Build Me a Ubicomp: Bespoke Ubiquitous Accessibility in Live Television Production Environments

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Abstract. Live television production remains driven by platforms which are modelled on systems developed before digitised technology, with specialized components and systems which were designed and developed entirely for a non-disabled plurality. The effect of this is that skilled production staff who become disabled are unable to continue within their roles, in many cases becoming forced leaving the television industry entirely. This investigation explores the possibility of using bespoke Ubiquitous Computer systems to circumvent existing practical and strategic restrictions upon reasonable adjustments in production roles. To make our findings, we draw upon twelve criticality-informed interviews with both production specialists and assistive technology experts, and an ethnographic study conducted in a television production environment. This investigation had a particular emphasis upon what practices are (legally) reasonable to adjust in a production environment, and thus allow the realistic targeting of adjustments to particular combinations of roles and disabilities. Through doing so, we describe a space for re-configuring existing user interfaces, practices and workflows in the production environment, introducing a new paradigm of Bespoke Assistive Technologies (BAT's). We also discuss the novel implications of Disability Discrimination Law and Ubiquitous Computing that arise from our investigation.

Keywords. Accessibility, Assistive Technology, Bespoke Assistive Technology Disability, Production Environments, Television, Ubiquitous Computing, Wearable Computing, Video, Editing

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1 INTRODUCTION

Live television production is underpinned by a diverse range of dedicated and highly skilled craft professionals who work within a complex and well-proved production workflow to deliver broadcast content. A range of professional roles, including Camera Operators, who capture content in the field and within the studio to Video and Graphics Editors and those who work in the Studio Gallery as Directors, Vision Mixers, Technical Managers and Sound Operators. These roles are notable for being demanding in at least one or more facet of human performance, as well as relying upon personal experience and expertise that is difficult and costly for organizations to replenish.

We consider what happens if one of these skilled production staff members acquires a disability or impairment which affects their role. In practice, this is a highly challenging situation relative to other employment opportunities; not only are these roles greatly demanding in terms of their human performance requirements, but production systems are not necessarily developed with accessibility in mind. Existing interfaces, and systems and their associated roles are primarily designed around a plurality of those who are non-disabled. This is despite the fact that many of these roles are expected to be fulfilled on a long term basis (a career), and the increased likelihood of existing operators becoming disabled due to the nature of these roles themselves. Nor is it possible – outside of some narrow cases, (primarily body braces for camera operators who have lost function in one arm) – to purchase accessible interfaces to existing systems that might enable them to continue in their role.

Given the specialist nature of these roles, the fact that it is rarely possible to purchase specific assistive technologies off the shelf is unsurprising. The result is that an operator who becomes substantially disabled is unlikely to be able to continue in their current role at the required performance standard using existing equipment. The effect is to conclude their career in the television industry, and having no immediate alternative livelihood.

If it is impossible to purchase an assistive technology, might it be possible to *build* one, instead? The recent proliferation of wearable augmented reality systems, the introduction of new approaches towards fabrication (especially 3D printing) and the emergence of a DIY agenda in respect of assistive technology would on the face of it appear to be a reasonable route forwards. However, this must be balanced with the strong emphasis upon risk and reliability that applies in respect to the production environment, as well as the significant health and safety concerns that arise in these sometimes uncontrolled environments.

We propose and validate a different approach to the DIY route which we consider to be more realistic in demanding environments such as production environments. Specific, those with recognized engineering competence deliver what we term *bespoke* assistive technologies (BAT's) which surpass the relevant requirements and standards, which – where appropriate to do so – will allow skilled staff who acquire disabilities to continue in them for years to come. In reality this is an extension of how certain types of assistive technology are ordinarily developed and assembled– for example most wheelchairs have custom built components specific to the individual user, but it is novel within the academic community to build one off assistive technologies in the wearable ubiquitous computing space for highly demanding workplaces.

Understanding this issue is methodologically challenging. The lack of assistive technology in production means that directly drawing upon the experiences of production staff is challenging. Whether or not a given technology should be deployed or developed is a legal question rooted in the duty to make reasonable adjustments[1], and this can sometimes require developing and deploying technologies that existing production staff members may disagree with or actively dislike. To derive the core competencies factors within these production roles we combine interviews and an observational ethnography to understand the detailed criticalities of each role, arriving at what are known in discrimination law as competency standards. We combine this with interviews with those already engaged in creating bespoke assistive technologies in other contexts, understanding how this approach can apply to this domain.

The methodological approach we develop here can be used in other challenging UbiComp environments that involve operator skill, thus creating a bespoke approach to assistive technology that applies far more widely that television production itself. Through this process, we provide detailed documentation of both the competency standards of live broadcast production environments (as they relate to four key production roles), and present examples of reasonable adjustments for professionals in these roles.

Considerable external factors, such as employment law, contribute to the implementation and uptake of these bespoke interventions, so we conclude with a treatment of our results from a disability discrimination law perspective. We conclude that in these circumstances, these interventions are 'reasonable adjustments' to explore – and depending upon specific solutions that arise (and their costs), implement.

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[1] These are otherwise known as Reasonable Accommodations in most jurisdictions outside of the United Kingdom.

1.1 Overview

This article is divided into several subtopics which whilst are interrelated, can also be considered separately. For the ease and convenience of the reader, we have provided the core highlights below:

Background (Chapter 2): This provides a summary of the core literature in this domain, including both live production environments (2.1) and ubiquitous assistive technologies (2.2). We also provide an outline of disability discrimination law (2.3).

Methodology (Chapter 3): We explain the overall methodological approach, including the restrictions placed upon us by the problem at hand. This includes our ethnographic observations (3.1.1), the interviews that we conducted (3.1.2. & 3.1.4), as well the development of assistive technology probes (3.1.3.). In addition, we briefly explain our analysis framework (3.2).

The Existing Space of Accessibility within Production Environments (Chapter 4): This chapter is in two parts; in the first part (4.1) we explain the general requirements and demands that generally apply to all roles within production environments. In the second part (4.2), we do the same, but for the individual roles we explore in this investigation, clustering the demands in respect of Physical (4.2.1), Cognitive (4.2.2) and Sensory (4.2.3) demands and requirements.

Reasonable Adjustments that can be implemented through Bespoke Assistive Technology (Chapter 5): The findings here are in three parts. In the first subchapter (5.1), we detail the core findings from our interviews with Bespoke Assistive Technology practitioners, which explain the process of developing these technologies, as well as their feasibility in challenging production environments. The second subchapter (5.2) explores with production experts how proposed bespoke assistive technologies could work in the context of television production. Finally, in 5.3, we offer a framework for how bespoke reasonable adjustments should operate in practise.

Disability Discrimination Law Implications of this Investigation (Chapter 6). We explain how this work can help create new legal obligations upon employers to make reasonable adjustments for employees in roles with high performance demands, drawing upon the bespoke approach to assistive technology advocated throughout this article.

2 Background

To frame our investigation into bespoke interventions for production crew, we first need to understand the existing state-of-the-art in

production technology, and how their use of technology can be applied to the DIY AT movement. To contextualize this in terms of appropriate employment practice, we also present a short background in discrimination law which underpins the development of such DIY solutions.

2.1 Live Production Environments

Although there is limited previous work within live production environments from a production perspective, work is delineated into three distinct areas: understanding the complexities of the work environment; augmenting existing workflows with emerging technology and practices; and leveraging technology for basic production tasks for end-users (rather than professional practice).

2.1.1 Understanding the Environment

Key in the landscape of understanding production environments is Perry *et. al.*'s [1] ethnography of a live sport production team working on location at an ice hockey game. Through close observation and discussion with the production team, they discovered that subtle communication techniques developed amongst the team in order to communicate personal intent and a shared understanding of the state of the production, using gestures for efficiency. This work highlights the key facets of a production workflow described by Zettl [2] which form the basis of most production environments. Additionally, outside of HCI, a variety of work has highlighted the complexities of multi-skilling [3] and practice based on self-reflection within TV production [4].

Continued advances in digital production technology [5] (aimed at improving production workflow, content delivery and improving quality) have had the resulting side effect that most 'physical' equipment used by production crew are effectively tangible controllers onto digital systems. The nature of a professionalised industry based on skilled experience with specific technology has limited the range of new interfaces available to control the underlying systems.

2.1.2 Interaction Technologies to Support Production

Amateur technology, in contrast supports innovation at a faster rate, and allows the development and testing of new interaction techniques and tools. A variety of examples support similar tasks and skills to those found in a professional broadcast environment.

Tangible interaction techniques representing media through physical objects (such as Siftables [6] and the tangible video editor [7]) have been demonstrated as a way of leveraging physical properties of objects and their spatial relationships to represent video playlists and simple

editing tasks. Similarly, alternative modalities such as gestures have been shown to be valuable for performing tasks with large amounts of video [8], and combined with speech input for performing more complex production tasks [9] and pen input for annotating video content [10]. Indeed, Vonolfen *et al.*. [11] have even demonstrated that it is possible to entirely virtualise the TV studio, removing some of the physical limitations of studio technology.

With these myriad new interaction techniques, bespoke production technology which responds to the specific needs of disabled users becomes a realistic possibility.

2.1.3 The Consumer Experience

Much effort is targeted towards the consumer experience of broadcast media [12, 13] highlighting the move towards mixed-mode consumption, second-screen interaction and mobile experience. Alongside these emerging practices an understanding has emerged in a movement towards pro-amateur production, now that consumer desktop PC's and mobile platforms have video editing capabilities. From this space has emerged pro-am interfaces which bring together new forms of interaction with existing production understanding. For example, Kirk *et. al.*'s (2007) [14] work with video and editing in the home explored consumers' interaction with video content in editing systems using touch and collaborative interaction technologies. The Bootlegger platform [15] leverages the existing participation of fans at events and the power of mobile technology to use groups of disparate people collectively as a coherent production team. In the context of production and Assistive Technology, this work not only shows how elements of production instructions can be communicated using simple on-screen overlays and descriptions, but highlights the real skill involved in producing the quality of content that consumers expect from broadcast content (and therefore the level of skill and experience required by the professionals). Similarly, the work by Perry *et. al.* investigating video broadcast at ice hockey games has been expanded to an understanding of how professional practices can be applied to pro-am users within similar settings [16], drawing out specific practices (such as mobile phone usage) to work with this user group. This demonstration of mapping professional practice onto consumer tools and technologies provides insights for mapping traditional workflows onto an alternative interface which might be required for a disabled user.

2.1.4 Examples of Production Interventions

The situational factors (such as responsiveness, temporal constraints, inter-group communication and cognitive load) which characterise the

broadcast environment are closely shared with wider production contexts. By understanding and abstracting elements of the production workflow, different modalities can be applied to perform some tasks. Bartindale *et. al.*'s work with MediaCrate (a situated tangible video mixing console) [17], and later StoryCrate [18] (a tangible interface driven rush-editing station) are examples of interventions which leverage the collaborative nature of tangible interaction to support professional production engineers in multi-skilling and being responsive to changing environmental constraints more efficiently, resulting in both example production interfaces using novel interaction techniques, and a deeper understanding of production teams.

The complete digitisation of the production workflow (driven primarily by the industry in projects such as BBC's IP Studio [http://www.bbc.co.uk/rd/publications /whitepaper268]) has allowed researchers easier access to explore alternatives to standard production interfaces. One such example, Engstrom *et. al.*'s [2] mobile vision mixer, enabled different input channels of a professional vision mixer to be selected using a mobile device, allowing the operator to be flexible about how and where their role was performed, removing some of the physical constraints of the traditional production studio. Indeed, all of these examples abstract the production tasks required for the workflow, replacing them with novel interactive modalities to perform similar tasks.

2.2 Ubiquitous Accessibility and the DIY Agenda

Disability is now a wide reaching concept, with around 25% of the population being recognized as having some form of disability in the United Kingdom[2]. The list of impairment groups includes physical and mobility disabilities, hearing impairments, visual impairments, cognitive disabilities and mental health disabilities, and indeed some people with disabilities have a combination of concurrent impairments. Within these groups, there is a large variation, for instance someone with a mobility impairment ranges from having a reduced degree of movement onto someone who is paralyzed from the neck down, whilst cognitive disabilities include people with varying degrees of disability, onto those who may have memory problems, intellectual disabilities, or challenges with concentration. Even an impairment which might – from a hierarchy of disabilities perspective [10] – be seen as being relatively minor or trivial could have a significant impact upon

[2] See the government statistics at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/321594/disability-prevalence.pdf

someone working as an operator, given the demands of human performance.

Universal design has been the dominant paradigm in considering Accessibility for a number of decades, perhaps beginning with the work of Selwyn Goldsmith, who set out in Designing for the Disabled [21] how to make the built environment accessible, introducing (what were then) innovations such as dropped curbs. Since then, there has been a burgeoning Universal Design agenda, which – with the introduction of the modern computer – has moved into Human Computer Interaction. Perhaps the most iconic aspect of this agenda is Web Accessibility, where successive editions of the WCAG guidance [22] have provided instructions explaining how websites might be made accessible, although there has been variable success in their implementation (see e.g. [23] [24]). It is well worth remembering that the Universal Design agenda also extends more widely than the WWW, including the design of artefacts and objects that we use in our everyday lives – for a full account of this, see Pullin's work which explores this in depth [25]. Overall, the approach of Universal Design is simple and widely applicable: take account of many human characteristics as possible, and reflect them in any system that is deployed, with the goal of ensuring that a resulting design is accessible to all.

