An Empirical Study of Issues and Barriers to Mainstream Video Game Accessibility

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ABSTRACT
A gap between the academic human-computer interaction community and the game development industry has led to games not being as thoroughly influenced by accessibility standards as most other facets of information and communication technology. As a result, individuals with disabilities are unable to fully, if at all, engage with many commercial games. This paper presents the findings of a pair of complementary empirical studies intended to understand the current state of game accessibility in a grounded, real-world context and identify issues and barriers. The first study involved an online survey of 55 gamers with disabilities to elicit information about their play habits, experiences, and accessibility issues. The second study consisted of a series of semi-structured interviews with individuals from the game industry to better understand accessibility's situation in their design and development processes. Through quantitative and qualitative thematic analysis, we derive high-level insights from the data, such as the prevalence of assistive technology incompatibility and the value of middleware for implementing accessibility standardization. Finally, we discuss specific implications and how these insights can be used to define future work which may help to narrow the gap.

Categories and Subject Descriptors
K.4.2 [**Computers and Security**]: Social Issues – *Assistive technologies for persons with disabilities*, H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

General Terms
Design, Human Factors

Keywords
Video Games, Accessibility, Access Technology

1. INTRODUCTION
Video games have exhibited a steady rise over the last few decades in their complexity, pervasiveness, and significance. No longer merely for entertainment, games have begun to be explored and embraced as tools for teaching [13], health [26], positive lifestyle persuasion [12], and even political interaction [20]. Yet for the most part, mainstream video games have developed largely parallel to and isolated from academic human-computer interaction (HCI) research [24]. Although recent efforts have attempted to bridge these communities (e.g. [2]), the divide largely remains.

Because of this divide, different design principles and standards of practice have evolved within the game industry than what is found in other fields with stronger ties to the HCI community [14]. One of the more profound ramifications of this phenomenon is that the game industry has not benefited from the HCI and ASSETS research communities' rich history of accessibility work. While great strides have been made in the accessibility of general-purpose software and technology (e.g. web content accessibility guidelines, alternate input device development, and operating-system-level accessibility standards) due in no small part to academic research translating to industry and practice, the same 'bleedthrough' effect has not applied to game development [27].

Because of this, many individuals with disabilities are finding themselves excluded from full participation in the world of gaming. As Miesenberger et al. argue, the need to address this exclusion is not simply a matter of helping individuals with disabilities play games, but rather "it is about [allowing them to take] part in a societal phenomenon of growing importance" (p. 253) [14].

Within roughly the last ten years, both the academic community and the game development industry —at times cooperatively and at times individually— have demonstrated an interest in and commitment to investigating and improving the landscape of mainstream game accessibility. As will be discussed in the next section in greater detail, the bulk of this resulting research takes the form of developing design recommendations for game developers based on laboratory studies and high-level modeling of impairments. While this sort of work has obvious value, its ecological validity is uncertain given the dynamic interplay of interests in the industry (i.e. entertainment, artistic, economic, pragmatic, etc.) as well as the complexity of the user population.

In this research, we aim to supplement the existing literature on game accessibility with a more embedded understanding of the problem space in the context of its ultimate users (gamers with disabilities) as well as the development practitioners who are typically the target audience of such publications. By building toward a richer understanding of accessibility's situation in the landscapes of gamer user experience and industry design and development, we can better understand the needs of these interests, putting all involved parties in the best possible position to determine what steps need to be taken next.

To this end, we approached this research with the following primary research questions:

- *RQ_1: What types of games are people playing or not playing as a result of accessibility?*
- *RQ_2: How are accessibility barriers manifesting in real-world use cases, and how are they handled when they occur?*
- *RQ_3: Where does accessibility currently fit into the real-world design processes of the industry?*
- *RQ_4: How do game developers think the acceptance of and adherence to accessibility guidelines could be improved?*

Our work consisted of two complimentary studies. First, we conducted an online survey of 55 gamers with disabilities, having a mixture of open and closed ended questions. Next, we carried out semi-structured interviews with six individuals representing vari-

ous roles in the game development industry. By synthesizing answers to these research questions from our data, we begin to identify previously unstated issues with the adoption of accessibility in mainstream game development, defining possible directions for future study and opportunities for design.

2. BACKGROUND & RELATED WORK

The push to improve the state of game accessibility is being carried out on two fronts. In addition to traditional academic research efforts, the domain has also been the focus of numerous grassroots initiatives coming from both industry and the community.

