect on their decisions and to discuss why they had chosen the positioning for individual items. An example of this activity is shown in Figure 1 (Right).

Roll Out

Over the period of 1 year this workshop was performed with 197 participants. Participants had a range of backgrounds and included university level students that were studying a range of computing discipline subjects (n = 110) and developers and designers from companies in the local area (n = 87). Students were openly recruited from within the university and developers/designers were recruited through pre-existing contacts that exist within the institution along with a range of social media and email adverts. Our inclusion requirements for the workshops were that participants should have been involved in the design and development process of a software system in the past and should have thought about accessibility during the process of doing so. During this work no participants self-identified as having a disability. We do not see this as a weakness in our work but more as a reflection of the recruitment pipeline within industry/academia and how it ill-serves people with disabilities. Our workshops focused on people that had made it through this pipeline, unfortunately people with disabilities had already been filtered out.

All students that took part in the work reported that they were studying on a range of digital technology programmes with this ranging from first year through to masters level. All participants reported that they had been involved in creating a number of software applications (either as a developer or designer) over the past 12 months. Professionals and students participated in separate sessions. Professional workshops had 8-12 participants per group with discussion groups of 3-4 participants. Student workshops had 15-20 participants per group with discussion groups of 3-5 participants. Workshops lasted for between 90 minutes and 2 hours, initial writing activities were limited to 30 minutes per workshop with the majority of time being spent on discussion. All workshops took place within the university campus and lasted between 90-120 minutes. Participants were not reimbursed for their time and the work was approved by our universities' ethical committee. Materials for this workshop are available online [10].

Data Analysis

During analysis, completed sheets from workshop sessions were used as the main method of interpreting research data. In Activity 1, all sheets were transcribed into a digital form

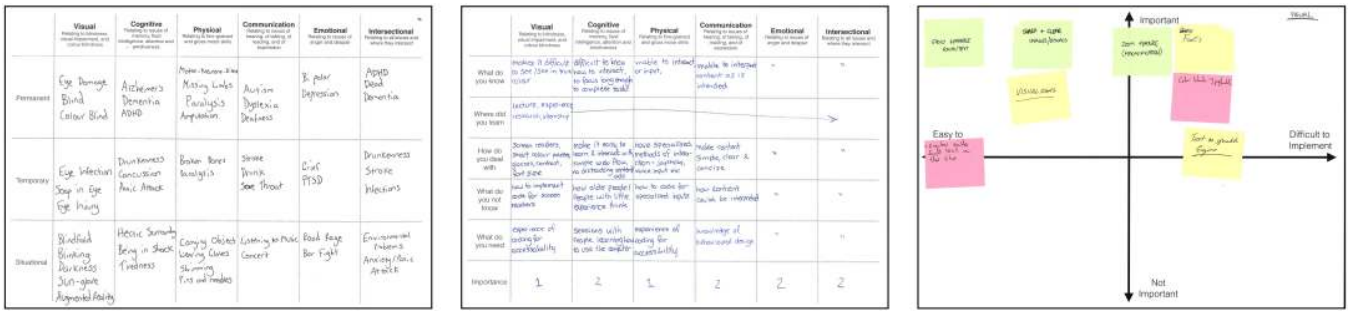

Figure 1: Sample Participant Sheets. Left: Activity 1; permanent, temporary and situational accessibility. Center: Activity 2; understanding of accessibility, current practice, and perceived needs. Right: Activity 3; methods of facilitate accessibility, prevalence, importance, and difficulty to implement. Further information is available in Results section.

on a per cell basis (3 accessibility types x 6 accessibility areas). For each cell, data was sorted into alphabetical order and then a count created for repeated terms. A card sorting activity was conducted on unique terms to assist in categorising elements. In Activity 2, data was categorised within accessibility areas. Individual points were, again, counted and resultant data visualised within mind maps for further analysis. In Activity 3, all sheets were transcribed into digital form with coordinate values (importance and ease), activity prevalence, and activity description being used. Data was sorted according to the accessibility area that was being discussed. Visualisations of data were created to overlay participant data on individual graphs for each accessibility area. We then examined these visualisations to determine common areas.

