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Inaccessible through oversight: the need for inclusive game design

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Abstract

Games are an important part of modern culture. The nature of most video games is such that it can be difficult for individuals with impairments to enjoy many titles. In many cases, this is not due to the games themselves presenting an impossible challenge, but because the games have been left inaccessible through the omission of common features. Mainstream titles are often accessible and inaccessible by turns. This strongly suggests that the resultant inaccessibility is an oversight rather than conscious design. Awareness building is an important process in improving the inclusivity of game titles. This in turn is important in ensuring that all members of society have an opportunity to enjoy a valuable recreational form. To this end, the essay discusses both the types of disability that could be supported and some common mechanisms by which this can be done. A short overview of several prominent game titles is included to provide real world context for the discussion. In this essay, the author argues that ensuring accessibility need not be a costly or an onerous task, and that great strides can be made by, simply adopting the existing good practice that is currently spread across mainstream titles.

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1: Introduction

It has become increasingly easy over the past few years to make a cogent case for the importance of video games in modern culture. Once, they were perceived to be a niche entertainment format enjoyed only by nerdy boys in the privacy of their bedrooms or in the speakeasies of the video arcades. The first video game developers were hobbyists who rode the contemporary wave of increasingly available computer technology, turning their love for the form into what would eventually become a multi billion pound world-wide industry. Computer games have changed the way in which we appreciate and interact with entertainment, and the impressive growth rate of the industry in terms of contribution to GDP and in real-terms sales is well documented (Entertainment Software Association, 2008).

Games now stand with movies, television and music as pillars of our modern culture. Playing computer games is no longer a marginal recreational activity but part of what it means to be an active participant in modern society. In the same way that access to other recreational forms is important in maintaining cohesion in a society, games have become part of our common cultural vocabulary. These are all encouraging trends for the industry,

Games are not simply ‘more of the same’: they have marked differences from many other forms of recreational entertainment in that they are active, rather than passive – we interact with games, we do not simply sit back and experience them. Not only this, we interact in a way that often requires a combination of nimble fingers and keen eyesight along with a grasp of timing and the ability to react within limited windows of opportunity. While this is not true of all games, for a substantial subset of the library of computer titles it is simply the case that if you lack the physical means to actively engage with a game, you simply cannot appreciate it in anything other than an observer capacity. Many games are inaccessible to individuals with physical or cognitive impairments. Sometimes this is a consequence of game design, but more often it occurs as a result of oversight. There is not a lot that must be done to make games accessible to the majority of disadvantaged individuals, but it is often not done simply because accessibility is not a high profile issue within game design.

This essay will argue that creating more accessible video games is both important to individual gamers, and also something that can be done with relatively little difficulty on the part of game developers. I will also discuss why this issue is important to gamers everywhere, and not only those unfortunate enough to be locked out of this common cultural recreational format. It is the hope of this essay that it can inspire developers reading to make accessibility a core deliverable with regards to the products they put out.

2: A brief overview of the problem

The core assumption in this essay is that many of the problems in producing accessible computer games are due simply to a lack of awareness, not just of accessibility as an issue that is germane, but also in terms of what actually constitutes an accessibility feature. The word itself conjures up an image of a massive additional development burden against what are often unknown and unknowable criteria. Accessibility is not a high profile issue, and this is not something in which games development is unique; even on the desktop and on the web, accessibility lacks the kind of wide-scale developer acceptance that is common to issues such as standards adherence. This in itself is a substantial problem, because raising awareness is difficult. Long, sustained efforts in this regard within fields other than computer games have resulted in accessibility becoming a ‘core deliverable’ of some software development (c.f. Heron, 2011; Heron, Hanson and Ricketts, 2011; Waller, Hanson and Sloan, 2009), but far from enough. However, accessibility features are built into the bones of many operating systems now. While there are many issues that remain to be solved, at least progress is observable.