2.1 Academic Research

Generally speaking, the landscape of game accessibility research has been dominated by projects which aim to develop specialized games that are accessible to specific impairment demographics. To date, visual impairment has been a popular area of interest. Examples include Blind Hero [28], VI-Bowling [15], and VI-Tennis [16], which seek to translate the gameplay concepts of mainstream games (rhythm in the case of the former, and exergames for the latter two) without the use of visual stimuli. Similarly, proof-of-concept games, such as the 'voice games' presented by Harada et al., take a similar approach to develop games accessible to individuals with severe motor impairments [10].

Building on the foundation of this type of ongoing work, other researchers have turned their attention to creating games that are simultaneously accessible to users with varying abilities. One of the first instances of this was *Terraformers*, a project out of Stockholm University which introduced a parallel audio-only gameplay mode into a traditionally structured first-person shooter game [25]. In favor of this type of highly specific implementation, other projects have attempted to create more general strategies for ensuring universal accessibility of games and game-like interfaces. The educational virtual world *PowerUp* from Trewin et al. used a comprehensive two-stage approach, wherein accessibility requirements were first determined using online survey inquiring about past game experiences and preferences [22] and iterative builds of the virtual world were then validated in controlled usability studies with subjects with visual or motor impairments [21].

2.2 Grassroots Industry & Community Work

Concurrently with much of the early academic work in the area, a groundswell was developing within the game development industry with a small but vocal contingent of individuals conscientious of and passionate about accessibility. After the formation of a game accessibility Special Interest Group within the International Game Developers Association (IGDA), the organization published a white paper which sought to introduce the nature of various impairments, outline strategies for avoiding resultant accessibility barriers, and establish the importance of the problem [3].

Shortly after, a number of community-driven organizations began to coalesce around the idea of taking a bottom-up approach to game accessibility, such as SpecialEffect [18] and the AbleGamers Foundation [19]. In addition to serving as information resources for gamers and developers alike, these organizations also work to connect gamers with the resources and knowledge they need to excel in-game. Most recently, in an effort to formalize the information they make available, some of these organizations have been publishing highly structured sets of design guidelines for use by the industry [7, 11].

2.3 Areas for Future Research

A common limitation across much of this prior work is a lack of consideration of the real world situation of game accessibility with respect to both disabled gamers and industry. In the case of the former, academic research on accessibility attempts to mitigate or work around critical accessibility barriers in gameplay, yet these barriers are typically predicted based on assumptions about impairments rather than through the empirical study of gamers. Exceptions to this, such as the development of the aforementioned *Terraformers* and *PowerUp*, tend to focus their attention on testing their own product (*PowerUp*'s requirements-gathering notwithstanding) rather than emphasizing the prevailing issues in commercial, *mainstream* games. Even the most rigorous attempts at prediction through heuristics, such as the 'Game Interaction Model' from Yuan et al. [27], has leveraged little empirical work to inform their understanding of the population's needs.

Industry has been equally marginalized by the style and approach of much of the existing work. Academic publications' implications sections and community-developed guidelines alike share the same primary audience: industry designers and developers. Yet for the most part, there still remains an opportunity for critical understanding of how accessibility *currently* fits into actual development processes. While it is easy to identify shortcomings in the accessibility of current game offerings and turn these into guidelines for best practices, it is much harder to ensure these messages are communicated to industry in a manner that is respectful of established practice and framed in a clear and understandable way in the context of the audience's process.

One of the strongest attempts to date to translate prescriptive accessibility recommendations into clearly-understandable lessons was the proof-of-the concept game *Game Over!*, which magnified accessibility barriers to such extremes that any individual would have difficulty overcoming them [9]. *Game Over!*'s target audience was game developers, and as an empathy tool to illustrate the criticality of accessibility barriers to them, it is outstanding. However, it too does not build on an understanding of real industry practice, and as a result comes across as assuming simplicity in the implementation of accessibility features. We believe that game accessibility research can go further to garner the insights needed to better understand the greater ecosystem of game accessibility. This research is offered as a first step.

3. PRIMING ACTIVITY

As a preliminary entry point into understanding the state of accessibility in mainstream gaming, we carried out a simple analysis task. We identified the top ten grossing PC games of 2011 in North America from a public source of sales data [23]. PC games were chosen out of convenience, as the first author —who carried out the analysis— is a PC gamer and does not own any other gaming platforms. Each game was then coded for 11 accessibility features, based on the IGDA GA SIG's 'Top Ten' [8], as either fully meeting the guideline, partially meeting it, or failing to meet it. Table 1 summarizes the activity's results. Note that 'difficulty control' and 'speed control' were grouped under the same entry on the SIG's list, but were separated here for ease of coding.