4 RESULTS

Permanent, Temporary, and Situational Impairments

In the first workshop activity, participants were asked to consider examples of different accessibility challenges that people may face. We asked participants to fill this in on 3 (permanent, temporary & situational) by 5 (accessibility areas) grid and to focus on the breadth of different challenges that people may face. We had indented for the design of the first workshop activity to remove the concept of otherness [35] and to act as an exercise where participants would see commonalities between permanent accessibility areas and those that are temporary/situational. Unfortunately, the results from this show a mis-match between accessibility areas and therefore led us to conclude that developers struggle to empathise with accessibility issues and subsequently design interactions for this demographic.

Visual Accessibility. Participants expressed a variety of perspectives relating to permanent and temporary visual impairments that exist and included a large number of examples within this first activity. Participants discussed permanent visual accessibility issues such as *astigmatism, blindness, cataracts, colour-blindness, and near/far-sightedness.* They also discussed temporary visual accessibility issues with these relating to health related matters (e.g. *eye swelling, eye surgery, eye infection, eye-patch, glaucoma, migraines, tunnel vision*), user situations (e.g. *blinking, closed eyes, darkness, drunkenness, forgotten glasses, sleep deprived*) and other external factors that related to multitasking and looking at multiple sources of visual information at the same time (e.g. *walking whilst using phone*).

When examining the situational impairments that exist there was a common theme of brightness in surroundings from participant responces (e.g. *bad lighting, blindfolded, bright environment, darkness, flashing lights, sun in eyes*) and a lack of issues relating to visual acuity, contrast sensitivity, field of vision, and colour vision [56]. This suggests a gap in how our participants may personally relate to these issues and that more work in developing user empathy [44] in this area may be beneficial. Participants also discussed temporary impairments relating to the use of technology and how new devices such as *virtual and augmented reality* also bring visual accessibility challenges due to hardware limitations.

Cognitive Accessibility. There are a number of areas that can affect individuals' cognitive function. This include aspects such as reasoning, memory, language, perception, speed, and knowledge [55]. Participants described a large number of cognitive accessibility challenges with a broad range of aspects being covered within permanent, temporary, and situational areas. Participants discussed permanent cognitive issues such as *ADHD, Alzheimer's disease, amnesia, autism, dementia, Down's syndrome, and short-term memory loss.* Temporary cognitive impairments that participants discussed mostly focused on a number of health-related issues (*e.g. concussion, dizziness head trauma, migraine, panic attack, stress*) and recreational activities (*e.g.drug usage, alcohol consumption, hangover*). Similar to our results within the area

of visual accessibility, the situational issues that participants discussed here only focused on a subset of areas that can affect user cognitive function. Participants described a limited number of situational cognitive impairments, with this focusing on multitasking type activities (e.g. *driving*) and environmental factors (*e.g. loud environment, mental fatigue from hot climate, sensory overload*).

Physical Accessibility. Physical accessibility can be broadly categorised under two headings; muscular-skeletal disability (relating to issues with body parts), and neuro-muscular disability (relating to issues with the nervous system). When examining physical accessibility, participants focused on permanent situations where movement has been drastically hindered or removed from an individual (i.e. gross motor ability), and not on areas where physical ability had been hindered in a way that effected small movements (i.e. fine-grained motor ability). Examples given in this category included *broken bones, motor neuron disease, muscle degradation, multiple sclerosis, paralysis, and Parkinson's disease.*

Temporary physical impairments that were discussed focused on the effects of being involved in accidents (e.g. *broken bones, arm(s) in cast*), consumption of large amounts of certain foods/drinks (e.g. *sugar, coffee, alcohol*), and situations involving *numb limbs, hand cramp, and pins and needles.*

Situational impairments that were discussed in this area focused on activities where physical limitations take place due to multi-tasking (e.g. *driving, eating, carrying objects*). Some limitations that were discussed also focused on limitations that were due to an activity (e.g. *wearing gloves, confined spaces*) but this was not discussed by many participants. Similar to before, a mismatch exists between the situational challenges that participants discussed and the muscular-skeletal / neuro-muscular disabilities that exist. Developing a better understanding of physical accessibility limitations for developers may be beneficial in the future to assist in increasing understanding in this domain.