However, this author does not see the issue being treated with any seriousness by either the games industry or the games press. In the world of academic research, the topic is unusual even within the comparatively niche field of accessibility itself. There is work out there (c.f. Trewin, Hanson, Laff, and Cavender, 2008; Yuan, Folmer and Harris, 2011; Allman, Dhillon, Landau, and Kurniawan, 2009), but it stands out almost precisely because of its rarity. Even were it the case that there were reams of academic research available, the sets of ‘accessibility researchers’ and ‘computer game developers’ contain relatively few overlaps and thus there is a difficulty in ensuring the research feeds meaningfully into the development process.

In addition, the problem is easily brushed away with arguments such as ‘well, there are people developing accessible games’, or ‘disabled gamers aren’t really a big market’. This thinking however is flawed on two primary grounds. The first is that most gamers don’t want to be stuck in separate ‘gaming ghettos’ where their only choices are specialised accessibility games. Disabled gamers, like the rest of us, want to play the best games that are out there. Audio games for the blind are an example of ‘accessible games’ that, while part of a solution to the accessibility issues in computer

gaming, are not enough in themselves. Such games are best provided as an extension to the game-play experiences available to others, rather than as an alternative for those unable to play the 'real' games.

The second problematic assumption in these arguments is that disabled gamers are a small market. Robinson and Walker (2010) estimate that around 32.5 million potential customers are lost to the industry as a result of inaccessible games, but even this noteworthy figure pales into comparison when one realises how important accessibility is for people who don't consider themselves disabled. Accessibility makes for a better game-play experience for everyone, it's just that certain groups will benefit disproportionately.

Developers have always found it difficult to write software for people with a significantly different profile of wants and needs (Keates and Clarkson, 2002), and the majority of developers are not disabled gamers themselves. As such, games tend to be designed for 'people like me'. This is at the core of both the problem and the solution – it is hard to convince people that they should be employing more disabled developers and in-house testers, but it is comparatively easy to convince them that accessibility is something that benefits 'people like me'. Awareness raising in this case then begins with a healthy dose of enlightened self-interest.

3: How games disadvantage gamers

Before we address how gamers are currently disadvantaged by many games, let us consider some of the categories of disability that must be addressed. Part of the problem is that there is no single solution for accessibility, and that which works well for one group may not work well with another – or worse, may stop working for particular individuals as their circumstances change. For example, automated speech generation is a reasonably good solution for many blind users with regards to dealing with large passages of text. It becomes less useful as one ages because it becomes more difficult for the brain to parse synthetic speech (Pullin and Newell, 2007). Thus, while this essay will differentiate between groups in this section, it should not be taken to mean that accessibility should be approached piecemeal. In reality, subtle blends of minor ailments are omnipresent, and even those who are 'blind' or 'deaf' have some degree of ability to discern light or sound. Moreover, even those of us who do not identify ourselves as being impaired often have minor ailments (such as poor eyesight) that could be addressed by more general accessibility solutions.

With that, let us talk about blind players. In many ways, this group is the one most disadvantaged by computer games and the one that would seem to be the least supportable by accessibility solutions. One of the primary characteristics of most modern computer games is that they rely heavily on visual processing. Leaving aside specialised accessible games and the continuing relevance of text-based gaming, a large number of games are simply going to be difficult or impossible for blind individuals to play. Any game in which visual parsing is the only way in which information can be obtained is going to suffer in this regard. However, even given this tremendous disadvantage, there are inspiring stories of blind gamers who have learned to master games through sound alone. Valve's *Left 4 Dead* (2008) is cited as an example (Schrier, 2011) in which the three dimensional soundscape can be used to locate enemies and path-find through to the goal. However, this is possible in part due to clever sound engineering and also the relative sparseness of audio – games in which multiple sources of sounds are heavily layered (such as the explosions, gunfire and screams that characterise many modern FPS games) obscure too many of the audio cues to be accessible.