The activity revealed that some features, such as colorblind friendliness and allowing controls to be reconfigured, were almost universally present across the top ten games. However, instances of most of the guidelines were inconsistent, implying that established accessibility guidelines (which are informed by research and practice alike) are not seeing complete adoption by industry.

This suggested to us that, in spite of a rich corpus of research into game accessibility and an active community pushing standards and guidelines on the industry, video games still have a long way to go to meet accessibility standards. The guidelines and novel solutions being offered up to the development industry are not

Table 1: Top ten PC games of 2011's adherence to IGDA GA SIG's game accessibility guidelines

✖ Did not meet guideline at all | ✓ Partially met guideline | ✓✓ Completely met guideline

	I Controller Reconfig.	II Alternative Controllers	III Sound Alterna-tives	IV Volume Controls	V High Visibility	VI Colorblind Friendly	VIIa Difficulty Control	VIIb Speed Control	VIII Practice / Tutorial	IX Accessible Menus	X List Fea-tures
Star Wars: The Old Republic	✓✓	✓✓	✓	✓✓	✓	✓✓	✖	✖	✓	✓✓	✖
Skyrim	✓	✓✓	✓	✓✓	✖	✓✓	✓✓	✖	✖	✖	✖
Battlefield 3	✓✓	✓	✓	✖	✓✓	✓✓	✓	✖	✓	✓✓	✖
Modern Warfare 3	✓✓	✖	✓	✖	✓✓	✓✓	✓	✖	✓	✓✓	✖
RIFT	✓✓	✖	✓	✓✓	✓	✓✓	✖	✖	✓	✓✓	✖
Portal 2	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✖	✖	✓	✓✓	✖
Deus Ex: Human Revolution	✓✓	✓	✓	✓✓	✓✓	✓✓	✓	✖	✓	✓✓	✖
Dragon Age 2	✓✓	✖	✓	✓✓	✓✓	✓✓	✓	✓✓	✓	✓	✖
The Witcher 2	✓✓	✓	✓	✓✓	✓	✓✓	✓✓	✖	✓	✓	✖
DC Universe Online	✓✓	✓	✓	✓✓	✓✓	✓✓	✖	✖	✓	✓✓	✖

being fully adopted, and as a result, barriers likely persist for many gamers. Likewise, there must be reasons beyond just a lack of knowledge about guidelines for why these guidelines are not being met in mainstream game design. Consideration of these possible outcomes led to the development of the set of research questions listed in Section 1, which in turn motivated the two studies discussed in the subsequent sections.

4. SURVEY OF GAMERS

In this section, we outline the design of and results from our survey with gamers who have one or more disabilities.

4.1 Method

We developed a survey to address RQ_1 and RQ_2. It was composed of a mixture of closed and open-ended questions. The former focused on subjects' demographics and the types of games they play, while the latter provided an opportunity for subjects to detail how their impairments impact their ability to play games and the barriers they face. The only inclusion criteria for participation were having one or more impairments, having experience with any kind of gaming, and being over 18 years of age. We distributed the survey primarily through three avenues. First, we posted a link and brief explanation on Twitter along with a request to retweet by Twitter users with connections to individuals with disabilities. Second, we sent an email with information and the link to various disability-related mailing lists. Finally, the first author was allowed to write a front-page guest post on the AbleGamers Foundation's community site, which explained the goal of the research and solicited survey participation. We offered respondents an entry to a drawing for a $50 USD Amazon.com gift card.

We performed basic quantitative analysis on the closed-ended questions. The raw responses from the open-ended questions were separated and we used an open coding protocol to tag each statement [5]. After completing this coding, the code set was further grouped by affinity to distill final high-level themes [5]. Table 2 summarizes the demographics for the survey participants. Note that subjects were allowed to choose to identify multiple impairment classes concurrently. The values given in this table refer to the percentage of subjects who identified with a given impairment, but not necessarily exclusively.

4.2 Results

We organize the results by our quantitative analysis of closed-ended questions and qualitative coding of open-ended responses.

4.2.1 Quantitative

Our survey's closed-ended questions focused primarily on participants' play habits, as per RQ_1. We first asked about the platforms on which participants typically played games, allowing them to select multiple from a list of the four major groupings: consoles (e.g. Xbox, Wii), non-gaming-specific mobile devices (e.g. iOS devices), gaming handhelds (e.g. PlayStation Vita, Nintendo DS), and computers (i.e. PC, Mac, or Linux) (see Figure 1).