Communication Accessibility. Issues relating to verbal and written communication were highly prevalent when participants were discussing accessibility challenges in this area. When examining permanent communication accessibility, learning difficulties relating to reading and numbers (e.g. *dyslexia and dyscalculia*) were discussed along with disabilities relating to communicating directly with others (e.g. *autism, deafness, speech impediment and stutter*). There was a slight tendency to focus on verbal communication methods within temporary and situational accessibility areas, however this is mostly likely due to the large crossover between visual and communication accessibility that was examined earlier. Participants discussed temporary communication accessibility issues that related to ill health (e.g. *ear infection, tonsillitis, throat infection, eye infection, hiccups*) and environmental factors (e.g. *driving whilst on phone, visiting dentist, bee stings*). Situational communication accessibility challenges that were discussed related to noise (e.g. *fire alarms, concerts, football game, crowded environments*), visiting new geographic environments (e.g. *foreign language, accents*), and reading information (e.g. *small text, bad handwriting*).

Emotional Accessibility. Overall participant response to examining emotional accessibility was poor. For the majority of participants this was an area that was either left blank or contained only one item within the initial matrix worksheet exercise. This was true for all three of the accessibility areas (permanent, temporary, and situational) and is worthwhile considering for examining future areas of work. A small number of participants discussed permanent emotional accessibility issues with this including areas such as *ADHD, Asperger's Syndrome, autism, bi-polar, and depression.* Temporary emotional accessibility issues that were discussed included life events (e.g. *death of loved one, grief, heartbroken*), and health-related conditions (e.g. *concussion and panic attacks*). Situational emotional accessibility issues focused mostly on events and situations where emotions can be effected with this including *driving, using technology, and attending sporting events.*

Accessibility Awareness and Future Needs

In the second activity participants were asked again to focus their thinking around the five identified accessibility areas. They were asked to describe the current methods that they use within software design when dealing with issues in these areas, what information they do not know, and what they would like in the future. In describing the areas that participants discussed we have grouped these using the previously described accessibility model but wish to stress that many of the issues are multi-dimensional and can fit into multiple areas (e.g. dyslexia can be described as a visual, cognitive, communication, and emotional issue).

Where Accessibility is Learnt. Participants gave a number of common situations where they have learnt about accessibility. Within this, no participants gave the exact same answer and it is clear that a wide variety of sources are used to gain information about accessibility. However, within this there is a lack of information regarding how to design accessible products and instead a focus is on a general overview of what accessibility areas are. Participants reported how they learned about accessibility through traditional learning formats (e.g. *university lectures, school, research, work, books*), discussions with others (e.g. *charity events, analysis of others, health care professionals, life experience, observation, told by person affected*) and through *software applications that simulate accessibility issues.*

Visual Accessibility. When discussing visual accessibility participants comments focused on two areas: accessibility for blindness and visual impairments (i.e. no vision), and accessibility for colour blindness (CVD).

Blindness and Visual Impairments: When designing interfaces for users with visual impairments, participants described methods such as larger text, larger buttons and having items in close proximity to each other. In this area, participants also mentioned a large number of activities that they assume users carry out to provide their own accessibility assistance with this consisting of text to speech engines (including OS level tools such as Narrator) and magnify options. However, participants also commented that they did not know the best way to implement methods for users to take advantage of these tools within their development and also what the impact of increasing font and button size would have on the overall experience of using a specific application. In addition to this, participants described how they do not know how different visual impairments may affect users and what the resultant coping strategies are that users may develop when interacting with technology. Participants believed that they required more training in this area with tutorials on how to incorporate accessibility aids, testing of readability, and feedback from visually impaired individuals being some of the most commonly requested for items. However, when questioned on this further, participants did not know what services existed to enable visually impaired users to assist in giving feedback. Participants also believed that more information on different types of visual impairments would assist them in developing more visually accessible applications in the future.

Colour Blindness (CVD): When designing products for users that are colourblind one of the main considerations that participants discussed was the use of colour schemes. Participants mentioned how different colour schemes could be used, colour schemes could be simplified, or that colour schemes could be changed to include a larger contrast between colours. Some participants mentioned that items such as third party browser extensions should also be used to compensate for any CVD accessibility issues. Participants mentioned that they were not comfortable in knowing which colour schemes would be the best to use, which colours individuals may struggle with, what the correct contrast ratios are to assist in designing CVD accessible interfaces, and also the different types of colour blindness that exist and how this effects end users. Participants stated that in order to move forward in this area they require information sources on providing suitable colour options, methods that can be used to simulate colour blindness, feedback from individuals with colour blindness in testing, browser extensions that can assist in development (e.g. [51]), and methods that can be used to change colours.

Cognitive Accessibility. When discussing cognitive accessibility participants comments focused on accessibility related to attention and memory issues.