Deaf users are perhaps the group best served by computer games already – subtitles in cut-scenes and dialogues are common, and even close-captioning is becoming more and more commonplace.

However, in cases where such support is not provided, deaf users become disadvantaged when information is presented only along the audio channel. If the sound of gunfire is the only immediate sign that their character is being fired upon, then deaf players will find it difficult to react in time to game-play events. Part of good user-interface design generally is that important information should not be restricted to a single channel of sensory input, and most games are generally good at incorporating visual or haptic feedback along with game events. The intention of this is often to increase the sense of immersion, but it has considerable positive impact on accessibility for the deaf.

The next major category of disabled users is those with mobility problems located either in one or both of their hands. Some users may have full control in only one of their limbs; others may be restricted to either a mouse or keyboard, but not both. Some can interact only with the use of specialised hardware such as switch controllers. Switch technology can range from simple buttons to proximity controls and beyond, and the key versatility is that they can be 'mixed and matched' to provide an accessible input regime specific to an individual. Other devices, such as accessible game controllers, allow for switches to map onto the regular buttons for a console – a switch controller may be controlled by foot, mouth, speech, or fingers and consist of any number of individual controls. Thus, with a suitable setup most users with movement impairments can work a game controller, although often lacking the speed and precision that can be accomplished with the normal two-handed setup gamers would use with a standard device.

Such regimes however are only appropriate when the user has the option to change the default configuration of controls. They must be able to map controller buttons to particular actions so as to ensure that the most commonly performed activities are handled by the switches that are most physically appropriate. While such facilities are very common in computer games, they are not universal and the lack of such functionality effectively disenfranchises physically impaired gamers from playing those titles. In addition, the restricted set of movement and functionality available via switch devices mean that games that require pinpoint precision, constant movement, fast reactions or complex combinations are disproportionately difficult to play. Many games offer appropriate compensations for these requirements, such as auto-aim, precision adjustments in controls, multiple levels of difficulty and other popular features – but more could easily be done to make games playable to those who must use non-standard controllers.

There are many more categories of special requirements than can be discussed in this essay – colour blindness and cognitive impairments are two categories that come especially to mind. Space limitations prohibit a full discussion of the topic, but I would be delighted to discuss other opportunities with interested parties. I do however want to discuss one other additional group in line with my statement above that accessibility is a 'big tent' issue – the group is that of older gamers.

The literature demonstrates that people who start gaming tend to keep gaming (Entertainment Merchants Association, 2009), and that as those of us who grew up with computer games age, we continue to play. The Electronic Software Association (2011) statistics show that on average an adult gamer has been playing for more than 13 years. There is no reason to assume that lifelong gamers will become less interested in the format as they age. Indeed, trends reported by Deloitte (2009) demonstrate that the number of baby boomers who have played a recently released game 'within the last six months' have more than doubled in some years.

This is where our self-interest should guide us – we are all getting older, and as a consequence of the aging process we are all becoming gradually less physically and cognitively able than we were the year before. Nielsen (2008) demonstrates studies that show a year on year decline of 0.8% performance in certain tasks from the age of 25. The aging process brings with it declines in fluid intelligence (Zajicek, 2003), eyesight (Fozzard, 1990; Schieber, 2006), psychomotor control (Stroop,

1935), ability to discern audio (Fozzard, 1990; Kline and Scialfa, 1996), cognitive capacity (Sharit, Hernandex, Czaja, and Pirolli, 2008; Nielsen 2008) and working memory (Laberge and Scialfa, 2005). In addition, as we grow older it becomes more likely that we will become afflicted with disabilities as a consequence of aging (Newell and Gregor, 2002), but also that we will have our own unique portfolio of minor impairments, none of which are significant enough to be considered a disability but which work together to make it harder for us to engage with games. Those issues which affect disabled gamers now are issues that will increasingly affect us as we grow older. Rational self-interest dictates then that we make accessibility in the here and now the norm, so that it becomes part of the cultural expectation in the future.