Workplaces environments with especially unique or challenging operational constraints are not fully subject to Universal Design, due to the nature of the roles involved, especially in respect of the human performance demands they present (the latter often having being addressed by a more evolutionary design process of trial and error over decades). Nor could they reasonably be so, because the specific individual needs of someone cannot be predicted in advance. Rather steps ought to be taken in response to individual needs as they arise, as well as ensuring that these systems include the elements of Universal Design necessary to smooth this process, e.g. allowing interfaces to be changed easily and therefore allowing adaptions to different users, as well as minimizing the need for unnecessary adjustments, for instance people with differing anthropometrics, through accounting for obvious human disabilities in the design process.

Much of this emerges practically, in any event – the question is how to adapt further for the individual who becomes disabled. Fortunately, there are two developments in assistive technology which relate to the variety of people with disabilities, and the individual needs that arise from a complex product of individual impairments and particular circumstances, including highly specific workspaces. The first is the development of what might be described as the Ubiquitious Computing Accessibility agenda, with an increasing development of UbiComp systems – beginning with the Digital Hearing Aid – and now extending

into the use of wearable computing as well environment situated systems.

For reasons of space and concision, we do not rehearse the full range of systems and implementations which have emerged out of this trend. Nevertheless, we list some pointed examples, including Scribe4Me, which is a system that provides mobile transcription for D/deaf people [11], the SenseCam – which was deployed as a wearable memory aid for those with cognitive impairments [12], Sensory Paint [13], developed for those with sensory impairments arising from autism, Kirkham and Greenhalgh [14], which explores the possibility of augmented conversational systems facilitated in a DIY context (and the ethical issues that arise from this) and Beckwith's investigation of active badges for tracking dementia patients [15]. This represents a small subset of a burgeoning field of activity, focused upon Ubiquitous Assistive Technologies, which is likely to accelerate going forwards.

The second is the move towards DIY assistive technology, which is created by end users (or their associates) for their specific needs. Recent investigations on this topic include Hook *et. al.* (2014) [16] which focused upon technology created for children with disabilities, and Tobias and Hurst (2010)[17]. All these submissions cite the high rate of abandonment – estimated at around 35% - as a justification for individual adaptations to technology. The work of Shinohara and Wobbrock [18] is also of great interest, in that it explores the range of barriers that arise from perceptions of assistive technologies, and in particular the need for alacrity in training end users, as well as the false perceptions of colleagues undermining its practical deployment. In this submission we focus upon bespoke assistive technology, which extends the benefits of the DIY approach through the use of professional production and engineering (as opposed the hobbyist nature of DIY), whilst still offering the same or increased flexibility and customization relative to standard assistive technologies.

2.3 Disability Discrimination Law and Reasonable Accommodations

Disability discrimination law is (legally speaking) a very recent innovation designed to protect the rights of those with disabilities. Arguably first mainstreamed through the introduction of the American's with Disabilities Act (1990)[3], analogous legislation has been implemented in the following decades in most countries, with the subsequent widespread recognition of the needs of people with

[3] Before this were provisions designed primarily for Veterans, for example the 1973 Rehabilitation Act, although it must be remembered that this represents a very small minority within the disability community. Interested readers may wish to read Anna Lawson's (2008) book [46] to explore how the reasonable adjustment duty has emerged and developed.

disabilities being brought about through the 2006 UN Convention of the Rights of Persons with Disabilities (UN CRPD) [34].

The core principle[4] of Disability Discrimination Law is the concept of reasonable accommodations (or reasonable adjustments in UK parlance). This recognises that there can be a need to make substantive changes from normal practise in order to give someone with a disability equal opportunities, including in the employment context. A reasonable accommodation does not mean that any individual request must be brought about simply because it could help a disabled person, but typically the law is very insistent in its demands, allowing a considerable cost and substantial amount of disruption before an individual request is unreasonable. (With respect to wearables and the provision of wearable support systems, this duty has already been reviewed at length in [35]) Consequently, the types of adjustments that an organisation can be required to make for an individual are wide ranging, and include provision of assistive technology (e.g. screen readers, different input devices and such like), additional support and counselling to support someone in an employment role, and significant adjustments to someone's role within an organisation. Together with the UN CRPD, the range of different disabilities means that a proportionality driven approach – namely a balancing of the needs of the disabled person and their human right to be included with the disruption or inconvenience which this can impose – underpins the duty of reasonable accommodations in all modern legal jurisdictions.

There are some more subtle facets of this duty. The first is the notion of reasonable consultation. This means that simply failing to make a reasonable accommodation is not a breach in and of itself, if this particular accommodation had not occurred to either party involved in a reasonable accommodation process. A similar, but distinct concern is the duty to make anticipatory reasonable adjustments, which amounts to adjustments which need to be made without any kind of request. Traditionally this would include building fixtures and fittings (e.g. ramps and automatic doors) as well as accessible websites, amongst other concerns, but can also extend to employment practises and steps taken to smooth the implementation of individual reasonable

[4] There are of course other aspects to this legislation, which we do not explore within this particular paper, given that we are only concerned with reasonable accommodations in an employment context. This includes a wide range of other legal duties that vary across jurisdictions. In the United Kingdom for example, under the Equality Act (2010) this would include the need to avoid direct and indirect discrimination, not to victimise someone for supporting a person with a disability, and public law considerations, such as the Public Sector Equality Duty (s 149) which requires proactive promotion and consideration of Equality (including for people with disabilities) by public authorities.

accommodations. These duties are discussed further from a UK perspective[5] later in this article.

3 METHODOLOGY

3.1 OUR APPROACH

The provision of AT for production staff is a current and present issue of concern for broadcasters across the world. After being approached to investigate the area, we quickly identified that there was a limited range of assistive technologies that current exist to support production staff. If an assistive technology cannot be purchased, then the conclusion is that it must be built – bespoke – for that individual instead. As such, the goal of this investigation was to understand whether or not a bespoke assistive technology (BAT) process is a viable option for ameliorating an acquired disability.

We approached this challenge in four key stages, summarised in Figure 1:

1. Ethnographic observations made in a real-world production environment.
2. Interviews with experts in bespoke assistive technology.
3. Design of speculative prototypes of assistive technologies for production.
4. Interviews with production crew to elicit their personal understanding of AT issues in the workplace. Central to the discussion was presenting them with the design ideas for DIY AT as probes [36] to explore possible interventions.

3.1.1 Ethnographic Observation

An expert in accessibility interventions spent an intensive six day period (with a variety of shift patterns) observing the production of a

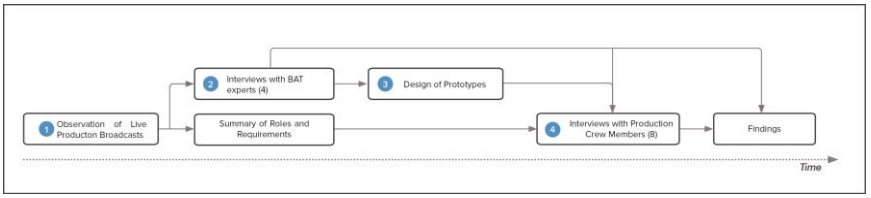

*Figure 1: **Overview of our approach. The core stages are numbered in line with the text in Chapter 3.1.***

[5] This would exclude Northern Ireland, which operates a different legal system concerning Disability Discrimination.

wide range of television program's in a live production setting at the BBC (**Error! Reference source not found.**), emphasizing News and Topical shows, as opposed more slow environments such as productions. We adopted the usual ethnomethodological approach towards ethnography used for understanding work and work practices [37]. A wide variety of observations were taken in note form across production locations e.g. studios and galleries, and of roles e.g. camera operator, vision mixer, sound mixer. Longer memos were developed after each observation session to inform later observations. Some informal interviews also took place during this period producing brief personal accounts of roles and workflows which greatly assisted in developing an initial understanding of how these production environments and roles operated in practice.

Incidentally, this approach closely mirrors the way new production crew are trained, mixing close observation with specific questioning of crew. This has the advantage that the observations caused minimal disruption to the normal working pattern, in which trainees are often present. The result of the ethnography was to form an initial understanding of how each role operated, as well as a core understanding of the requirements and human performance demands that result, including how these arise from the technology already deployed and widely used within those environments.

3.1.2 Expertise in Bespoke Assistive Technology

Role	Camera (Studio)	Camera (Field)	Vision Mixer	Sound Mixer
P1	E	E		
P2		I		
P3	I			
P4	E	E		
P5	E	E	I	
P6	E	E	E	E
P7	I		I	E
P8		E		

Table 1 ***Expertise of Interviewees. Those who are expert are marked with an E, whilst those who are intermediate are marked with an I (blank spaces means that this particular area was not within their usual work). These were arrived at by summarizing each participants discussion of their competencies and experience. Note that to preserve anonymity of what was said by each participant, we do not use this participant numbering in the discussion of later interviews. This investigation considered a larger number of roles, however, we focus upon a subset which are the most challenging to ensure concision.***

We conducted four semi-structured interviews with experts in the development of assistive technology systems at CanAssist[6], a world leading organization for implementation and delivery of bespoke assistive technology. They have successfully rehabilitated a number of people with disabilities back into demanding employment roles. The experts possessed a range of skills, including electronic and mechanical engineers, deployment, user integration and health professionals.[7]

Through guided discussion, we aimed to reveal the unique concerns that arise when considering bespoke assistive technology in high performance work-place environments, such as live broadcast production. Issues of safety, reliability, flexibility and viability were all key elements of the discussion.

These sessions were focussed upon understanding the processes of developing bespoke assistive technologies for the workplace. As such, we emphasized consideration of the practicalities of any intervention and the cost of making bespoke systems, the boundaries of such

[6] http://www.canassist.ca/

[7] To avoid identification of individual participants, we do not provide a more detailed description of their individual roles.

approaches in respect of feasibility tensioned against complexity and how Health and Safety challenges are addressed. We framed the scope of the discussion by providing detailed information on production environments. Emphasis was placed on the unique and demanding nature of the production environments (time pressure, location constraints). Existing wearable systems were also outlined (such as the Epson Moverio) and explored with participants.

3.1.3 Assistive Technology Probe Design

The result of these two phases of investigation was a set of speculative (and some implemented) examples of assistive production technology. Since these were central to the interviews perfumed with crew members, we frame our discussion in Section 5.2 around these prototypes. The four were chosen to represent a cross section of impairment and underlying technology so as best to illicit a response from interviews, in effect serving as technology probes [36]. Each was rooted in existing consumer technology, to ensure that these systems were seen as implementable and useable.

Concern was given to making sure each was a reasonable adjustment in line with the law, and that disabled people would therefore be entitled to use them within the workplace, along with consideration in terms of the 'reasonable adjustment test' (which under the UN CRPD generally involves the same principles across most jurisdictions, but we applied the English Equality Act (2010) for this work). From a practical viewpoint, this is a more nuanced implementation of the proportionality approach suggested by Iachello and Abowd [38] when exploring whether the design of Ubiquitous Computing systems; the distinction is that they were inspired by the law, whereas we actually (and necessarily) adopt it.[8]

3.1.4 Interviews with Production Crew

Facet	**Description**
Hearing (Communication)	The use of hearing in order to understand conversations and radio communications.
Hearing (Sound Quality)	The use of hearing in order to assess the quality of sound from a transmission or package, with a view towards ensuring that a broadcast has a sufficient sound quality (as perceived by viewers)

[8] What we have done should be distinguished from Value Centred Design [47], as well – although we might have said to have adopted the "value" of disability inclusion in the workplace – Value Centred Design would not involve this kind of rigour or skilled legal consideration of this issue, and would not be ideal because such an approach would inevitably drift into an implementation of Deal's hierarchy of impairments [20].

Whole Body Movement (or Agility)	The ability to move rapidly in order to effectively operate equipment.
Physical Strength	The ability to apply a sufficient amount of force to operate a heavy piece of equipment, or the strength and endurance necessary to use bulky or physically burdensome pieces of equipment.
Fine Motor Control (hands)	The ability to (reliably) operate a piece of equipment using small and accurate hand movements in order to effectively issue commands.
Reaction Times	An operators time to respond to a given stimulus, or cue, including actions in response to scripts or schedules.
Working Memory	The capacity to keep track of a number of tasks to be performed.
Concentration (Sustained)	The ability to retain a high level of performance and situational awareness for a sustained period of time.
Visual Field	The window and degree of which someone can observe visual phenomena.
Visual Acuity	The quality and accuracy, including regard of any (uncorrected) blurring, of someone's vision.