Across the board, PC/Mac/Linux gaming was the most popular gaming platform for all impairment classes. Console gaming was the second most popular, with hearing impaired gamers playing on consoles more frequently than any other group. Gaming handhelds had the lowest usage rates of any platform for motor, visual, and cognitive impaired participants, and the second lowest rate for hearing impaired participants. It is unclear from the data whether we can assume this to be indicative of any inherent accessibility challenges of the platform, however, as such handhelds in general are witnessing a steep decline in popularity since the rise of smartphones and other mobile devices [17].

We also asked participants to report, on a seven point scale, the frequency with which they engage in play in four distinct styles: single player independently, in which the player is self-sufficient; single player collaboratively, in which the player works with one or more other people to collaboratively play a single player game; multiplayer online, in which the player engages with one or more

Table 2: Respondent demographics for survey study

Total Survey Respondents: 55	
Age	10-29 (51%), 30-39 (20%), 40-49 (20%), 50-59 (5%), 60+ (2%), No Response (2%)
Gender	Male (58%), Female (38%), Other (2%), No Response (2%)
Impairment Class (not mutually exclusive)	Motor (69%), Visual (11%), Hearing (16%), Cognitive (15%)

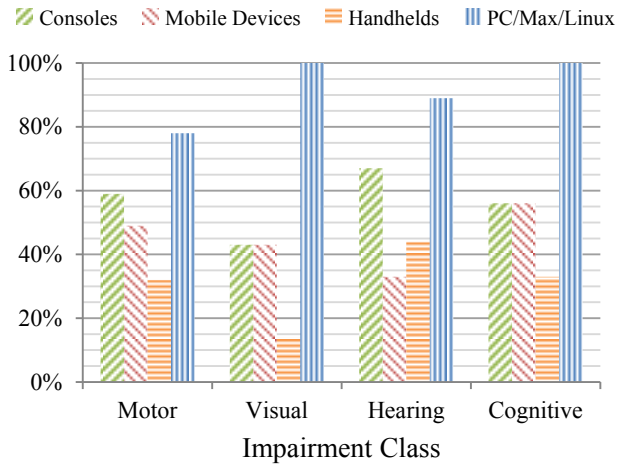

Figure 1: Percent of participants from impairment classes who play on different major gaming platforms

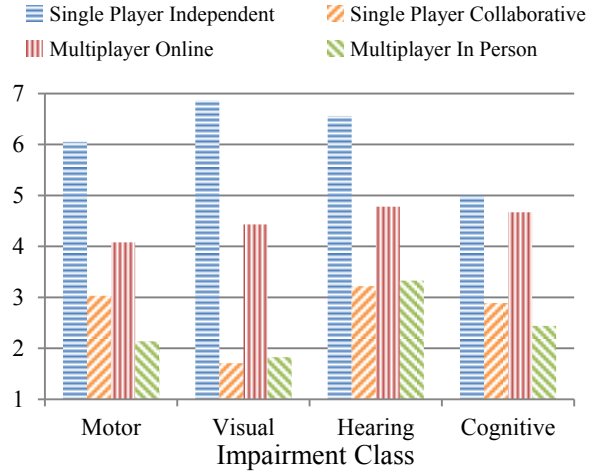

Figure 2: Reported average frequency (7 maximum) with which gamers play in four general play-styles

remote partners; and multiplayer in person, wherein the player is collocated with others to play a multiplayer game (see Figure 2).

For all participants, multiplayer gaming of any sort was reported to be engaged in far less frequently than single player (independent) gaming. Given the current general popularity of multiplayer gaming across all platforms [23], this is a somewhat surprising result, indicating that there is possibly something inherent to the multiplayer style that pushes away or does not appeal to gamers with disabilities. Collaborative single player gaming, while universally less popular than playing independently, was most common among the motor and hearing impaired participants.

An additional potentially telling finding can be taken from the demographic information and concerns the reported impairment classes visible in Table 2. Motor impairments were predominant across the participants, with the highest occurrence rate of any impairment class by a large margin. If this is to be taken as representative of the landscape of disabled gaming in general, it raises the obvious question of 'why?' While all motor impairments combined indeed represent a larger percentage of disabled population than the other impairment classes [1], the difference does not explain the entire margin seen here. It is worth noting that most popular impairment-class-specific subforum on the AbleGamers Foundation's online forum is the one focused on motor impairments, suggesting that motor-impaired gamers make up the bulk of the AbleGamers community. This could be seen as a source of potential selection bias for the present study, given that the AbleGamers community was one of our recruiting vectors. However, it can also be interpreted as further evidence that this trend holds true beyond the context of our research.