Even leaving aside our own inevitable physical and cognitive decline, we are all being disadvantaged by the current state of accessibility in computer games. The work of Newell and Gregor (2002) argues that there is little difference between an extraordinary user (in this context, a gamer with physical disabilities) and an ordinary user in extraordinary contexts. Games that are accessible to the deaf are also playable to those of us who prefer to play with the sound off or who must wait for a replacement sound-card in the mail. Games that offer fine-grained control over precision and auto-aiming will still be possible for us to play when we are laid up in bed with a broken arm. We are in extraordinary contexts more often than we might think, and we too can benefit from a better accessibility regime in games even if our needs are only fleeting.

4: Simple design principles

All of this may sound disheartening if you want to put accessibility as a core focus of your development. Given the range of problems that must be supported, it may seem impossible to find the time and money to add accessibility features. Happily, this is only a problem of perception – many games are entirely playable with only the right range of commonly incorporated features. These features often aren't envisaged in terms of accessibility– the rich audio landscape of Abe's Oddysee (1997) for example was never envisaged as an aid for the blind (Schrier, 2011). However, the inclusion of many features I will discuss in this section is commonplace. It is their exclusion that creates for problematic situations. It is my belief that the decision not to include such feature stems from the fact developers are not aware of how important they are as opposed to more substantial reasons such as cost or time constraints.

First of all, close captioning (or at a minimum, subtitling) is vital for creating an accessible game for the deaf. Importantly, this shouldn't be limited to just cut-scenes and dialog, but should extend to every part of the game world. A small text snippet such as [gun fired close by] during regular play will allow for gamers to react to in-game events. Subtitling incidental dialogue will ensure that immersion is maintained, although it is a common sin in subtitles to fail to indicate who is speaking. However, subtitles by themselves are not enough – it is also important that people be able to control the text that is presented. Allowing players to adjust colours, sizes and (if possible) fonts ensures that even if deafness is combined with minor eye-sight impairment it can be adequately supported.

In some cases, where the text is integrated directly into the game world (such as in Deus Ex: Human Revolution, where much information is to be found on in-game computers) it may not be technically or aesthetically possible to support different fonts and sizes. In such cases, offering a zoom facility can act as a happy medium.

Related to this is the importance of providing important game feedback along multiple channels of output. It's not enough for a game to indicate my space-ship is on fire with a red light on the cockpit controls. Those who are colour blind are going to miss that and find the gameplay to be frustrating as

a result. Where aesthetic considerations prohibit control over colours, multi-modal output is vital. Sounds accompanied by visual cues are both more striking and accessible, and where they are conceptually problematic they can be relegated to preferences in the game options.

A more costly, but ultimately extremely rewarding, option is to ensure that your audio landscape can be 'layered'. Pertinent gameplay information that is otherwise available only visually should always be accompanied by meaningful sounds. A set of footsteps drawing nearer and then receding can, when accompanied by three dimensional sounds, allow a blind player to navigate a game through audio clues alone. However, as indicated above, complex audio environments such as battlefields can limit the usefulness of audio clues because they are drowned in the general background of noise. Games allow us huge amounts of control when it comes to rendering graphics – we get to choose texture qualities, bloom, shadows, anti-aliasing, draw distance, and more. A regime in which similar control is given over to audio would provide great benefits. Setting the individual volume sliders for game-play noises, background noises, and immersion noises; or being permitted to switch categories of sound off entirely, would allow for an individual to create a playable, personalised audio profile.

Many games allow for the volume of in-game events, music and background noises to be set already – all that is required is a little more differentiation between those events that are vital to navigating a game world, and those that are mostly immersive. Finally, since many in-game events may have no sensible, realistic audio cue, it would be useful if these were accompanied by 'accessible' sound cues that could be turned on when needed. Instead of silence, for example, provide a pattern of beeps. The ideal regime would be one with a rich, expressive soundscape and within which I could turn on accessible sound cues, turn up the volume of pertinent gameplay information, and turn down 'flavour' sounds.