Table 2. ***Each facet of the Scale of Accessibility and the meaning of each element.***

Eight in depth semi-structured interviews were performed with members of production crew within their normal production environment. These were recorded, anonymized and transcribed before analysis. Interviews were conducted in three distinct stages: general background on their role and knowledge of disability and accessibility

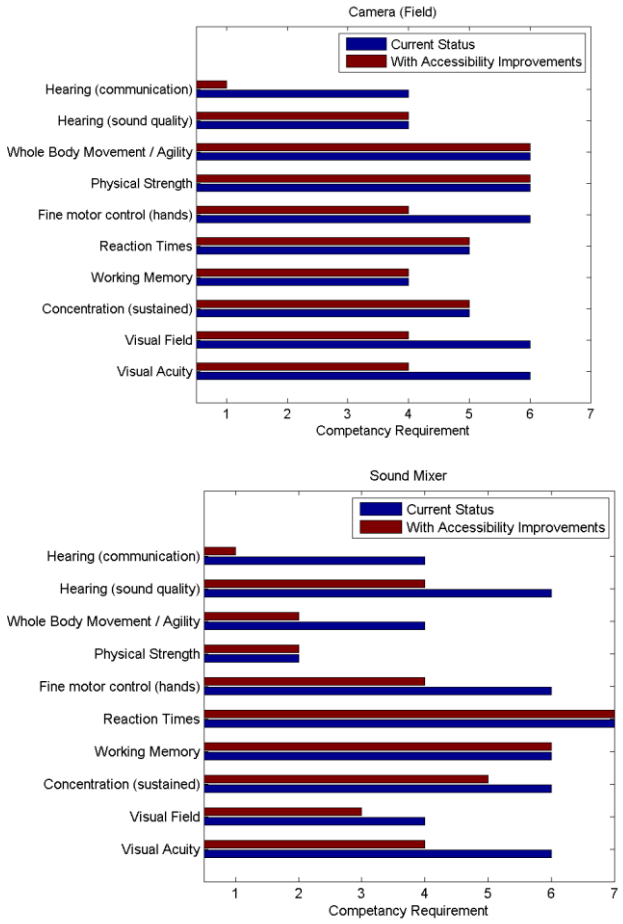

Figure 2 ***Examples of individual Scales of Accessibility as diagrams. Note that the blue bars for each element are the proposed accessibility levels with the current equipment, whilst red bars represent the expected requirements with proposed accessibility improvements.***

in the workplace; exploring the existing performance requirements of production roles using our "Scales of Accessibility" framework (See **Error! Reference source not found.** for examples of these). This was followed by a design discussion using the four designs developed previously as technology probes [39] to explore specific interventions that might be apply to the interviewee's role. Due to the multi-skilled nature of production, participants were considered experts in many areas, summarized at length in **Error! Reference source not found.**. Throughout the interviews, responses to the following core concerns were drawn out:

Confirmation and update of how the production environment operates, and the core competency standards involved. This would include necessary elements of human performance and variation of roles and circumstance.

- The extent to which these competency standards arise from limitations with existing equipment and interfaces, rather than being integral to the role.
- Specific practices and infrastructures that could be adjusted in response to the needs of someone with a disability, using the probes as a discussion tool.

As an introduction to thinking about accessibility, participants were shown a collection of quantitative data (generated by the researcher from the observations) on the perceived impact of particular roles on function ability (the facets of which are summarized in **Error! Reference source not found.**). This rating (1 - no demand at all to 7 - highly demanding) was provided for each role for each facet of impairment for both existing practice and after a possible intervention. This data was used as a prompt for discussing the problems which disabilities or impairments would prove problematic in particular roles. Gradation, range and the impact of cognitive disability could be highlighted using this data to explore past any preconceived ideas of impairment.

3.2 Analysis of Data and Reporting Results

Thematic analysis [19] was performed on the interview transcripts, using themes initially identified through observation and subsequently refined through discussion with experts. Contrasting accounts were weighted and scrutinised carefully to ensure that restrictions and limitations arrived at can be fully justified within the practicality and legal environment of production.

There are two sets of findings. In **Section 4 we** focus on scoping and understanding the environment of production in terms of accessible technology, and the demands placed on individuals in such situations. We present this analysis as a foundation for future work in the area, and to ground the following discussion about specific technology interventions. **Section 5** provides a discussion of specific assistive solutions for production which arose from presenting participants with the design probes.

4 The Existing Space of Accessibility within Production Environments

To contextualize the themes drawn from the data, it is helpful to provide an overview of the main production roles (see Figure 6) that were discussed in the interviews. The core roles that our participants were involved in are as follows:

Camera Operator (Studio)

Figure 3: A series of (standard) studio cameras (left) and a jib-arm camera (right).

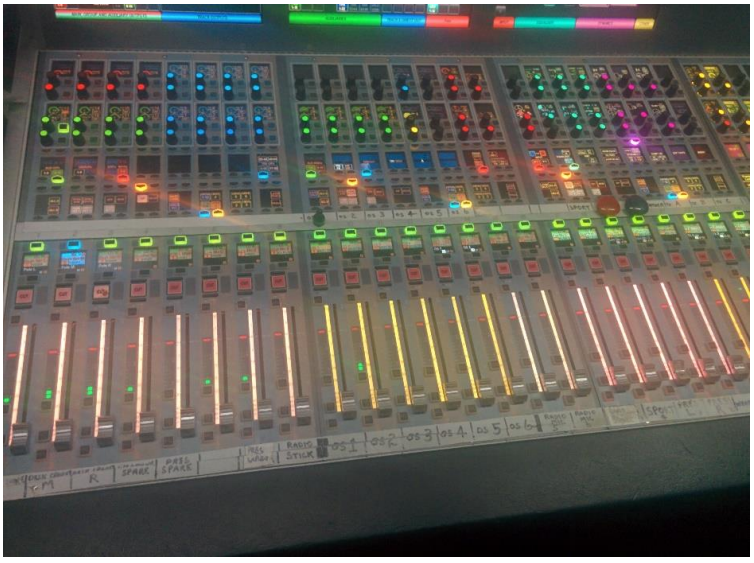

Figure 4. Sound mixing desk. The sliders that alter the volume for each microphone are found at the bottom of the mixer.

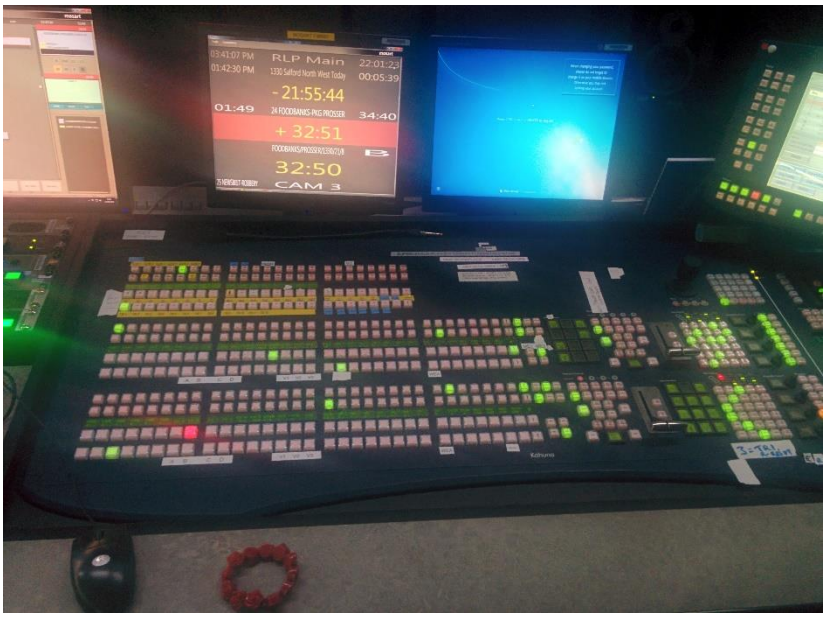

Figure 5: Vision mixer. Note the paired rows of buttons, as well as the handle on the right. It is also possible to program the vision mixer with a wide range of alternative functions for automation and complex presets.

number of both remote and manually operated cameras, both requiring human operators to reposition. Cameras can be located on tripod or on a jib arm, with the latter requiring additional training (Figure 5). Combinations of jib, static and tripod cameras are used depending on the show and shot required. As an example, the lunchtime news bulletin with a single presenter and no guests requires very little camera setup, whilst the breakfast show requires a jib arm and multiple cameras, and is thus more demanding.

Camera Operator (Field)

A field camera operator is required to produce professional quality shots, normally as part of a team, of ongoing events outside of a studio setting. This can include the coverage of live events in challenging public places, reacting to spontaneously to particular events as they occur. It involves carrying and using a large range of portable equipment, such as lighting and microphones, in order to maintain the quality of the recorded footage. Given the nature of these environments, and the fact that some events carry their own innate danger, this role generally involves a high degree of risk, which a skilled operator can minimize through care and planning.

Sound Mixer

Audio is taken from numerous sources, both external and internal to the studio and controlled by a mixing desk (**Error! Reference source not found.**). As well as closely listening to remedy problems with sound quality (and to fine tune the audio in response), the primary role of the sound mixer is to ensure that only the correct microphones are being

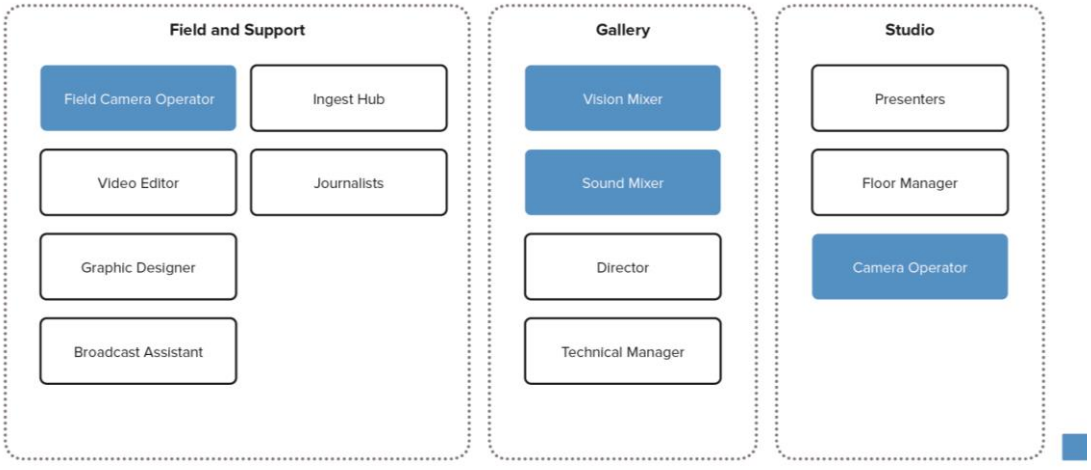

Figure 6 ***Overview of production environment roles.***

broadcast. The operator accomplishes this using a range of physical sliders and knobs and experienced operators often react before events visibly occur.

Vision Mixer

The role of a vision mixer is to switch (cut or fade) between individual camera shots or recorded content. This role works closely with the Director but can respond on their own to specific events, or on their own initiative. Each input source, (camera, recording etc.) and output destination (studio monitor, broadcast) is controlled by two rows of buttons (see **Error! Reference source not found.**). One row has the video source (normally a live camera) that is being broadcast; the other has the video source which is due to be broadcast. The rows are mixed between by sliding the handle at a varying speed – the effect of doing this rapidly is in practise to cut between cameras.

4.1 Operational Requirements in a Live Broadcast Production Environment

Four key themes emerged from discussion of the production environment with crew. These themes take the form of core competencies within the production workflow.

4.1.1 Time Pressure and Reflexivity

Time-pressure is a particularly strong area of concern, especially in the live (as opposed to documentary) production context. In live production, it was explained that:

"You just have to be quick. That's the tricky bit. I think, in other forms, Songs of Praise, Children's are split, there is a bit less pressure as opposed to the time constraints. … [In News] it has to be done, has to be done now and if it's not done that's not acceptable. Failure is not an option and when it does fail, we know about it. You get a talking to."

Not only is there a demand of quality against tough time limits, there is also a lack of predictability in these environments, due to things not always going to plan – with the effect that the program can be so pressured that parts of the program are not finished as they go to air.

"Yes, that's the difference, but there is, I mean having spent a lot of years in studios working away, you know, if everything goes according to plan that's fine. Frequently it doesn't, not in the news environment. … We are still making the programme while we are on air."

Much of the operational work focusses upon finely balancing competing demands, and also being ready to think on one's feet, to manage the inevitable crises that occur. As a result, some operators went as far as

to explain that their main skill was effectively time management, with their role largely emphasizing a continued tensioning between quality of the final production, and the need to balance a range of competing and evolving demands from various departments:

"We'll just discuss it in the morning and then, you know, you just use your skill at judging how much time you're going to have to – you know, whether what they expect is and then you just sort of have to just bring them down a bit from whether it's achievable in the time."

In summary, merely working in a live television production environment places strong cognitive demands upon all production staff members, as well as a strong cognisance of time and prioritisation in response to this. In particular, many crew members build up a kinaesthetic knowledge (such as the sound operator) which allows them to respond very quickly to complex situations.

4.1.2 Mental Robustness

Given these strong demands, it is perhaps not unsurprising that mental robustness was also a concern raised as being a core competence, with there being a particular need for staff members to be robust in this regard:

"You need very developed coping mechanisms in order to survive in television, I believe. Mentally you need to be completely there."

The level of stress highlighted did vary amongst the roles somewhat, with the multi-role nature of some operators adding to this, as they were expected to be even more aware of their surroundings. Another concern was the content (i.e. the raw footage) which was seen by operations staff, but never broadcast:

"Multi-roled, multi-skilled, yes, and stress. The stress of what we're doing can, you know, be fairly high. … You know, the things we watch on television, you don't see what goes on behind that, and say if somebody's – you know, if you've got young children yourself and you have to go to something where something horrible has happened to a child or something like that, it's hard."

Whilst stress itself is not unusual in production environments generally, the lack of perceived (and actual) control over events and the reactive nature of this work demands a particularly strong level of mental robustness and flexibility.