4.2.2 Qualitative

We here outline the themes distilled from the qualitative coding toward answering RQ_2. We include direct excerpts from respondents to provide example cases of the relevant phenomena.

Incompatibility with assistive technologies

Participants frequently stated that a common root of many accessibility barriers is an inability to interact with a game using the assistive technology solutions they require. Visually impaired gamers noted that their text-to-speech systems are often unable to interpret the information being presented by the game's interface.

> *"There have been many games I would like to play, but they […] aren't screen reader accessible"* **–F, 18-29, Visual Impairment**

Assistive technologies which modify the ways in which a user can send input to a game are vulnerable to the same limitations, according to subjects.

> *"This has happened quite frequently. It is usually games that are "Games For Windows". For whatever reason, these games usually do not work well with other programs such as 'autohotkey'."* **–M, 18-29, Motor Impairment**

> *"Some games don't recognize input from my onscreen keyboard. I give up right away."* **–F, 40-49, Motor Impairment**

Even in the context of consoles, when careful licensing control of peripherals generally ensures compatibility, modified assistive controllers sometimes fail to work with games as expected.

> *"Some PS3 games are not working with my Quad Controller."* **–M, 18-29, Motor Impairment**

Participants with such experiences expressed a shared frustration, making comments about confusion as to why assistive technologies work in some cases but not others. At times, the blame was placed directly on game developers.

> *"My voice commands work fine in most games, so I dont understand why the developers wont let them work everywhere."* **–F, 30-39, Motor/Cognitive Impairments**

Asking for help

In cases where a player is unable to fully engage with a game, even with the aid of assistive technologies, a frequent strategy appears to be getting assistance from others when a barrier arises.

> *"I can also have a roommate help with stuff like QTEs [Quick Time Events] that I don't have the dexterity to pass even with my controller."* **–M, 18-29, Motor Impairment**

However, while many may leverage this sort of 'social assistance,' there seems to be an accompanying reluctance and feeling that it diminishes the gameplay experience.

> *"Every console game that comes out now I rely on my PCAs [Personal Care Attendants] to play for me, with strategic in-*

put on my part. It's not the same, but it's better than nothing." **–M, 18-29, Motor Impairment**

Some even choose to forego this option, expressing that the diminishing effect defeats the purpose of playing the game entirely.

"There's World of Warcraft--always wanted to play that, but there's been no way to do so. I looked for several months […] and found no way I could participate, unless I had [someone else] control the computer for me, which to me takes away the fun of the game." **–F, No Age Given, Visual Impairment**

Motor impairment complicating multiplayer

Participants cited a perceived inability to be competitive, as a result of their motor impairment, as pushing them away from multiplayer gaming. Frequently, phrases such as 'keeping up' and 'level playing field' came up in describing this effect. Often, participants used language indicating a strong desire to be able to play multiplayer games were it not for this issue.

"I have always wanted to play either Xbox 360 games or PS3 games but could never find a way to play at a level like everyone else." **–M, 18-29, Motor Impairment**

"I used to play totally different kinds of games- racing, GTA, skateboarding, but now play mostly casual or sim games since I can go at a slower speed. I no longer play multi player since I can't keep up with other players." **–F, 50-59, Motor Impairment**

Other times, social pressures and feelings of being 'different' push players away from multiplayer gaming, even when their impairment does not compromise their competitiveness. A perceived fear of acting atypical in some way as a secondary result of impairment results in a strong social pressure that at best makes multiplayer uncomfortable for the disabled gamer and at worst makes them choose to avoid it altogether.

"I get very frustrated and have trouble communicating w/ other players properly & in turn, they react negatively to me." **–F, 40-49, Cognitive Impairment**

"I can't always control sudden movements that my hands make and sometimes that affects my playing. it's why i generally don't play collaborative games since it annoys ppl [people] when i do sudden weird things." **–F, 18-29, Motor Impairment**

5. INTERVIEWS WITH GAME INDUSTRY

To understand the perspective on behalf of game developers, we also conducted an interview study with people who play various roles within the development cycle at several different game development studios.

5.1 Method

To gain a deeper understanding how accessibility currently fits into the real-world design practices of game development, we conducted a series of interviews with individuals with various roles in the game development and publishing industries. The interviews were semi-structured with questions designed to speak to aspects of RQ_3 and RQ_4. After addressing an initial question set with participants, we provided a copy of the results from the initial priming activity where we coded the top 10 games for their adherence to accessibility guidelines (i.e. Table 1) as a prompt for further discussion. We used a combination of word-of-mouth and cold-contacting to reach out to individuals in the Seattle area who work in the game industry in some capacity. In all, we recruited six participants (P1-P6) who were interviewed on four separate occasions; three of them worked for the same company and were therefore interviewed as a group for convenience. The interviews were audio recorded and transcribed, and an open coding and grouping process was used to identify key concepts and themes.