As to game options, it would be wonderful if games incorporated speech output for their text-based menus, so that they were more easily navigable by the blind. I appreciate though that this is something of a 'wish list' request.

I discussed above how switch input devices can be combined with special controllers to create an input regime that works for those with mobility problems. As a developer, there are a handful of minor things that can be done to make this work properly. Offering control mapping is the first and most important of these. Individuals with severe mobility restrictions must often ration their inputs, focusing on only the core functionality rather than on the full range of game mechanics. It is vital then that the limited number of switches be permitted to activate the game inputs that are most useful. Thankfully, control mapping is very common – problems remain though until control mapping is ubiquitous.

There are additional things that can be done at the game design level to create accessible games, but these overlap between technical considerations and mechanics design. Towards the technical side of the issue, an accessible design will allow for auto-aiming, fine-grained precision settings on controls, a control flip for left handed players, and different levels of difficulty. Allowing targets to be set without turning to face them is also a huge boon for disabled gamers. A seldom seen but hugely appreciated feature is to allow games to be played at different multiples of 'regular speed' – someone with control issues can benefit hugely by playing a game at half, or even quarter, speed. As with all accessibility settings they don't need to be the defaults for your game, but having the options there will allow a wider range of people to enjoy your work.

A more complex and integrated solution is to build a game which is beatable using only a subset of game abilities. Such a game is infinitely preferable, in terms of accessibility, than one that requires complex combinations of abilities and a wide range of niche mechanics. Here we run the risk of having accessibility impact on the game-play experience of everyone else. It is entirely

understandable that developers would not want to potentially compromise the integrity of their designs to ensure accessibility, but perhaps as a compromise it should be permitted for players to 'skip' sections of the game that they simply cannot beat. Having failed to perform a task four or five times in a row the player can be asked 'do you want to move to the next bit' and thus there are no walls to progress based on complexity of required input.

5: Examples in modern games

All of this is somewhat abstract and perhaps unconvincing as a result. It is easy to say 'all games already do this', but examples of violations are tremendously common. In this last section of this essay, I will discuss three games that have noteworthy features with regards to accessibility – some of these are deficiencies, and some are simply game mechanics that have proven to be especially valuable to disabled gamers.

The first of these is Deus Ex: Human Revolution (2011). There is a staggering amount of flavour text available in the game that is difficult to read for those with minor visual impairments on modest equipment. In addition, the nature of the gameplay, even on the lowest difficulty settings, is extremely punishing for those who lack fine grained control. Combined with this is the omission of control mapping beyond the ability to invert the X/Y axis. From a gameplay perspective you can play through in a number of styles that limit the need for quick paced combat. However, the boss fights abruptly, and without warning, forcefully switch you back to a hectic 'run and gun' play-style. This may not seem like an accessibility concern, but the nature of the game leads you to believe multiple play-styles (including those that are non-confrontational) are viable and the fight becomes disproportionately more difficult if you advanced your character along those lines. Allowing players to 'skip' the fight would have perhaps been narratively unsatisfying, but at least would have ensured that the battles were not brick walls that barred progress. Finally, Deus Ex incorporates the familiar 'red HUD for an enemy' UI metaphor – while this is commonly understood, it makes it difficult for a colour blind gamer to differentiate friend from foe.

However, Deus Ex does offer a number of significant accessibility tools. Rather than having to hold down controls for certain mechanics, you can click to 'toggle' between one mode and another. Additionally the game design involves for the most part sequences of button presses rather than combinations, this in itself rendering the title much more accessible to those with significant mobility or dexterity impairments.