4.1.3 Team Work

Team work was highlighted as a crucial aspect of performing effectively in live production environments. This is true more generally within the

broadcast environment, given the interrelated nature of each-others roles, where one person in a given role would act in response to smaller cues offered by someone in a related role.

"It's not just purely mechanical. It's not. And there's a lot of symbiosis. … Occasionally you make mistakes. But it's anticipating; planning ahead. "I'm not on air. What shot is he going to come to next?"

There might be said to be a mutual dependability amongst staff, and in particular a need for people who are able to work reliably within

Figure 7. ***The live television production environment where observations took place. Top is the studio, with the gallery in the below photo, both of which were actually observed when programs were on air (as well as before and after the shows themselves).***

competence is common to any human factors domain that relates to human cognition (see e.g [41, 42]), and in particular scenarios with time sensitive or skilled roles.

4.1.4 Shifting Production Roles and Technological Advancement

Economic imperatives, increasing automation and the advancement of production technology has a natural effect upon how roles are shaped and evolved. Probably the biggest change has been a move towards a multi-role nature of production, where most staff would have skills at differing levels within the production environment, rather than being purely focused upon one role as they might be in the past. This leads to a remarkably distinctive approach compared even to 10 years ago (consider for instance the account of Broth [43]).

The introduction of multi-purpose satellite trucks, which are said to serve as a 'one-stop shop' for recording material, editing it and then preparing it for transmission as a complete package, is a particularly strong example of this:

"At the moment they are having to be two-person operated because you need someone to operate it and someone to do the other stuff. So it's supposed to be one person, and that's a tall order. The stuff that we're asking people to do, to be honest is, you know… It's not unreasonable, but they are people who already have a certain level of skills, and we're just pushing that, basically. And if you have to do that five days a week, ten hours a day, that's pretty knackering."

However this is justified on economic grounds, with one participant pointing out that manpower is reduced, with one person *"doing three people's jobs in effect. … And it cuts down on all the manpower and driving and stuff like that."* This issue is not purely confined to the field, indeed it is pervasive throughout the whole production pipeline. For example, one participant explained that: *"The graphic designers do studio cameras as well because the studio cameras element is quite straightforward on the news programmes. It's just pointing at a single guest, and that's how other designers utilise the time better"*

The natural effect of this new approach towards of working has heavily shaped the performance demands of each role, with the effect of often lowering performance requirements to reflect the fact that people are not expected to perform at such a high level in their secondary skills:

"The BBC when I joined it was an amazing organization with incredibly highly trained people. Each one did his specific job and doing it to a world class level. … We now multi task, but nothing to the level of skill of people who were doing it full time were doing it and we've accepted that. We've

Role	Physical	Cognitive	Hearing	Vision
Camera Field	Highly demanding from a fitness perspective, involving the rapid deployment of a range of heavy and bulky camera equipment. This role could be tolerant to a range of minor reasonable adjustments, e.g. braces for a one-armed camera man.	Highly demanding. Requires the ability to maintain situation awareness, whilst shooting high quality footage, and the ability to react reliably and quickly to specific events as they unfold.	A camera operator will need to maintain situational awareness, and to hear instructions from colleagues. To an extent they can – in some circumstances – have a limited responsibility for sound quality.	The operator needs to maintain situational awareness, and to quickly react to events within their field of view, and to determine if a shot is of a suitable quality.
Camera Studio	Most cases are moderately demanding. There is a need for a moderate degree of fine motor control. Some shows are more challenging, requiring the operator to move quickly between cameras and use a jib-arm.	There is a need to keep track of shots, and to react to occasional events as they unfold, although this is confined to a studio setting.	The main need is to use hearing to listen to the talk back system. There is no responsibility to assess sound quality.	Reasonably demanding, in the sense that the operator needs to know where they are located within a studio, and to have some quality of vision to determine whether the shots (as displayed on a viewfinder) are in focus.
Vision Mixer	A vision mixer is a desk bound role. However, it requires the rapid and accurate selection of a range of physical buttons in quick succession, on a large vision mixing desk.	Reaction times are very important in this role, given the need to set up a range of cameras in quick succession.	Moderately demanding – there is need to follow the talk-back, and also to act as a second director.	Demanding – the vision mixer needs to be able to observe events as they unfold in the studio through a range of monitors.
Sound Mixer	Like a vision mixer, a sound mixer is desk bound. The role requires rapid and accurate use of a range of sliders mounted on a desk.	Reaction times were determined to be especially important, with the need to open the correct sound fader in response to events within a split second. There is also a need to keep track of the progress of the program itself.	Highly demanding, given that the sound mixer will need to assess the sound quality of the output, and adjust this accordingly.	Demanding – the sound mixer needs to be able to observe events as they unfold in the studio through a range of monitors, including to anticipate who will begin speaking next.

Table 3 Summary of Criticalities from Individual Roles, based upon Chapter 5.2.

accepted that we don't have television images that could be as good as they should be. … It's really a shame because as those standards have slipped one way, the quality of television receivers has gone the other way."

What is perhaps equally interesting is that these demands vary amongst individual shows, depending upon the nature of their content, and the expectations of the audience. This can vary strongly in respect of editions of a show, for instance there is a stronger emphasis upon

Breakfast episodes in the week, compared to the weekends. The roles themselves also vary strongly depending on the nature of the content. For example, vision mixing was said to be highly challenging on music programs due to the rapidity of shots:

"Yes. Not that we do Top of the Pops any more, but something that was musical would be a bit more of a challenge, because the music's cut to the beat and the PA counts it and that's how they do the vision mixing"

4.2 Requirements and Criticalities for Specific Roles

Production environments are evolving substantially in response to new technology, with an increased emphasis upon most staff becoming multi-skilled, and a concurrent reduced focus upon people becoming world experts in individual roles. The effect of this shift is to emphasise experience in television itself, as opposed a role specific skill, as being something that requires preservation. At the same time, all roles emphasise reaction time, mental robustness, and the ability to perform under strong time pressure, without making significant mistakes.

Key to understanding how assistive technology can be developed for this environment however comes down to understanding the expectations of specific tasks within each role. These roles should not be seen as static sets of requirements, but rather as indicative of likely demands and challenges which arise from the core requirements of each role. The following discussion identifies a range of criticalities which arose through a discussion of existing practices and equipment used within the production space, and thus an expected barrier to people with disabilities (see Table 3).

4.2.1 Physical

All of the roles involve significant physical demands. Studio camera operators require the ability to move around the studio safely and reasonably quickly, as well as to manoeuvre the camera's themselves. There is also a need to operate the core controls on the camera, as they currently exist.

"You have to be able to walk around yourself and push the camera. You have to be two-handed, because with one hand, you can zoom and pull focus with the other one."

Notably, the physical demands increase in respect of more challenging shows, especially if the jib-arm is used. For example, this is seen as the core addition on the Breakfast shows:

"The only addition is, like you say, the Jimmy Jib and the physical restraints that that gives you for, like I say, not hitting anybody with it and keeping out of the way."

Field camera operations are far more demanding physically compared to studio-based roles, due to the need to run between shots and carry heavy equipment in the field itself. This includes lighting equipment and additional cameras that always need to be available in response to events as they unfold. As one field operative put it:

"You do if you are going away from the camera you need to take it with you because you never know what you are going to need to have to do. You can't just keep nipping back to the car to get another thing, it would slow down the process of making television dramatically. It's also very unprofessional, you know, you should be able to just continue filming whatever is requested of you."

The impact of this is often to limit the physical health and wellbeing of camera operators. One participant described a core part of his role as being a *"donkey"* and explained that his role had meant that: "*In the last five years I've had two slipped discs and a broken back.*", whilst another observed that *"Most camera people, all their backs go and everything"*, and a third person we spoke to was unable to carry on as a camera operator due to injuries sustained in that role.

The second, compounding issue, is the dynamism of events and the impossibility of controlling the environment, which often means running around events as they unfold. One participant gave the example of soldiers on a parade as being one representative example of this, explaining that:

"Because they march at full tilt. You have to get ahead of them, so if a platoon of soldiers walked past you and you need the shot of them walking past, you then have to get in front of them, through a crowd and they don't hang about, they march at full pace. So you sprint."

He did go onto explain that it was possible to make minor adjustments for some relatively minor cases: "*I know there are cameramen who have only one arm. Braces and things that allow them to continue to work and very successfully, so it is possible, but difficult"*, as well as explain that some small adjustments to equipment were possible, for instance to address minor limitations in hand-eye co-ordination. However, field camera work remains physically punishing in its own right, and this currently places a strong limit upon who can undertake these roles

Vision and sound mixing are both desk bound in nature.[9] However, they both place strong emphasis upon hand-eye co-ordination, and where appropriate, involve the use of both hands. For a vision mixer, this involves a strong degree of manoeuvrability:

"You know, you've got to be very manoeuvrable to go from one camera to the other to a mix to a fade, to a dissolve, whatever."

The same point was made for a sound mixer. As such, any intervention for those with physical impairments for both sound and vision mixers would likely focus upon remapping controls to maximise the use of remaining physical functionality.

4.2.2 Cognitive

All roles are cognitively demanding, simply due to the nature of working in a production environment. However, each manifests demands in unique ways, and is usually dependent on acquired. We document this for two reasons; first to show the difficulty of making reasonable adjustments for those who acquire a range of cognitive impairments, and secondly to help indicate the level of skill that would be preserved by other types of reasonable adjustments.

Studio camera operation is one of the cases where there are relatively limited demands, the main knowledge being how to control the camera skilfully, and to perceive the appropriate shots that need to be undertake:

"You do, you need an awareness of space, you need an awareness of proportion of size of things in relation to another. You need an ability to take on board a certain level of training so that you are aware of the options open to you as a camera operator. I could do the same shot from three different positions, to the untrained eye they'd be the same shots. To the trained eye there would be a difference and that difference would be for a reason."

In general, the demands upon reaction times are relatively limited, presuming that the program in question is not particularly complex. Most, but not all shots, are formulaic, helping to minimise the cognitive load involved.

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[9] It was argued by one of our participants that there was a need for a sound mixer to run into a studio and repair technical issues with microphones. However, taking the overall picture, we found that someone else could perform this role if it became necessary (based in part on discussions with other participants who were less convinced that this would be problematic), and this would already be a reasonable adjustment. As such, this concern does not apply for

" So there are so many different variables on a big studio production. Like whereas Breakfast is very formulaic. You know where the cameras are going to go. You know what is required."

By contrast, camera operation in the field is arguably more cognitively demanding. The main reason for this is the strong need to maintain – common to a wide range of demanding operational environments [44] – a high level of situational awareness. This is due to the need to react and account for a wide range of safety concerns inherent to working in dynamic and potentially volatile environments:

"You really do need to be aware of all of those kinds of things that you plan ahead, you predict what's likely to happen, you actually evaluate it and update it when you get there. … I mean a good one is a fire, you know, the number of times I've turned up to film a fire and you can get very involved in it because it's action and there is lots of things going on and it makes great pictures, but if the wall falls on you…You know, you're not a good cameraman. … Filming anywhere near traffic it's quite common to see a cameraman step backwards and what that might not realise is a lorry's wing mirror misses the back of their head by inches, because they never look behind, you just step back to get a wider shot. … It is an environment where you can come unstuck very quickly, particularly in crowds, anywhere near water, anywhere near traffic."

Sound Mixing and Vision mixing also place very strong cognitive demands upon operators. Here, the primary concern is reaction time, which in respect of sound mixers, was noted to be *"definitely off the scale"* for sound mixers, and being so demanding in this regard as to be a role that *"few would be willing to take on"*. Vision mixing also placed a strong demand upon reaction time, as well, although this also appeared to be rolled together with a substantive need for situation awareness:

"Yes, reaction time is probably the key thing on vision mixing, I'd say, because they'll often, what's the word…? You know, they'll take their own direction. If the director has missed something, then they'll cut it up or cut to something, even if they've not been instructed to."

Overall, it can be said that each role is cognitively demanding, although in subtly different ways. The degree to which these roles are demanding will vary somewhat with the nature of an individual show, but even a simple program imposes strong minimum pre-requisites in relation to cognitive ability. Moreover, this places a strong limit upon the reasonable adjustments that might be made by adjusting how other members of the crew perform their roles in order to assist a disabled crew member.

4.2.3 Sensory (Hearing and Vision)

A studio camera operator requires a reasonable degree of visual ability, to enable them to avoid hazards and identify their relative location in the studio, as well as ensuring that the cameras themselves are aimed and focussed. The main limiting factor for anyone with poor vision was the small size of the displays (although this could be increased), as it was explained: *"you have to have vision suitable to see a monitor that's five inches"*. Hearing is more problematic. Although there is no need to assess sound quality, there is a need to monitor the Talkback sound system. As one participant explained it:

"It is important that you hear exactly what's being said over talkback. … It's something that can be accommodated to some degree, but you do need to have a reasonable amount of hearing. … You are also concentrating on listening very carefully to the talkback, because there's an awful lot of it. Only bits of it are relevant to you and if you miss it, it's too late, they don't repeat."