5.2 Results

The grouping of interview transcript codes yielded numerous high level themes, and many bear direct relevance to RQ_3 and RQ_4. These themes are listed and described here, along with evidentiary direct quotes from our interview participants.

'Low-hanging fruit' of accessibility comes first

From the interviews, it was apparent that certain accessibility features are more likely to be implemented simply because they are easier or more straightforward. Examples include colorblind-friendly color palettes and inclusion of subtitles.

Several participants directly acknowledged simplicity as a factor in how they prioritize which accessibility features they can and will address.

"I'm always looking in the beginning at colorblindness." **–P3**

"Colorblind-friendly colors and including subtitles…yeah, I think those are the first two we get around to early in the [development] cycle, because I guess they're the easiest and most obvious. Low-hanging fruit is always attractive in software development." **–P6**

One participant emphasized that a major factor in determining the ease with which an accessibility concern can be tackled is the ability variance within the relevant impaired population.

"If someone has a hearing impairment, you just need to put text on the screen to mirror important audio cues. If they're colorblind, you don't use colors as a sole distinguishing…you know, trait. […] It feels like a straightforward equation – if this is the impairment, that is the solution. But with things like motor impairment, when one person's needs can be so different from the next, and the same solution won't work for both, it's a lot harder." **–P1**

Value of in-house expertise

Even when the accessibility goal is clear and simple, it only gets addressed if somebody is conscientious of it and makes it a priority. While some such needs might be obvious enough that any designer or developer should be able to recognize them, others are less so. One of the strongest themes to come from the interviews was the value of having individuals with impairments —or at least a familiarity with them— involved in the development process to inherently advocate for these concerns. Multiple participants mentioned cases where coworkers with impairments identified potential issues early, allowing low-investment changes to be made.

"We sort of cheat at [attention to colorblindness] because we have several colorblind people in the studio, so it's covered for us at all times." **–P4**

"I remember one case where one of our test coordinators…he had problems with one of his hands, and it made it hard to hold it in a certain position on the keyboard. During an early pre-alpha demo we had, he noticed what the person running it was having to do on the keyboard, and commented that he wouldn't be able to do it. The devs overheard and implemented it so you could change the controls. […] If they hadn't

caught on that quick, I doubt they would have been so eager to roll a new feature." **–P6**

One interview participant offered the following perspective on the way the game industry's transitioning demographics have altered conceptualizations of game accessibility.

"If you think about the game industry up until very recently, relatively speaking it's been predominately dominated by young men. These are guys that are young. They feel immortal. So when you talk to them about things like hearing loss, vision loss, fine or gross motor impairment, things like that, it just doesn't even register. They have no concept. Now the great news is that game developers have become much more diverse over the years […] and we're starting to see individuals with disabilities coming in." **–P2**

This is a particularly interesting insight because it goes beyond speaking to a lack of awareness or education. It posits the possibility that, at times, certain impairments are truly so foreign a concept to able-bodied individuals that they are unable to conceptually grasp their implications. In these cases, the power of outside voices speaking to the importance of accessibility is fundamentally dampened. While the changing demographic landscape of the industry may in this sense explain past resistance to accessibility advances, it similarly suggests the possibility of a brighter future.

Pressure to adhere to standards

A key determining factor in whether or not an accessibility issue is addressed comes down to where the call to act originates. One participant commented that pressure to adhere to standards would ideally come from internal positions of authority, such as executives, making them ideal targets for accessibility education and outreach efforts.

"If [pressure to make games accessible] isn't coming from higher up internally, like a director with a personal interest or stakeholders or something, it's much less likely to get done. They're the ones you need to get through to." **–P1**

Multiple participants specifically made mention of legislation as another —perhaps even more effective— potentiality to drive action on the part of developers and publishers.

"The 21st Century Communications Act and the fact that now there is going to be more scrutiny on game consoles and the software that runs on it I think has gotten more attention from game publishers on making games more accessible. Because it becomes something they can't ignore anymore." **–P2**

"If the government mandates and says 'here are the standards, meet them or we'll fine you" or something, that might work. Buildings have ramps because of legislature and mandates, not because every architect decided to follow best practices." **–P1**

Role of middleware

The most common unprompted idea for improving the status quo of accessibility to come out of the interviews concerned middleware. In this context, the term 'middleware' refers specifically to a game's underlying engines, or in another sense, the framework on which it is built. There is an entire sibling industry to game development centered around creating such middleware. Game developers often implement their game ideas using these standard starting points when it is easier or more cost effective than writing all underlying code from scratch. As a result, games from different studios often share the same engines for graphics, input handling, and other common requirements. Examples of popular middleware include Gamebryo, the Unreal Engine, and Unity.