The next title under discussion is Batman: Arkham City (2011). As a (relatively) able-bodied gamer, this author was frustrated by several sections which require the player to throw a remote-controlled device, navigate it around obstacles, flip it around corners, and then finally hit a small target at the end of the route. One such section required the author to try this for ten or fifteen minutes until finally giving up, checked a webpage, and found that despite the dialog clue to the contrary, it was the wrong thing that was being targeted. The lack of the ability to skip such intricate sections turned what was a relatively interesting puzzle into a frustrating chore. The huge range of tools in Batman's arsenal all come into play at points in the game, and those who cannot master the more complex or intricate of these will be unable to progress. Additionally, gameplay mechanics that were simple in the precursor Batman: Arkham Asylum (2009) have become increasingly intricate in this title – navigating the game world by flight is a notable example of this.

Other accessibility problems include colour-coded information in 'detective mode', the need to rapidly press buttons in quick succession to pry open grates or pull down pillars, and the lack of captioning of certain kinds of sound information. In addition, Batman suffers from no facility to remap controls. To

its credit, it offers relatively smooth combat even for those who only have access to the 'hit' and 'block' buttons, with batman turning himself to face foes, target enemies, and react to incoming attacks.

Other games, such as Fallout 3 (2008), are remarkable in demonstrating just how accessible games can be. Some of this is simple availability of technical features, but there are aspects of the game design that are just inspirational. For the latter, the VATS (Vault Assisted Targeting System) deserves special note. This was originally envisaged as a system to bridge the gap between the turn based combat of earlier Fallout games and the FPS perspective of Fallout 3. The system lets you pause game combat, select parts of a target to shoot or strike at, and then press a button to carry out the actions. All the need for twitchy trigger fingers and aiming is handled by this, and with a limited budget of 'action points' to spend, it doesn't compromise on game difficulty. It offers fully mappable controls, 'perks' that can be purchased to increase the number and regeneration rate of action points, and the ability to change colour schemes on the game dialogs. It includes closed captions, subtitled game logs, and much more. Perhaps its sole significant fault is the amount of time one must spend navigating game menus and the lack of significant audio cueing as to which options are currently selected.

I should note here that these games have been selected primarily because they are games which I have personally played and enjoyed, rather than being selected as particular exemplars as a result of notoriety or significance. They should not be considered anything other than a representative sampling of mainstream titles that I happen to have available. For those interested in seeing accessibility reviews of other games, I wholeheartedly recommend the AbleGamers website at ablegamerfoundation.org.

6: Conclusion

We are all, at times in our lives, extraordinary users. Those features put in place to support extraordinary users are neither niche nor extraneous. Perhaps the greatest thing about the state of accessibility in computer games is that we are already so close to doing it well. It is possible, mixing and matching different features from different games, to design an accessible mainstream title. Individual games fall down, often quite badly, but they all fall down in different areas. There is reason to be optimistic that, with enough awareness, we could open up a tremendously rewarding hobby to more and more people. It is important that societal recreational forms are accessible – in many ways, as a species, we are defined most by how we recreate. The importance of games as cultural entities has increased dramatically over the last ten years, and we are in a position to ensure that we can set a standard for inclusivity that honours the prominence of games in the modern digital economy.

For the most part, the ways in which we can do this are not difficult or onerous – we have all the tools available already. We can make a great start by simply adopting the 'good practice' that is available in many games – adopting the design principles discussed in this essay will go a long way towards opening up more computer gaming to a large and rewarding market. But, we can always do more and always go farther. We don't have to stop at 'good enough'. Indeed we shouldn't let 'good enough' be good enough. What is important is that we get to that point because once we have, the problems that are left to solve can focus on the inspirational rather than the mere mechanical. The inaccessibility of games is, in large part, simply due to oversights and mistakes rather than something fundamentally impossible, or even difficult, to address. Beyond these, there is room in this world for 'accessibility engines' that can be incorporated into games in the same way that can be done for graphics engines or physics engines. I believe we must work harder to raise the awareness of accessibility as a 'gamer issue', and to bring more disabled players into the design, development and testing of game titles.