This point also applied naturally to both Sound and Vision Mixers, who also rely upon either the director's instructions or Talkback. For Field Camera Operators, whilst hearing was not used to assess sound quality, it was vital for maintaining situation awareness: *"Once your eye is in that camera, I think your situational awareness comes from your hearing. Visually even if you've got one good eye, you are not using it, it's closed or out of focus."* Thus hearing was not important as a matter of quality, but also as a matter of minimizing the risk of physical harm or serious injury to the operators.

Inevitably, a vision mixer would need to be able to see the video feeds in order to determine which camera is the most appropriate to switch to. Perhaps less intuitively, the sound mixer relies upon visual ability as well as being able to hear effectively. This is because they need to predict when someone will speak, so that they can adjust the faders in time:

"But that's where you do need to be able to see because you'll see it on the cameras. That's why on the sound desk you will have preview of the studio cameras. People when they speak they usually – there's a twitch. There's a little movement."

Surprisingly, it was suggested that it is possible for someone with a hearing impairment to be a sound mixer, at least upon a functional basis:

"To what level you want to do it? I think you need good hearing, which I haven't got. But functionally, for a news programme, I have actually been in a situation, especially on an outside broadcast or something, where the

rig has been terrible, or the monitoring has been terrible, but I believed it was right what was going through the desk and I've just done it on the needles."

However, it would not be reasonable for someone to be employed primarily as a sound mixer on this basis – hearing is still required to perform the role adequately in most cases.

5 REASONABLE ADJUSTMENTS THAT CAN BE IMPLEMENTED THROUGH BESPOKE ASSISTIVE TECHNOLOGY

The central question of this work is what steps can be realistically undertaken in order to adjust (or augment) the existing Ubiquitous Computing Systems within production environments in order to make them accessible to a wide range of people with disabilities. Each individual case is of course highly specific to an individual, and how they perform a role. Nevertheless, we can identify and illustrate a range of specific reasonable adjustments that might be implemented, either though adaptions to existing systems, or new systems which sit on top of existing production practice. After explaining the bounds of a bespoke reasonable adjustment process, we discuss several of these systems below, in order to illustrate the space of what might be accomplished. Note that these proposed (or actual) systems had the advantage of being presented in some form as part of our interview process.

5.1 THE BESPOKE REASONABLE ADJUSTMENT PROCESS

We interviewed a number of Bespoke Assistive Technology experts in order to understand whether this approach could be viable in professional production environment. Our interviews with bespoke assistive technology experts led to three areas of concern: the conceptualization and iterative design process, managing risk (and ensuring health and safety), and the boundaries upon what can be reasonably produced by a bespoke process.

5.1.1 Developing Bespoke Assistive Technology

The process adopted for designing bespoke assistive technology is not dissimilar to a highly responsive iterative design process. The overall process is deliberately designed to ensure that an appropriate solution is arrived at that provides suitable support for a disabled person's needs, as explained by one interviewee:

"Well, upon a first meeting, I mean in essence a request in terms of how we operate formally. Individuals from the community would submit a request. That could be generated from the client, the end user themselves … Once we receive one of those forms, whether or not it is a community based

request or a formal referral through a healthcare provider, we would initiate a first meeting, so an assessment would take place. Those, although not structured in terms of a checklist, that's where myself or one of my colleagues, as an engineer, along with our client relations team, would assess our ability to develop or deploy an already developed technology that would do one of two things. I mean you can meet their goals, bridge their accessibility barrier to another piece of technology or, even at that point, you can still certainly suggest devices, products or services that are already in the market. We're not saying, "We're building what you're asking for", we're looking a bit before that and saying, "What type of solution could exist for you".

Throughout the development, normally there is a real emphasis upon meeting and interacting with a client, in order to ensure that a given technology fully suits their needs.

"It's meeting the actual client. Having them go over and play or work or try out their technology. Because no matter what testing you do, nothing replicates that perfectly the way that actually giving them their product and then they'll go at it. They will let you know if it's something they like about it or don't like."

However, the way in which this can take place varies naturally in accord with the nature of a given project.

"Typically, maybe an in person meeting and that varies. If we're looking at say just a first meeting to see if that's a project of relevance for us in our terms of varied expertise, so let's say a chat for an hour, something where we're developing a much more specific specification, which will come later after we've engaged them as a client. That's probably several follow up emails and conversations with their care team, their family. We're having to go back and travel back to a home if it's a physical adaption to a piece of equipment in their home."

It can be concluded that the approach adopted is similar to that usually used for iterative design. The distinctive aspect is bringing to the table a strong degree of expertise and experience in bespoke assistive technology, which is then drawn upon to direct that process towards producing the most appropriate piece of bespoke assistive technology for a given clients' needs and circumstances.

5.1.2 Building in Reliability and Safety

One overwhelming question that must be asked is how a system is made reliable and safe in the bespoke context. This is especially concerning in the context of professional environments. The main approach used is to ensure that a system developed is sufficiently simple, and to remove unnecessary complexity:

"Well, making mistakes, one of the things that we really try to do, because mistakes often arise when you make something overly complicated. We really try to strive on making things very simple. Because not only is it easier on us but it's also easier on the client. We don't want to have to spend thousands of hours designing a pencil holder for someone that needs it for their wheelchair versus if we can do it in a simple way, an elegant way, and it's going to be simple and elegant for the user to use, that's going to be way more effective spending a year on a pencil holder that's got a built-in cup holder and a USB port."

However, this in itself does not prevent the development of more complex systems when appropriate to do so. One particularly interesting example was the development of a mechanised barber's chair that rotated close to a client to enable a barber who had lost their legs to get close enough to effectively cut hair[10]:

"However, in order for us to meet our levels of satisfaction with the safety, we did include things that you wouldn't normally see in a barber shop, increased signage. … Built right into the design are certain safety factors. For instance, the plinth or the platform that it stood on represented the operating space. The barber, as the owner of the piece of equipment and operator, could say to a client or if there was a child in the shop, "The safe area to be is if you're not standing on that platform, you're not in danger of this piece of equipment"."

There is also a strong emphasis upon non-interference, through separating out the individual's other essential technology (assistive or otherwise) from the additional bespoke technology.

"The battery, that's not something that we connect to the wheelchair's own battery because we want to make sure that regardless of how long they're using the camera, or if there's any reliability issues, that it doesn't affect their mobility."

Naturally, it would be reasonable to expect a similar strategy to be adopted with other equipment in a television studio (or another performance critical environment), thereby ensuring the assistive technology does not interfere with existing equipment, including its use by those without disabilities. In addition to this, there are further strategies adopted in order to effectively over-engineer the assistive technology so that the risks are effectively minimised and mitigated.

"Yes. I mean in terms of the reliability testing, we rely quite heavily on modelling. We don't have an accelerated life testing facility here.

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[10] A video overview of this system can be found at: https://www.youtube.com/watch?v=Q5DxNpJHN00

Essentially adding those robust features and making the decision about materials is how we get our long term reliability, not by absolutely minimising the amount of material that went into it for instance."

In many respects, this process is assisted by the nature of bespoke assistive technology, where it is relatively inexpensive to add additional amounts of material in order to obtain the necessary robustness.

"If were making 100 million of a brace, if we had shave off 10g of material, 10g times 100 million, that's an enormous amount. And that's enough. That could save a lot. But because we're doing one brace for one person, you know, we always design it so that it is without any shadow of a doubt going to be completely safe for a functionality and what we tell them to use and beyond that. Because we know that every device you make, chairs. You know, people don't just sit on them. They stand on them. They kneel. They hold something. So they're undergoing much more than the recommended sort of usability. So we really ensure that everything is overdesigned as well to ensure that it's safe."

The overall conclusion therefore is that the professional engineering approach adopted is sufficient to ensure a great degree of safety and reliability, and thus would be reasonable to deploy in a production environment.

5.1.3 The Space of Bespoke Assistive Technologies

How far can bespoke assistive technologies go in terms of furthering the needs of people with disabilities? Perhaps surprisingly, we found few limits in respect of the equipment that might be produced. The boundaries are cases where there are strong laws as to what could be produced, for instance modification of a car:

"*For example, in a request to modify a vehicle for improved access for a person that had a spinal cord injury that would have involved modifications to the structure of the car. That's something that we can't undertake reasonably. It would have to go back and it would be assessed and essentially deemed a modified vehicle and recertified by Transfer of Canada … It's just one of those situations like we understand that we can probably take on the engineering of this task, but we wouldn't be able to necessarily fulfil on something that would be road legal after which of course that jeopardises the whole project. That's something that we would likely step away from."*

Interestingly, this means that existing (local)[11] laws can – on occasions – serve as a barrier towards creating technologies that could otherwise

[11] The specific issue here would be of less difficulty in the United Kingdom for instance, where there appears to be more liberal legislation and processes for custom and rebuilt vehicles.

be engineered. As such, it is reasonably to conclude that local laws are an important limitation upon Bespoke Assistive Technologies, and thus the technologies that can be developed will vary significantly across jurisdictions. The question is not usually whether or not would ultimately be legal, but how onerous it would be to meet those requirements, and demonstrate that they have been met. The other context of concern is the medical case, where there has be compliance with the obligations that flow from this. Participant AE explains how the balance of this takes place:

"We can't install this on your body. But at the same time, we have all the time people coming to us with injured bodies. Injured body parts. Issues with comfort. That's a big one. And they may have an idea or a concept of what they want. But the main thing is you have to meet and understand completely what they're going to use this for. Because it can't just be used for everything necessarily."

There were also practical limitations of what could be accomplished. Some hardware would need a certain amount of maintenance when deployed, which could be limiting in a professional context.

"For instance, a breath controlled switch, sip and puff, there's additional things to deal with like filters and saliva traps and all of that. You're introducing something else into the environment and also it's going to be set up for that individual. There's definitely maintenance in terms of the sanitation and making sure that they stay reliable by keeping the moisture away from the switch itself."

Sometimes the implementation of given bespoke assistives are delayed, whilst underlying technology that can be adapted is brought to be market, thereby making the customization process more reasonable to carry out:

"*So even technical in nature, like for camerawork, a big part of the reason that we actually were a bit tardy getting off the ground with it, but that was because we were waiting on the technology to become available to support Android on QT. It wasn't quite yet there. We all knew about it, it was in the pipeline over at Digia, but it wasn't actually ready in a more or less usable form so we had to wait on that."*

However, the overriding consideration is quality of life and improvement possible with bespoke assistives, with the decision making generally being based upon the wider impact that can be made.

"And a lot of them are quality of life. We have a lot of clients that can't do a specific thing that they used to enjoy. Or we've had people that wanted to go fishing. We've had a couple of people who used to fish a lot and then they got in an accident or something happened and they can't fish. And being

able to, within a span of, you know, anywhere between two to eight months get them back fishing independently. That's incredible."

5.2 EXAMPLE SYSTEMS

We now proceed to consider example systems which would be helpful for this context, with a view towards demonstrating that a bespoke approach towards production accessibility can overcome the strong barriers identified above. Each system is described in detail, before the findings are discussed.

5.2.1 Polecam Powerchair

The Pole-Cam Powerchair is an already existing system[12] developed by CanAssist currently being used by a video journalist which removes the need for an operator to be able to physically lift a camera, or indeed even be able to walk. It is a remote controlled boom mounted to an electric wheelchair, which has a camera mounted at the end of it. A joystick controls the usual camera controls, whilst a second joystick controls the wheelchair as normal. The boom can be raised and lowered by sucking or blowing into a sip and puff switch. In accessible settings, this system might be used in order to replace a normal camera operator, thus making this role accessible to people with a reasonable range of people who have disabilities.

Perhaps unsurprisingly, this system attracted the most discussion. The main issue raised was that whilst this system was technically capable, it also attracted criticism about the unpredictability of events limiting its potential in the News context. One natural issue which was raised is the lack of accessibility, or predictability of it, which was required for such a system to be used:

"*So, one job, on paper, looks like it might be suitable, but until you get on site, you don't know what it's going to be. It could be an interview at someone's house and the guy says, "Ah, I can't do it in my house, because I've got the builders in, but my friend's got a flat on the 3rd floor, we can do it up there." You know what I mean? … The lift might be broken, so I'll carry the stuff up three flights of stairs. You just don't know until you get to the job. I'm not being negative, but I've done this job for an awful long time."*

Nor was it practical to manage teams of camera people in order to ensure that only those places which were highly likely to be accessible

[12] A video illustrating the use of this system is available here (this was used as part of the demonstration of the proposed system): https://www.youtube.com/watch?v=_HPU6DxzIU0

for a disabled camera operator. This is simply because jobs are often allocated across a very limited number of camera crews and need to be allocated so that a camera crew based upon location. Another challenge is that certain unpredictable events are unlikely to be fully trackable by a system of this design:

"I could go out tomorrow, filming, I don't know, a walkabout with Miliband and he's going to walk down Market Street in Manchester, which is pedestrianised. Perfect, you could use it on that. But then, someone jumps out of the crowd and throws an egg at him and runs down the street chased by the police."

However, our participants were a lot more positive about the opportunities to use this system for occasions which were more predictable.

"It could do almost every prime minister thing I've ever done. You could do interviews in offices and could do voxes, I guess."

They also noted that there were a wide range of opportunities in the documentary context, as well as in certain large studios – including for live broadcasts in the latter case.

"I reckon it's a great idea … It would be able to be used the same as our Jib Cam is used in our studio because that has a base that's considerable in size."

It was also explained that there was a possibility of obtaining higher quality shots, due to the smoothness of the wheelchairs, offering some advantages of existing platforms.