Because middleware handles low-level functions of game presentation and interaction, participants noted that they were the best way to handle implementation of certain accessibility features.

"From a console gaming perspective, [assistive technology] wise, a lot of it relies on middleware companies to put in some of these hooks, some of these features" **–P2**

"We would love to be able to do things like make the game self-voice or be parsable by text-to-speech systems, but that's just not feasible with the engine we're using. From a design perspective, tagging UI elements, objects, bits of the game environment with metadata for blind players wouldn't really be that intensive. […] But the problem is, that information has to get sent out to the OS level in a way that is compliant with what the text-to-speech system is listening for, and that's something that wouldn't be feasible to develop from scratch. It would have to be supported by our engine." **–P6**

One of the perceived burdens in making games more accessible is the resource cost in time, effort, and money to implement changes. With minimal software asset sharing between game projects within a given studio (beyond common engines, if applicable), the prospect of having to reengineer solutions to the same set of problems over and over is daunting and unattractive. But if these features were part of foundational middleware, some believe the problem would be seen as more approachable and guideline adherence would increase.

"Having game developers reinvent the wheel every single time they do a game with accessibility is going to be a pain. If the you know Unreal engine itself supported some core accessibility functionality, and publishers didn't have to reinvent it over and over, you're much more likely to get people to [follow accessibility guidelines]" **–P2**

The game developers themselves do not see achieving this goal as their responsibility, understandably, as middleware is largely outside their spheres of influence. Instead, it is suggested that the same bodies developing and defining accessibility standards on the PC reach out to console manufacturers and middleware developers alike to begin introducing standardized accessibility.

"In a perfect world, what I would love to see is people who specialize in software accessibility on the PC go to console manufacturers and say 'we know that there is all this great middleware out there that you guys are already utilizing, what are the common ones you're using? What we'll do is go engage with them and say here's how we can inject accessibility.'" **–P2**

Difficulty implementing assistive tech on consoles

A final theme concerned the difficulty designers face whenever they attempt to develop novel input hardware for a console. Developers expressed that, in many ways, the world of consoles is a series of walled gardens. Unlike traditional computing, where set standards like USB and Bluetooth allow anyone to develop and release new peripherals, console manufacturers each use their own systems, making cross-console design difficult. Moreover, they require the inclusion of proprietary identifying hardware (i.e. chips) in peripherals, making circumvention of their strict and extensive approval processes impossible.

"It's hard when you have first party…developing and shipping out console hardware. They make it almost illegal to mess around with that. Whereas with a PC, it's just a USB cable, and you program the software." **–P4**

"Developing hardware input devices for consoles is costly. It's a hard process to go through Microsoft and Sony. They want to have their own chips in it. You can't monkey around." **–P5**

Rather than speculating that this way of thinking on the part of console manufacturers might change at some point, it was theorized that the event which will change the status quo would be the personal computer's transition into the living room.

"That gap will probably be bridged whenever the PC makes it into the living room, which will probably be soon. That will probably start switching then. You'll be able to plug and play any [assistive technology] devices." **–P3**

6. DISCUSSION

From the quantitative analysis of the empirical data garnered by these studies, we can begin to cast a spotlight on some specific facets of the real-world context of game accessibility issues.

6.1 Barriers: manifestations and solutions

Considering the quantitative data from Study I, it would seem that computer gaming is by far the most favored among the disabled based on this sampling. The ability to use a more diverse selection of assistive technologies than are available on competing platforms makes computers a far more flexible option. While still enjoyed by a large percentage of gamers with disabilities, consoles present more issues. Themes distilled from the interviews concerning console development highlight the difficulty faced by developers when attempting to develop new assistive hardware or implement software accessibility features. This research did not attempt to classify survey participants according to impairment with more granularity than overarching class, but had it, it is plausible that we would see an even sharper drop off in the percentage of console gamers among those with more serious specific physical or sensory concerns.

Also worth further attention is the finding that multiplayer games are pushing away gamers with disabilities. Some of the contributing factors call for further inquiry, such as understanding the aspects of multiplayer gameplay which make implementation of accessibility features more challenging. Others, such as the social factors relating to real or perceived stigma, are much more complex and will require solutions that go beyond just technology.