Attention: When designing interfaces to deal with attention issues participants commented that short precise information should be used and that easy to understand instructions should be present. They felt that non-cluttered interfaces and simplified text with short paragraphs were the best methods that could be used to aid in this area. They also discussed that breaking information into manageable chunks and using images could be used to assist in keeping the user attentive. However, participants didn't know what exact effects specific attention issues would have on a user and what levels of severity this includes. They felt that in order to fully understand issues in this area they would require user testing to be carried out and would also need extra time to implement improvements that would assist users in this domain.

Memory Issues: Participants believed that they could assist users with memory issues by creating interfaces that contained simple, non-complicated text with properly labelled and identified pages within an application. Tactics such as showing users their previous interactions and location (e.g. breadcrumbs) were other techniques that participants believed were beneficial in this area. They also discussed how clear explanations and aspects such as hints and tips within a help system were methods that could be used to assist in creating accessible interfaces. Participants commented that they were not aware of aspects such as how often individuals should be reminded of their location within applications (or the best way to accomplish this), and also what elements of application design are difficult to remember. They discussed how they need information regarding these aspects in order to create better applications in the future but did not describe any specific tools that they believed would be beneficial.

Communication Accessibility. When discussing accessibility surrounding the area of communication participants comments focused on hearing loss and also language based cognitive disabilities such as dyslexia.

Hearing Loss: When discussing methods that can be used to assist users with hearing loss, participants responses focused largely on situations where users would have no hearing ability at all and not on areas where slight hearing loss may occur. Participants discussed how they currently dealt with issues in this area by relying on visual interactions, high quality and clear text, and clear visual prompts. They also discussed how using subtitled videos and translating videos and instructions into a textual alternative could be used to create more accessible media content. Participants discussed how they did not know the impact and effectiveness of changes that they were implementing in this area

and how communication cues could be created in a manner that would be useful for those that needed them. They also expressed concerns in how to effectively design clear visual prompts that end users would find useful. Participants main ideas for what is needed in this area focused on the use of simulation with several participants mentioning aspects such as testing with sound off or wearing ear plugs to test content. Other participants believed that they required more guides and information on how current auditory accessibility techniques (e.g. subtitles) worked and could be successfully implemented within their own work.

Dyslexia: Participants discussed how using larger text, easier to read fonts, and clear language were some of the main methods that were used when designing dyslexic friendly interfaces. They noted, however, that they didn't know how different individuals that have dyslexia are affected and what particular aspects each individual has difficulty in understanding within an application. They also expressed concerns regarding the impact and effectiveness of any changes that they make to interfaces and how this would benefit users.

Physical Accessibility. When discussing physical accessibility issues, participants focused on the areas of limited/low mobility (i.e. users that are able to use a traditional input device) and no mobility (i.e. users that require specialist devices).

Limited/Low Mobility: When discussing methods that can be used to assist users with limited/low mobility, techniques currently used by participants focused on alterations that can be made to their own design practice but also a reliance on third party and OS level adaptions. Participants discussed techniques such as only including a limited number of interactive objects, creating simpler layouts that make items easier to reach, and using larger buttons that will reduce error rates. Additionally, techniques such as having touch targets in easily accessible places (e.g. important buttons on the lower half of a (mobile) screen) were mentioned. They also commented that alterations to mouse sensitivity, speech control and alternative input types are techniques that they believed users themselves would employ. Participants were not aware how successful current accessibility solutions in this area, and that they did not know the best way to test the physical accessibility of applications. Participants made additional comments about the one handed use of mobile phones and mentioned that they did now know how to design for different phone screen sizes to assist in one handed operation, and if the hand that a user was currently using should be used to influence the design of a mobile interface layout. They also mentioned that they were unsure what an individuals expectations are when organising content and what sort of impact the changes that they could implement would have to assist an end user. Participants believed that they required assistance in the future with the placement of items, and information on what features could be implemented in order to assist accessibility in this area.

No Mobility: Participants described a very low number of techniques that they use to design for users with no mobility with aspects such as easy interactions, alternative control methods, and simple navigation structures being mentioned. Participants commented that they did not know the current solutions that are used to assist with physical impairments and what the different ranges of issues are that people may face. They also discussed how they were not aware of how many individuals are affected by these issues or what percentage of these individuals use assistive aids when using technology. Participants discussed how they would like to find out more about what features can be implemented to make applications more physically accessible for users and what sort of testing could be carried out to assist with this.