"And they are stable yes, and I mean the wheelchairs have incredibly smooth operating motors and things and they can travel very smoothly across the floor, you could probably get tracking shots or whatever."

He then went on to explain:

"Well the orchestra doesn't move, it's a rigid point, everything within the orchestra stays put, so it would be very easy to position a number of camera operators such as this to produce a really good video coverage of perhaps a performance of an orchestra or a choir something like that."

There were some minor concerns raised in respect of safety, although it was noted that this was no different to those cases where a non-disabled operator was operating the existing equipment.

"Yes, well, you know. It's just as easy to knock someone with the boom if you are able bodied as well, so yes as long as your grasp of how to make good television is still there, then yes that will definitely work."

Whilst this system might not be suitable for live news production, it certainly is a route to enabling people who acquire a disability to return to meaningful and productive camera work, with a degree of careful reallocation of programmes.

5.2.2 Text-based Talk-Back

Text-based Talkback. Talkback is a radio system which is used to communicate within a production environment, primarily between a gallery and a studio, and is essential to most roles. However, this system is completely inaccessible to people with a range of hearing impairments, given the need (noted above in 4.3.3) to listen carefully to the entire stream of radio traffic over a radio throughout the broadcast of a program. This proposes using a chorded keyboard, together with a system like Google Glass (i.e. a wearable display of some form), in order to send text messages to a D/deaf person working a system in a studio. This relies on the fact that many roles are based upon a deterministic set of commands that can be very efficiently communicated, and most parts of a role are pre-determined in advance of a show being broadcast.

In practise, there were two real questions in respect to the practicality of this – is the role simple enough in terms of its instructions, and would someone situated in the studio be able to relay them quickly enough.

For most television programs, this is deterministic, with most of the show being determined by a shot list:

"Well the shot list would be a good way of getting to 90% of the programme and so long as they could hear the gallery, the gallery would tell them what they wanted because things are changed. Especially if the gallery were aware that somebody was working in an environment who did have a slight disability or whatever."

"I think if you said, "Two shot left, two shot right, mid shot," whatever, and they were predetermined commands, then I don't see why you couldn't."

The commands in many shows are simple and infrequent. However, in other cases, they can be more complex, making the implementation of such a system more challenging in those circumstances.

"If X is on camera, and if I'm in the directing seat, I need to give X– I need to tell X what it is I need. "I want a screen five and two presenters and I don't want to see screen two." So he knows exactly where – he needs to put his camera then in a different position rather than 'there'. Because all of a sudden I can see screen two and I don't want screen two because I've got something that's going to go on there and I tell X, "Right I need you – I don't want to see screen two at all."

This route was seen to be more challenging for some of the more demanding shows, with a concern expressed that: *"The other thing is who is going to input that? You'd need some system where it was typed at the speed it was spoken, because if the guy says to me in the studio, "Get a close up" I need to do it then, because they are looking to cut to it*". This was echoed by a participant with experience of directing, who was concerned that this could be unduly complex.

"And once you want – I need you to pan left now. I'm looking for the key to tell you to pan left. Then you've got to get that command, process it, and make sure that it's the right camera doing the right thing. But the problem with things like pan left, pan right, when you're looking at cameras, is you can just keep doing that. You need to know what you're panning left to. That's where the communication comes in. If Richard's on camera, I'll ask him to pan left and exclude screen one so he knows where he needs to go left. You need to give people – people need landscape; they need a benchmark on cameras. Because if you just said, "Pan left," you might do 'that' or might just do 'that'. Where's the gauge there."

It is worth noting that a stenographer is usually seen as a reasonable adjustment for D/deaf people in an employment context. Thus, even in the event that instructions could not be keyed by an operator with the spare capacity or training to do so, then a Stenographer[13] could be used to broadcast to a wearable display at a suitable speed, presuming that they were adequately trained for this context. Thus, such an approach could be deployed within the context of reasonable adjustments reasonably widely for someone with a profound hearing impairment.

5.2.3 Foot-Pedal Vision or Sound-Mixer

We proposed a foot-pedal based vision mixer in response to the possibility of a user who was one-handed. The modified system would replace the handle with a foot switch, as well as being installed in such a way that it does not impede normal use of the vision mixer by someone without a disability. The goal of such a system would be to assist someone who did not have movement in one of their arms (for instance, having lost mobility on one side of their body due to the effects of a stroke).

This overall proposal attracted little criticism, with most participants being easily convinced of this. For a vision mixer, the step would be adapting a handle to a foot-pedal, which was agreed across our participants to be reasonable. However, it was recognised that this

[13] A stenographer provides support for D/deaf people by typing – in real time – what is being said by a speaker, using a special chorded keyboard that allows them to obtain a sufficiently high word-rate per minute (WPM) with a great degree of accuracy.

could not work for some shows which were particularly rapid: "*You know, if you've got a fast One Direction number, you might have 100 shots in it in three minutes.*"

With a sound mixer, the real constraint would be the use of one hand to work all the faders. As it was explained, *"you've got to have agility. And I find I can only do three faders with one hand."* However, there is a route around this, which he went on to explain: *"On average you'd have one plus two plus a down-the-line. So that would be five microphones; five faders. Of which taking your point, if you adapted for the presenters being on the foot pedals or something, then yes, you could actually do it with one hand. … I just think something that's fixed and always there, you're happy that it's left and right presenter. It's always on your left and right foot. Anything else that you build up on the desk, you can do it with your hand. That's what I was thinking."*

Presuming that a program had a limit on how many sources were involved at one time, then such a route would certainly be feasible. As such, it is fair to conclude that adaptions of vision mixers and sound mixers can take place with bespoke accessible interfaces in a suitably practical manner for them to be viable as reasonable adjustments.

5.2.4 Indoor Navigational Studio Camera

Our final proposal was the use of an indoor navigational system to help a partiality sighted camera operator navigate around the studio. Some people with visual impairments have a limited view of the studio, for instance due to a narrowed field of view, but can see a small area in front of them perfectly clearly. This system[14] would assist someone with such a disability by using markers in a studio to track where the individual cameras are (and their orientation) relative to shot specific positions, and then plotting the results on a wearable HUD display, thus enabling the visually impaired person to track where the current camera is and prepare to complete the next shot.

This received no opposition, and a uniformly positive response. It was agreed that there was a need for "an awareness of space, you need an awareness of proportion of size of things in relation to another.", although this could be realised by a 2D representation of a studio, given that this location would be well known to the operator. One participant conceptualised the system as being similar to car navigation: *"Yes, I mean you could have the same kind of sensors that you have in terms of the reversing aid on a car and you could actually mount LEDs around the viewfinder, so that if you were dragging the camera back and there was*

[14] We also used a video of a similar system to support discussion of this particular proposal: https://www.youtube.com/watch?v=5vUi0DXtXs4

another camera behind you, one of the LEDs or two of the LEDS would come at the bottom of the screen which would indicate there was something coming up behind you. There are ways and means of doing it.".

It was suggested that – like with our other proposed adjustments – there would be some particular shows where this approach would be less practical, due to the unpredictability of the required shots (and the possibility of shots being off stage). However, given the range of shows for which this would work, this issue is not in and of itself problematic.

5.3 Bespoke Reasonable Adjustments in Practise

The above discussion explored two core stages of any bespoke reasonable adjustment process; how Bespoke Assistive Technologies are developed and made, and whether or not appropriate designs of

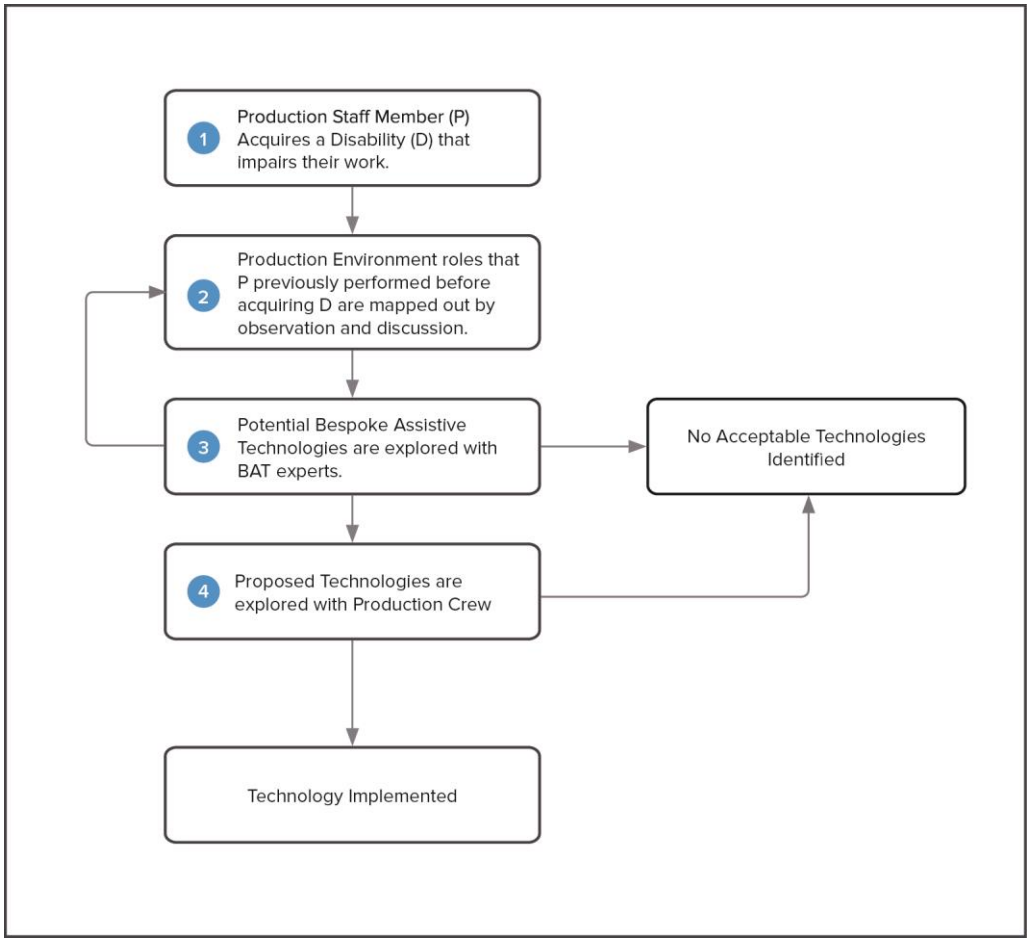

Figure 8. ***Procedure for implementing Reasonable Adjustments through Bespoke Assistive Technology. Highlighted in green are the steps undertaken in this work. Note that this process – although not realised in such a way for this research – can be conducted interactively. There are two possible outcomes from this process, either an assistive technology is identified (and subsequently constructed), or it is determined that one cannot be developed in response to the individual***

Bespoke Assistive Technologies might be used in production environments.

We found that not only can Bespoke Assistive Technologies be developed to a suitable standard for production environments, but there is a wide space in which they can be made. In proposing new (or more often than not, adapted) systems that might be used in these environments, we then found that there are a number of viable systems that can be developed in response to rather significant impairments.

These findings effectively propose a wider process (summarized in **Error! Reference source not found.**) for developing bespoke assistive technologies in response to individually acquired disabilities. This process starts from the point where a Production Staff member (P) acquires a disability that impairs their work (D). For instance, they might lose a degree of functional mobility that prevents them from using equipment, or obtain a degree of sensory loss.[15] The goal is to explore whether or not a Bespoke Assistive Technology could be developed to enable them to perform one or more roles that they previously undertook in the production environment.

The first point – which we completed in respect of four roles within this investigation (in Section 4) – is to map out the roles that P has potential to continue in, in order to understand the core cognitive demands and characteristics involved, and why they are so. It is important to also understand how they might vary within a role, not least because it is possible for someone to partially perform a role (e.g. working on particular shows in response to their disability) as a reasonable adjustment in and of itself and for this to be combined with a BAT. The goal is to find a viable role for someone supported with assistive technology, not necessarily for them to perform their job in the same way that they used to.

The mapping of roles can then be used as basis for proposing new technologies, in conjunction with the application of expertise from Bespoke Assistive Technology (BAT) professionals. These proposed technologies then should be explored with existing professionals in Production Environments in order to understand their viability, with the outcome being whether that technology can proceed (as is), or with modifications. In some cases, it might be that a proposed assistive technology would not be viable at all.

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[15] We do not consider cognitive disabilities here, as our process was not validated for or designed in respect of this space. However, it is certainly possible in some circumstances that BAT's could be developed in response to these types of disabilities going forwards, and this is a development we would certainly welcome.

Unlike the single stage process we conducted in the abstract within our case, we envisage that the approach adopted would be more iterative, being trailed until either an assistive technology emerges and is developed, or alternatively, no acceptable technologies are identified. Following this process is likely to lead to a potential assistive technology which otherwise would not have been conceived, and thereby significantly increase the number of production staff members who can remain working productively in this field after acquiring a substantive disability.

6 Disability Discrimination Law Implications of this Investigation

Having explored possible steps for people with disabilities in the Broadcasting Context, it is important to determine whether these (and in particular the process of developing these adjustments we have developed) would amount to reasonable accommodations. Clearly in the business world, the distinction between suggestions to help employees and obligations which ought to be acted upon is clear and an important consideration.