Surprisingly few participants described barriers related to commonly known accessibility requirements such as an inability to hear critical audio or visually distinguish artifacts (outside of cases of total visual impairment requiring text interfaces). This could simply be a result of our survey sample consisting of mostly individuals with motor impairments. However, it is also plausible that these barriers are actually less common now. Considering the interview theme of low hanging fruit, it would seem that some of these more straightforward features of inclusion have reached a degree of cultural penetration in the world of design that they are being addressed on a regular basis, which is very promising. If the technical barriers associated with some of the more challenging accessibility issues could be addressed, there may be more of an opportunity to make games more accessible in the near future.

At a high level, it would seem that the majority of current barriers to accessibility tend to manifest as an incongruity between games and the assistive technologies or input modalities a user is attempting to play them with. When facing such a circumstance, gamers tend to be relatively persistent and work to find alternate ways to achieve their goal. One of the more common strategies, as stated earlier, was seeking the assistance of able-bodied friends and family. This might seem like a strange workaround that, as ASSETS researchers seeking to facilitate independence, we should not bother designing for. But alternately, we can interpret it as another potential use case for the kind of 'human-powered access technology' proposed by Bigham et al. [4]. Social assistance has always been a powerful asset to the disabled community when it was impossible or unfeasible for technology to meet a given need. Given the current state of game accessibility, it might be a compelling design opportunity here.

6.2 Access and industry: bridging the gap

It is apparent that the landscape of game development is as dynamic as the evolution of games themselves. The steady (albeit perhaps slow) influx of a more diverse workforce including individuals with disabilities has made concerns relevant to accessibility more prominent in the industry than they have been before. Studios which are fortunate enough to have in-house expertise on accessibility are made aware of potential issues earlier in development cycles, making developers more willing and able to address them. Outreach efforts that seek to encourage people with disabilities to participate in the game design community may make a positive difference in this area, much as other research has sought to promote inclusiveness in computing fields through engagement with racial or gender minorities (e.g. [6]).

Yet in spite of this, the status quo of game accessibility has much room for improvement, as published guidelines are still not being followed by many mainstream and independent studios. The participants from industry we spoke to suggested that initiatives to improve accessibility need to come from the top down. While developing novel accessibility solutions and publishing guidelines is constructive, these steps will only be optimally effective when the audience they specifically address are the stakeholders and executives with the authority to drive change.

From our findings, it seems apparent that middleware is one of the most promising directions for future work in this domain. Nearly every participant acknowledged that the introduction of standardized accessibility features into widely utilized middleware packages would dramatically accelerate the industry's adoption of accessibility guidelines. This type of solution is appealing to developers at a fundamental level because it allows them to more easily implement features which they might not otherwise have the resources. Through the identification of assistive technology incompatibilities as a predominant cause of accessibility barriers from the survey, it is also clear that such an approach would be a pragmatic way to address numerous accessibility needs at once. We made efforts to engage directly with middleware developers to better understand the potential future role of middleware in game accessibility from their perspective, but have thus far not had success in recruiting interview participants. Even so, we have no reason to believe attitudes would be significantly different within that facet of the industry.

7. CONCLUSION

We believe that, by delving deeper into the practical state of game accessibility in the real world through study of the perspective of gamers with disabilities and the game development industry, we have identified key areas for consideration as future work in this domain. Based on industry's identification of middleware as a critical link in the chain of accessibility, invested parties (be they

researchers, community organizations, or forces from within the industry itself) should work with middleware developers in an effort to define and implement standardized accessibility features that can be carried across platform lines. Not only would this help to mitigate many of the compatibility issues gamers with disabilities face when using assistive technologies, but it is likely that it would promote and facilitate uptake of accessibility standards in general. Additionally, we believe researchers in the intersection of assistive technology and community/crowdsourcing should also consider this application space, as our findings regarding gamers' leveraging of social assistance to overcome accessibility barriers highlights a potential intervention target.

Our survey sample cannot be assumed to be completely representative of the population of all gamers with disabilities. However, given the inherent challenges in recruiting from such a small subset of the population, and as this research is presented as only a first step calling for a more thorough and comprehensive understanding of the game accessibility problem space, we feel that our findings are valuable. Above all, we hope that this work can serve as a demonstration of the types of insights that can be gained from interacting with the broader ecosystem of game accessibility. We believe that our research suggests the kinds of directions for further work—by academia, industry, and the community alike—which are not apparent until one begins to expand the framing of game accessibility to include all relevant perspectives.

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