Methods to Facilitate Accessibility

In the third activity participants were asked to pick an single accessibility area from the ones previously discussed and to pick activities or techniques that are used to assist users in this domain. Participants ranked these activities in terms of there perceived prevalence, importance, and difficulty.

Visual Accessibility. Many participants chose the visual accessibility area to focus on in this third activity and a large number of techniques were discussed between the workshop sessions. Participants felt that techniques such as using the alt attribute within web development (and other platform equivalents) were very prevalent and of high importance. They also described how selecting easy-to-read fonts, the use of magnification options, and system brightness settings were all common methods that can be used to assist in visual accessibility. Participants also discussed elements that had a lower level of prevalence. This included adapted colour settings (including dark modes and methods to assist with CVD), text-to-speech engines (including audio descriptions), and accessible responsive design. Finally, participants discussed elements that they believed were important to assist with visual accessibility but were not prevalent. This included aspects such as voice commands/navigation, alternative methods of conveying colour, digitally correcting optical issues. Participants discussed some of the reasons behind low levels of prevalence for these techniques and issues such as difficulty in implementation and not being aware of how implementation could occur were key determining factors.

Communication Accessibility. When discussing techniques that are used to assist in the area of communication accessibility, participants believed that techniques that were simple to accomplish were generally the ones that had the highest level of prevalence. Techniques such as subtitles, using recognisable icons, and simple typefaces were all discussed

as things that can be done to improve accessibility with a low level of difficulty. Items such as the implementation of text-to speech, auto-correcting, and using suitable plain language were described to have moderate levels of difficulty and implementation prevalence. Finally, techniques such as developing built in colour overlays, neural interfaces, and speech-to-text interpretation were all described to be difficult to implement and therefore had low levels of prevalence.

Physical Accessibility. Only a small number of groups chose to discuss physical accessibility. A large number of the techniques that participants believed were common in accessible design in this area focused on designing for one handed mobile usage; operable with one hand, important links reachable by the thumb, adaptive design patterns, use of spacing and white space. Participants discussed how these techniques were all of high importance and could be achieved with only a small level of difficulty. When discussing techniques that had lower levels of prevalence, participants discussed aspects relating to alternative input devices with this including eye-tracking, speech-to-text, and neural control. Participants discussed how these methods had a higher level of difficulty attached to their implementation.

Cognitive Accessibility. Many participants discussed methods that could be used to assist in developing digital products that cared about cognitive accessibility with the majority of these focusing on designing for areas such dyslexia (also encompassing communication accessibility) and designing for older adults. Participants discussed techniques that they believed were very common and considered approaches such as using consistent application layout, validation for any input, and help guides as methods that could be used to assist users. Participants also discussed elements that, whilst important, were not as prevalent and this included a large amount of alterations to products to personalise the overall experience. Changes included alterations to colour, interface, language complexity, help offered, and content organisation. Participants explained that whilst these methods are important, they are also very difficult to implement in terms of determining the needs of a specific user and also in how these implementations would then be achieved.

Emotional Accessibility. Very few workshop groups decided to focus on emotional accessibility, with techniques that were discussed mostly focusing on methods that would reduce stress and anger. Participants discussed how methods such as low downtime between interactions, built in instruction systems, and user personalisation were all methods that could be used to assist with emotional accessibility. Participants suggested that the majority of these techniques were prevalent in applications and are things that they may expect to see to support users.

5 DISCUSSION AND FUTURE WORK

Empathising with Accessibility

RQ1: What is the developer awareness of permanent, temporary, and situational accessibility challenges?

Previous work has discussed how it is important to include representative users when conducting research and that an induced situational impairment does not constitute the same experience as a permanent disability [48]. However, temporary and situational accessibility challenges can be used as a method to create empathy within developers [46] and also exists as an area where design challenges exist due to the increasing range of situations where technology is now used [52]. In our work we have shown that developers are aware of a large number of permanent challenges that users face within the areas of visual, communication, physical, cognitive, and emotional accessibility. However, it is worth noting that a limitation in this work is that we did not test participants knowledge of the *characteristics* associated with individual disabilities (e.g. what are the vision problems associated with being short-sighted?) and therefore cannot state that participants are aware of the implications of individual disabilities, but only that they are aware of technical names that are used. This is an important aspect to consider as we showed that there was often a mismatch between the characteristics associated with permanent accessibility challenges that participants discussed (e.g. short-sightedness and glaucoma both effect visual acuity) and the characteristics of situational accessibility challenges that were discussed (e.g. dark environment and sun-glare on screen are effects on visual brightness). Whilst this mismatch could be down to participants not being aware of any situational impairments that are similar to certain disabilities, it also suggests that developers may not fully understand the challenges that are faced by users that have disabilities. In turn, this may lead to a situation where developers will struggle to design new accessible interaction techniques in the future.