The scenario poses some novel legal questions, given the necessary reliance upon Bespoke Ubiquitous Computing.[16] Indeed this issue applies in a broader context, in any high stress but specialist environment. We therefore ask the following question, based upon the existing legislation:

Under the below conditions, is there a legal duty to develop a bespoke 'reasonable accommodation' through the development or adaptation of a Ubiquitous Computing system? If there is such a duty, what is its extent and could this in part be anticipatory?

[16] Perhaps surprisingly, the fact that this investigation was conducted *in abstracto* (i.e. without using a real disabled "client") does not have any impact upon the legal aspects of this work. Disability and individual impairments are diverse. The same applies for production roles. As such, each case would need to be determined on its merits *de novo*, as opposed a fixed piece of technology or set of reasonable adjustments being applied. Intuitively this might make more sense when considered against the fact that there is no obligation in law for disabled people to prove that a given reasonable adjustment to work (with both *Foster vs Leeds NHS Trust and Butcher vs Croft Vets and Anor* going as far as to oblige reasonable adjustments that are highly unlikely to work). If disabled people had to demonstrate that reasonable adjustments were likely to be work, then the natural effect would be to negate the duty to make reasonable adjustments in most cases, simply because reasonable adjustments generally are individual specific, as well as evolve with the introduction of new technologies and practices.

1. *The person P, who may benefit from such an adjustment, is an employee (not a volunteer) of the large organisation E, whether public (i.e. an arm of the state) or private.*
2. *That the role of P is a skilled and highly specialist operator in a complex workplace environment.*
3. *That P has a disability recognised under legislation, and that the only means to make a reasonable accommodation is through the bespoke development or adaption of a Ubiquitous Computing System which has some prospect of enabling P to return to work for E.*
4. *That the role and environment reflects a skill level which is challenging and potentially costly to replace.*

Broadcasting operators satisfy all four conditions. To give a concrete legal realisation, we answer this question using UK law, relying only on the duty of reasonable adjustments as found in s.20 of the Equality Act (2010) [17] . Given the similarity of this type of legislation across jurisdictions, and the current non-ratification of the UN CRPD by the USA[18], it make sense to focus upon the UK jurisdiction, although we highlight (see footnotes) some core cases from the US and Canadian contexts to help illustrate how this argument applies more widely.

We ignore the additional public duties that might apply to some operators such as the BBC, and we do not rely upon the availability of alternative supports (e.g. Access to Work[19]) in order to justify the central case of bespoke reasonable adjustments. The advantage of doing so is that our conclusions and findings generalise more widely, rather than being based upon legal obligations (and the availability of government assistance) which are peculiar to a relatively narrow set of organisations.

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[17] http://www.legislation.gov.uk/ukpga/2010/15/section/20

[18] Although the USA has not ratified the UN CRPD, over 150 other states have now done so. In most cases where a country has signed but not ratified the UN CRPD, the failure to ratify does not actually flow as a consequence of the core reasonable accommodation duty (as termed in the convention), but the failure to meet their obligations to those who may be considered to lack "mental capacity". One striking example is the Republic of Ireland, where the current law in force remains the Lunacy Act of 1871, rather than more progressive legislation (in England and Wales, the Mental Capacity Act (2005) applies, which is sufficiently modern – although far from immune to criticism – as to meet the UN CRPD's requirements).

[19] Access to Work is a scheme in the United Kingdom that subsides reasonable adjustments for people with disabilities. This subsidy has the natural effect of broadening the reasonable adjustments that might be made, by helping to eliminate defences that might be made on cost grounds. However, given that this scheme is being reformed, and there is a lack of similar schemes in many other jurisdictions, it is better not to rely upon that schemes ongoing existence.

However, we do assume that an organisation is large enough to have flexibility in what roles employees are allocated. The provision of technology is not the only reasonable adjustment that can be made for someone with a disability. Adjustments can be made to roles themselves, and the law now recognises that these steps can sometimes be rather drastic. For example, *Archibald vs Fife Council*[20] considered reasonable adjustments in respect to redeployment within that organisation, after a manual worker was unable to continue in their role due to an acquired physical impairment, but could potentially fulfil other vacancies within the organisation. The House of Lords concluded that it was a reasonable adjustment in *Chief Constable of South Yorkshire Police v Jelic*[21] which concerned the redeployment of a Police Officer with an Anxiety Disorder, perhaps somewhat extends *Archibald*, noting that a job swap (rather than simply a redeployment to an already vacant position) would be a reasonable adjustment under the facts of that case. Part of the reasoning was based upon the fact that the law allows, and on certain occasions expects, disabled people to be treated more favourably. Whilst in some cases a bespoke assistive technology would likely be a sufficient reasonable adjustment by itself, it is important to remember that this approach is far more likely to be successful if it can be combined with other steps for a newly disabled employee. As such, it is important to proceed with this presumption in mind.[22]

There are three core concerns which need to be addressed in our legal analysis, namely the legal duty that applies in response to specific requests ("the individual duty"), the implications that arise from the reasonableness of any discussion that takes place in response to an individual's request for accommodations ("reasonable consultation"), and whether there are any steps that fall under the duty to make adjustments automatically without a specific request ("the anticipatory duty") that emerge from this investigation. We take each concern in turn.

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[20] http://www.bailii.org/uk/cases/UKHL/2004/32.html

[21]http://www.bailii.org/uk/cases/UKEAT/2010/0491_09_2904.html

[22] Similar arguments have been accepted under US legislation. For example, the Third Circuit of Appeals in *Colwell v. Rite Aid* found that it was a reasonable adjustment to change someone's shift patterns in response to an acquired vision impairment (the reasoning being that night driving become dangerous for that employee). In *Equal Employment Opportunity Commission vs United Airlines*, the Seventh Circuit of Appeals also affirmed that re-assignment to a vacant position was a reasonable accommodation (even if there might be better external applicant for that vacancy).

6.1 The Individual Duty: Can Bespoke Assistive Technologies be a Reasonable Adjustment?

That it can be a reasonable adjustment to develop and subsequently build an adapted or bespoke Ubicomp system may appear to be a counter-intuitive notion. There is no direct legal precedent, given the novelty of both Ubiquitous Computing and the notion of bespoke assistive technology. However, Disability Discrimination Law is highly fact specific, and not concerned with the type of technology deployed, but the abstract application of the notion of a reasonable adjustment to a specific set of circumstances (i.e. 'the facts'), which under the individual duty, is a decision made in response to a given proposal. Whether an adjustment is reasonable depends on the core factors set out in the Disability Discrimination Act (1995) under the supplementary provisions in 18B[23], which were subsequently adopted for decision making with respect to the Equality Act (2010)[24]:

"(a) the extent to which taking the step would present the effect to which the duty is imposed;

(b) the extent to which it is practical for him to take the step [proposed];

(c) the financial and other costs which would be incurred by him in taking the step and the extent to which it would disrupt taking any of his activities

(d) the extent of his financial and other resources;

(e) the availability to him of financial or other assistance with respect to taking this step;

(f) the nature of his activities and the size of the undertaking"

Also of note, (highlighted by inclusion of criteria 4), is the guidance of the (then) Disability Rights Commission in 2004[25], which stated amongst other matters that:

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[23] This can be found in Cordell at 26. http://www.bailii.org/uk/cases/UKEAT/2011/0016_11_0510.html

[24] This is generally similar to other jurisdictions. For instance, in the Canadian case *Central Alberta Dairy Pool v. Alberta* (Human Rights Commission) it was recognised that "undue hardship" included a consideration of "financial cost, disruption of a collective agreement, problems of morale of other employees, interchangeability of work force and facilities." It was also noted that "the size of the employer's operation may influence the assessment of whether a given financial cost is undue or the ease with which the workforce and facilities can be adapted to the circumstances. Where safety is at issue both the magnitude of the risk and the identity of those who bear it are relevant considerations". In the US, the test is "undue hardship" (in the employment context), with very similar factors also being expressed directly in the Americans with Disabilities Act (2010) itself (see 42 U.S.C. § 12112.).

[25] This can also be found in Cordell, at 27.

"It would be reasonable for an employer to have to spend at least as much on an adjustment to enable the retention of a disabled person – including any retraining – as might be spent on recruiting and training a replacement".

The expense of training and recruitment is high in the Broadcasting industry, particularly given the emphasis upon experience of tools and practices which the industry depends on, and would similarly apply to a wide range of skilled operational roles across a broad range of industries. The other concern, subsequently addressed *in Foster vs Leeds Primary Health Trust*[26], is that the prospect of success does not even need to be a real one for an adjustment to be reasonable. Until recently, financial cost was assumed to be irrelevant to employers in making adjustments, until the case of *Cordell vs the Foreign and Commonwealth Office*, which ruled that an adjustment of over £150,000 a year cost was excessive.[27] As can be averred from this, the duty of reasonable adjustments is an expansive one indeed.

Our first question is whether or not the proposal of a bespoke ubiquitous computing system is truly novel in a legal sense. If it were to be, then it would not be possible to make a prediction as to the result if the question of bespoke assistive technologies were to be raised in a court of law. Fortunately this is not the case. As it happens, the idea of a bespoke reasonable adjustment in itself is not a new one. Non-technological adjustments are often bespoke, for instance the delivery of a specific type of workplace counselling, the modification of a role. From a technical perspective, existing reasonable adjustments include the effectively modification of a piece of software using Jaws Scripts to enable screen readers to access it. Perhaps the most seminal case for this question is that of *Croft Vets vs Butcher*[28], which determined the provision of private counselling was a reasonable adjustment, and even though on the facts of that case it had a limited likelihood of successfully restoring that person to work (as well as involving an employee of relatively low skill compared to our context, and an employer with a far lower degree of economic resources). Simply because in our case the development of a system happens to manifest in a bespoke piece (or adaption) of Ubicomp Hardware does not mean that there is any real distinction legally.

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[26] http://www.bailii.org/uk/cases/UKEAT/2011/0052_10_1406.html

[27] This picture is reflected in a wide range of international case law. For example, in the US case of *Argenyi vs Creighton University*, a D/deaf medical student was found to be entitled to expensive communication support (in excess of $100,000) in order to enable them to complete their degree program.

[28] http://www.bailii.org/uk/cases/UKEAT/2013/0430_12_0210.html

Having established that this case is not novel, the next question is the application of the usual principle of proportionality, which in practise involves apportioning cost and risk. Compared to many reasonable adjustments, this process is of fairly minimal risk (to both an employer and the disabled individual), given the now proven approach (see above) of developing bespoke assistive technologies within CanAssist, and the consequent likelihood of success if a system is commissioned. Investigating *whether* a system can be developed for someone is comparatively cheap, and is fully integrated into the investigation of whether or not an assistive technology can be already purchased for someone. The fact that most of the risk is captured in the assessment rather than construction stages largely narrows the cost question down to whether or not the end product is cost effective in the event it works, due to the high likelihood of success at this step. Because of the considerable expense in replacing an expert operator is on a similar scale in the worst case for developing a bespoke assistive, together with the resources of these organisations, in most foreseeable cases, the cost and risk restrictions are unlikely to render the development of a bespoke assistive Ubicomp system unreasonable. Moreover, investigating this issue is almost certainly a reasonable adjustment in and of itself, even if this investigation does not yield a positive result (i.e. a bespoke assistive technology that is feasible to implement).

6.2 Reasonable Consultation

It is worth briefly remarking upon reasonable consultation and its implications. The natural finding is that the approach we have taken would not have been reasonable to predict before the investigation outlined in this submission that a bespoke approach would lead to a broad range of potential reasonable adjustments. Therefore, the fact that bespoke adjustments have not been made to date does not in and of itself imply a breach of the reasonable accommodation duty.

Moreover, even if some requests may have been made and refused for bespoke reasonable adjustments, these requests might have not have had the authority that this article by virtue of being a formally conducted (and subsequently peer reviewed) investigation As such, a request or plea from a disabled person for a bespoke assistive to be developed for themcould well have been reasonably rejected in the past, however if this article were to be drawn to the attention of the parties in a consultation process for reasonable adjustments, then no such defence would exist going forwards. The result is that this article – through publication – has the effect of converting what might have been previously optional into clear legal obligations to, at the very least, effectively explore a bespoke approach with a reasonably open

mind, and to make any reasonable adjustments that arise out of this newly introduced avenue of exploration.

6.3 The Anticipatory Duty

The final question is whether or not this investigation creates new anticipatory obligations[29] for employers. The answer cannot be derived from precedent, due to the relatively limited body of relevant law. Therefore it is worth highlighting some points which might make an investigation of this kind an anticipatory adjustment, without committing to a stronger conclusion where this would be an obligation.

The first point in favour of this route is cost, with this investigation being both low impact and relatively inexpensive to run. The cost in our case, with all incidental expenses included was under £10000, and is likely to potentially benefit at least 1000 people within the organization it was carried out in alone. It is reasonable to suggest that at least 50 people out of that 1000 (i.e. assuming 5% become substantially disabled within their career) could benefit from bespoke reasonable adjustments. As such, this would be a minimal sum per potential beneficiary, given that in *RBS vs Allen*[30], a bank was required to make over £200,000 worth of adaptions to one branch to enable a relatively small population of wheelchair users to use the banks services where offered.