We suggest that future work in this area should focus on developing ways for users to better empathise with accessibility challenges. Current methods of accomplishing this are through physical products such as the Cambridge Inclusive Design Toolkit [7] and browser plugins such as ChromeLens [2], NoCoffee [31], and Funkify [28]. Steps should be taken so that developers can better understand accessibility issues and design interactions that take this into account.

Understanding Technology Usage Patterns

RQ2: What techniques are used by current developers when creating accessible applications and what information do these developers perceive that they require to improve their practice?

In our results we have shown that our participants were aware of a large number of techniques that can be used

to assist in making accessible applications. However, there was a clear lack of knowledge on the best ways that these techniques can be implemented and what the overall effect of implementation has on increasing accessibility. Participants highlighted the need to include testing with people with disabilities when developing products but also that they were unsure how to best go about this and what support exists to enable this to occur.

Participants showed a mix of attitudes towards accessibility with a range of opinions on who is responsible for enabling people with disabilities to interact with technology. Participants discussed how this was a mixture of software developers, operating system and hardware manufacturers, and also people with disabilities themselves.

Methods such as including representative users in the teaching of CS programmes [13] gives a first hand account of accessibility issues that may face a given population. We suggest that future work in this area should focus on methods that can be used to include people with disabilities in the training and development of accessibility teaching and also within the testing of digital products.

Simple Methods of Accessibility Implementation

RQ3: What methods of implementing accessibility do developers perceive to be important and is this related to the perceived difficulty of implementing these aspects?

There are many resources that are available for developers that can assist in creating accessible content. Examples of this include techniques for implementing accessible web content [57], guidance for specific content creators [3], and guidance for creating inclusive design patterns [41] and inclusive components [42]. In our work we were unable to determine what broad aspects of accessible design our participants deemed to be most important across the entire range of accessibility areas covered. This is to be expected as accessibility is an area in which one-size-fits-all design does not work [16, 17]. However we have given details regarding specific examples of accessible implementation that participants believed were important within our results. We were able to show that the implementation of accessible components is more likely to happen if developer perceive this to be easy to accomplish. We suggest that future work in this area should look at lowering the barrier to entry for developers that wish to create accessible products.

It has been argued that part of the increase in web accessibility has been down to improved code practice and not a shift in developer attitude [47]. If true, we suggest that more work should be conducted on creating component and software libraries where accessibility is 'baked in' from the beginning and present within any example code. This is already beginning to occur with libraries such as Bootstrap [37] including WAI-ARIA components within a number of interactive element examples. We suggest that more work should be carried out to promote this type of exercise.

6 CONCLUSIONS

In this paper we have presented the framework for a workshop that can be used to discuss digital accessibility. We have run this workshop with 197 developers/designers and digital technology students and have made the materials for this workshop available online.

Participants exhibited an understanding of accessibility challenges that exist within the categories of visual, cognitive, physical, communication, and emotional accessibility but there are gaps in participants knowledge of situational accessibility challenges. For example, when participants were discussing situational accessibility challenges relating to visual accessibility the main theme that was apparent related to brightness but very little examples were given relating to contrast, saturation and focus. We suggest that these gaps are linked to areas where **developers struggle to empathise with accessibility issues and subsequently design interactions for this demographic**. We have also shown that there is no one singular source of knowledge that our participants have used to develop their accessibility practice, and have suggested that in order for the overall standard of accessibility to improve an effort must be made to promote learning resources in accessibility implementation and not accessibility assessment.

Participants were able to give details of methods that are used to create accessible interactions in a number of different areas. However, it was clear from participant comments that there is a lack of understanding of the techniques that people with disabilities currently use when interacting with technology. Participants discussed how this **lack of understanding in how a person with disability uses technology impacts on how technology interactions are designed**.

Finally, we examined the techniques that participants found to be important when developing accessible products. We saw that a relationship exists between the perceived difficulty of an accessible method and the prevalence of that method within software design. We were unable to see any relationship between perceived difficulty and importance and suggest that **developers require easy methods of implementing accessibility features in order to increase overall technology accessibility**.

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