This is not of course (unlike wheelchair access) a scenario where there is a clearly articulated likelihood of actual harm by failing to make the anticipatory adjustment, in this case a special kind of investigation. These individuals in theory could apply for individual adjustments, unlike the customer in *RBS*. However, it is certainly arguable that an investigation of this kind would greatly smooth these types of reasonable adjustments, and thus prevent cases where a bespoke assistive technology was not taken up and to make the implementation of such requests more efficient (including in some cases identifying bespoke technologies which would not have been otherwise identified).[31] It may also allow employers to adapt both the structure

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[29] In respect of English employment law, the Equality Act (2010) does not impose an anticipatory duty in an employment context directly. However, not adopting such an approach could be a failing under the Indirect Discrimination provisions, and we assume this route may apply instead.

[30] http://www.bailii.org/ew/cases/EWCA/Civ/2009/1213.html

[31] Some public sector organisations have additional obligations that bring about stronger anticipatory duties though a different route. In England and Wales this would be under the Public Sector Equality Duty (s.149 of the Equality Act (2010)). For our context, this would likely extend to promoting the inclusion of people with

of roles and training as to maximise the opportunities available to an employee who becomes disabled in the future. So there would be a substantive benefit to disabled employees, although whether or not this is sufficient for this proposal to be a reasonable adjustment remains an open point of law. Obviously, for now, this duty could also only apply if this suggestion was placed before an employer, for the similar reasons identified under the discussion surrounding the duty of reasonable consultation.

7 CONCLUSION

This article has made a number of contributions to the production of television and ubiquitous computing, principally in documenting existing practice in both production roles and bespoke assistive technology, before then going on to depict the types of systems which could be deployed in response to the needs of individual operators who become disabled.

Perhaps the most interesting finding is the implication for the rights of people with disabilities, namely that in professional roles they can often be entitled – as a legal right - to have a bespoke piece of assistive technology development for them. Due to how the principle of a reasonable consultation (set out in Section 6.2) operates, we have potentially created new legal obligations through this investigation merely by making the counterintuitive become intuitive, advancing disability discrimination law in and of itself. In our context, a bespoke assistive is most likely to be development or adaptation of a Ubiquitous Computing System (including in some cases, a Wearable). Moreover, the investigation we have documented has potentially expanded the anticipatory duty, therefore (arguably) placing a requirement for an investigation to take place before any reasonable adjustment requests arrive from disabled staff or even those with disabilities who aspire to be operators.

Our methodology offers a route towards exploring reasonable adjustments by creating new technologies for some people with disabilities. We also demonstrated the viability of this route through the exploration of four responsive prototypes. However, these prototypes were (necessarily) characterised by a degree of simplicity, and thus our method has not been validated in more complex settings. As Meyerson and Meyerson point out, "*A judge, unlike a scientist, is not "just deferring decision until more research becomes available. Rather, a judge is electing a specific course of action that definitively resolves*

disabilities in production environments more generally, rather than simply those who it happens to employ.

important social and legal rights ….” [45]. This is precisely the limitation with our work. Whilst we clearly set out steps that would work for more traditional disabilities, we do not offer technological steps that would help those with more complex disabilities, for instance those who acquire cognitive impairments. Thus, it must be remembered that whilst we include more disabled people through our work, there are some that will remain excluded by its application – and in effect this will impinge upon their legal and social rights in the workplace (at the very least). Future work ought to be directed at addressing this issue.

Synthesising discrimination law, existing methodologies, and a new articulation of bespoke assistive technologies has proved to be a fruitful route towards beginning to maintain the employability of those in production environments who may acquire a disability. We suggest that our experience might be useful more generally, not only in developing more responsive and adaptable television production environments (including for those without disabilities), but in those wider cases where operators and other skilled professionals face strong demands upon human performance. Looking to the future, we would therefore ask the Ubiquitous Computing community to make full use of our findings, and to consider how these legal provisions could be taken advantage of going forwards.

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8 REFERENCES

1. Perry, M., Juhlin, O., Esbjörnsson, M., Engström, A.: Lean collaboration through video gestures. Proceedings of the 27th international conference on Human factors in computing systems - CHI ’09. p. 2279. ACM Press, New York, New York, USA (2009).
2. Zettl, H.: Television Production Handbook. Cengage Learning (2011).
3. Verna, T.: Live TV: An Inside Look at Directing and Producing. Focal Press (1987).
4. Caldwell, J.T.: Production Culture: Industrial Reflexivity and Critical Practice in Film and Television. Duke University Press (2008).
5. Fletcher, J., Kirby, D.G., Cunningham, S.: Tapeless and paperless: automating the workflow in tv studio production. BBC Res. White Pap. 141, (2006).
6. Merrill, D., Kalanithi, J., Maes, P.: Siftables: towards sensor network user interfaces. Tangible Embed. Interact. (2007).
7. Zigelbaum, J., Horn, M.S., Shaer, O., Jacob, R.J.K.: The tangible video editor. Proceedings of the 1st international conference on

Tangible and embedded interaction - TEI '07. p. 43. ACM Press, New York, New York, USA (2007).
8. Marilly, E., Gonguet, A., Martinot, O., Pain, F.: Gesture Interactions With Video: From Algorithms to User Evaluation. Bell Labs Tech. J. 17, 103–118 (2013).
9. Yamamoto, M., Osaki, K., Watanabe, T.: Video Content Production Support System with Speech-Driven Embodied Entrainment Character by Speech and Hand Motion Inputs. Springer Berlin Heidelberg, Berlin, Heidelberg (2009).
10. Ramos, G., Balakrishnan, R.: Fluid interaction techniques for the control and annotation of digital video. Symp. User Interface Softw. Technol. 105 (2003).
11. Vonolfen, W.: Virtual studios for TV productions-limits and chances. Proceedings. IEEE 8th International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises (WET ICE'99). pp. 267–270. IEEE Comput. Soc (1999).
12. Doughty, M., Rowland, D., Lawson, S.: Who is on your sofa?: TV audience communities and second screening social networks. EuroITV. 79–86 (2012).
13. Jenkins, H.: Convergence Culture: Where Old and New Media Collide. NYU Press (2006).
14. Kirk, D., Sellen, A., Harper, R., Wood, K., Ave, J.J.T., Ng, N.: Understanding Videowork. (2007).
15. Schofield, G., Bartindale, T., Wright, P.: Bootlegger: Turning Fans into Film Crew. CHI. ACM Press (Association for Computing Machinery) (2015).
16. Juhlin, O., Engström, A., Önnevall, E.: Long tail TV revisited. Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14. pp. 1325–1334. ACM Press, New York, New York, USA (2014).
17. Bartindale, T., Hook, J., Olivier, P.: Media Crate: tangible live media production interface. Proceedings of the 3rd international Conference on Tangible and Embedded interaction. pp. 255–262. ACM Press, Cambridge, UK (2009).
18. Bartindale, T., Valentine, E., Glancy, M., Kirk, D., Wright, P., Olivier, P.: Facilitating TV Production Using StoryCrate. CnC '13. , Sydney (2013).
19. Engström, A., Zoric, G., Juhlin, O.: The Mobile Vision Mixer : A mobile network based live video broadcasting system in your mobile phone. MUM 2012. 3–6 (2012).
20. Deal, M.: Disabled people's attitudes toward other impairment groups: a hierarchy of impairments. Disabil. Soc. 18, 897–910 (2003).
21. Goldsmith, S.: Designing for the Disabled. (1963).
22. Web Content Accessibility Guidelines 2.0, W3C World Wide Web Consortium Recommendation (http://www.w3.org/TR/WCAG20/).
23. Lazar, J., Hochheiser, H.: Legal aspects of interface accessibility in the U.S. Commun. ACM. 56, 74–80 (2013).
24. Blanck, P.: eQuality: The Struggle for Web Accessibility by Persons with Cognitive Disabilities. (2014).
25. Pullin, G.: Design meets Disability. (2009).
26. Matthews, T., Carter, S., Pai, C., Fong, J., Mankoff, J.: Scribe4Me : Evaluating a Mobile Sound Transcription Tool for the Deaf. Ubicomp 2005 159–176 (2006).

27. Hodges, S., Williams, L., Berry, E., Izadi, S., Srinivasan, J., Butler, A., Smyth, G., Kapur, N., Wood, K.: SenseCam : A Retrospective Memory Aid. Ubicomp 2006. 177–193 (2006).
28. Ringland, K.E., Zalapa, R., Neal, M., Escobedo, L., Tentori, M., Hayes, G.R.: SensoryPaint : A Multimodal Sensory Intervention for Children with Neurodevelomental Disorders. (2014).
29. Kirkham, R., Greenhalgh, C.: Social Access vs. Privacy in Wearable Computing, IEEE Pervasive Computing (2015).
30. Beckwith, R.: Designing for Ubiquity : The Perception of Privacy. IEEE Pervasive Computing 2, 40–46 (2003).
31. Hook, J., Verbaan, S., Durrant, A., Olivier, P., Wright, P., Hague, T.: A Study of the Challenges Related to DIY Assistive Technology in the Context of Children with Disabilities. DIS 2014 597–606 (2014).
32. Hurst, A., Tobias, J.: Empowering individuals with do-it-yourself assistive technology. ACM ASSETS. ACM Press, New York, New York, USA (2011).
33. Shinohara, K., Wobbrock, J.O.: In the Shadow of Misperception : Assistive Technology Use and Social Interactions. CHI 2011 705–714 (2011).
34. United Nations: United Nations Convention on the Rights of Persons with Disabilities (UN CRPD). (2006).
35. Kirkham, R.: Wearable Guide-Dogs and Digital Ramps: An Exploration of Disability Discrimination Law and Wearable Computing. IEEE Computer 48, (2015).
36. Hutchinson, H., Mackay, W.: Technology probes: inspiring design for and with families. SIGCHI. (2003).
37. Crabtree, A., Rouncefield, M., Tolmie, P.: Doing Design Ethnography. 183–205 (2012).
38. Iachello, G.: Privacy and Proportionality, (2006).
39. Hutchinson, H., Mackay, W.: Technology probes: inspiring design for and with families. SIGCHI. (2003).
40. Braun, V., Clarke, V.: Using thematic analysis in psychology. Qual. Res. Psychol. 3, 77–101 (2006).
41. Hollan, J., Hutchins, E., Kirsh, D.: Distributed cognition: toward a new foundation for human-computer interaction research. ACM Trans. Comput. Interact. 7, 174–196 (2000).
42. Hutchins, E., Klausen, T.: Distributed cognition in an airline cockpit. Cogn. Commun. Work. 15–34 (1996).
43. Broth, M.: The Production of a live TV-interview through mediated interaction. Proc. Log. Methodol. (2004).
44. Endsley, M.R., others: Theoretical underpinnings of situation awareness: A critical review. Situat. Aware. Anal. Meas. 3–32 (2000).
45. Meyerson, M.I.: Significant Statistics : The Unwitting policy Making of Mathematically Ignorant Judges. 37, (2010).
46. Lawson, A.: Disability and Equality Law in Britain: The Role of Reasonable Adjustment. Hart Publishing, Oxford (2008).
47. Friedman, B., Kahn, P.H., Borning, A.: Value Sensitive Design and Information Systems. 1–27 (2003).

TABLE OF CASES (UK LAW)

Case	Summary	Web Link
Archibald vs Fife Council (2004) UKHL 32	The House of Lords (now succeeded by the UK Supreme Court) found that the duty reasonable adjustments could involve transferring an disabled employee to a vacant position within that organisation, without a competitive interview process. This redeployment would still have to be reasonable under all the circumstances. It was also observed that the duty of reasonable adjustments necessarily involves more favourable treatment, in order to fully account for the needs of those with disabilities.	http://www.bailii.org/uk/cases/UKHL/2004/32.html
Chief Constable of South Yorkshire Police v Jelic (2010) IRLR 744	Employment Appeal Tribunal (EAT) ruled in favour of the appellant, who was a serving police officer, that it would be a reasonable adjustment to swap that officers role with another serving constable, in order to address the challenges faced by the officers anxiety disorder. (under the circumstances of that case)	http://www.bailii.org/uk/cases/UKEAT/2010/0491_09_2904.html
Cordell vs the Foreign and Commonwealth Office (2011) ICR 280	EAT ultimately ruled that providing a team of lip speakers in response to the appellant's hearing impairment was not a reasonable adjustment, because the costs of more than £100,000 would be excessive.	www.bailii.org/uk/cases/UKEAT/2011/0016_11_0510.html
Royal Bank of Scotland Group [RBS] Plc v. Allen (2009) EWCA Civ 1213	The Court of Appeal ordered a privately owned bank to spend £200,000 to install a platform lift in one of its branches, even though online services were available and the installation would involve the loss of an interview room.	www.bailii.org/ew/cases/EWCA/Civ/2009/1213.html
Leeds Teaching Hospital NHS Trust v. Foster (2011) UKEAT 0052_10_1406	EAT awarded £50,000 to the appellant, who was suffering undue "stress" under a particular manager. The appellant claimed that stress was due in part to bullying and harassment. EAT ruled that the employer failed to redeploy the appellant even though it was highly unlikely that redeployment would successfully rehabilitate him in the workplace.	www.bailii.org/uk/cases/UKEAT/2011/0052_10_1406.html
Croft Vets Ltd. and Others v. Butcher (2013)	EAT found that the employer was in breach of the reasonable adjustment duty because of its failure to pay for private medical treatment to treat the employee's depression—despite the availability of a free comprehensive public health service.	www.bailii.org/uk/cases/UKEAT/2013/0430_12_0210.html