And we must never forget that, while accessibility is vital for certain groups of gamers, accessible games are better games for all of us.

7: Acknowledgements

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8: References

Allman, T., Dhillon, R. K., Landau, M. A. E., and Kurniawan, S. H. (2009). Rock vibe: Rock band (TM); computer games for people with no or limited vision. *Proceedings of the 11th international ACM SIGACCESS conference on Computers and accessibility*, Assets '09, pages 51-58, New York, NY, USA. ACM.

Bethesda Game Studios (2008). *Fallout 3* [Disc]. Xbox 360. Bethesda, Maryland, USA.

Deloitte (2009). *State of the Media Democracy Survey*, Fourth Edition

Eidos Montreal (2011). *Deus Ex: Human Revolution* [Disc]. Xbox 360. Montreal, Canada.

Entertainment Merchants Association (2009). *Annual Report on the Home Entertainment Industry*.

Entertainment Software Association (2008). *Essential Facts about the Computer and Video Games Industry in 2008*.

Entertainment Software Association (2011). *Essential Facts about the Computer and Video Games Industry in 2011*.

Fozzard, J. (1990). *Vision and hearing in aging*, pages 150-170.

Heron, M (2011). *The ACCESS Framework: Reinforcement Learning for Accessibility and Cognitive Support in Older Adults*. PhD. Scotland: University of Dundee.

Heron, M.J., Hanson, V., & Ricketts, I. (2011). *Accessibility Support with the ACCESS Framework. Digital Engagement '11*. Newcastle, United Kingdom.

Keates, S. and Clarkson, J. P. (2002). *Countering design exclusion through inclusive design. SIGCAPH Comput. Phys. Handicap.*, (73-74):69-76.

Kline, D., & Scialfa, C. (1997). *Sensory and perceptual functioning: Basic research and human factors implications* (pp. 27–54). New York: Academic Press.

Laberge, J. C., & Scialfa, C. T. (2005). Predictors of web navigation performance in a life span sample of adults. *Human Factors. The Journal of the Human Factors and Ergonomics Society*, 47(2), 289–302.

Nielsen, J. (2008). *Middle-Aged Users' Declining Web Performance*. Jakob Nielsen's AlertBox.

Oddworld Inhabitants (1997). *Oddworld: Abe's Oddyssey*. [Disc]. Playstation 2.

Pullin, G. and Newell, A. (2007). Focussing on Extra-Ordinary users. In *Universal Access in Human Computer Interaction. Coping with Diversity*, pages 253-262.

Robinson, E., Walker, S. (2011). *Gaming on a Collision Course: Averting significant revenue loss by making games accessible to older Americans*. AbleGamers Foundation.

Rocksteady Studios (2009). *Batman: Arkham Asylum* [Disc]. Xbox 360. London, United Kingdom.

Rocksteady Studios (2011). *Batman: Arkham City* [Disc]. Xbox 360. London, United Kingdom.

Schieber, F. (2006). Vision and aging. In J. Birren, & K. Schaie (Eds.) *Handbook of the Psychology of Aging* (pp. 129-154). Academic Press, 6th ed.

Schrier, J. (2011). How a Blind Gamer plays Zelda by *Ear*. *Wired Magazine*.

Sharit, J., Hernández, M. A., Czaja, S. J., & Pirolli, P. (2008). Investigating the roles of knowledge and cognitive abilities in older adult information seeking on the web. *ACM Trans. Comput.-Hum. Interact.*, 15(1), 1–25.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18(6), 643–662.

Trewin, S. M., Laff, M. R., Cavender, A., and Hanson, V. L. (2008). Accessibility in virtual worlds. *CHI '08 extended abstracts on Human factors in computing systems*, CHI EA '08, pages 2727-2732, New York, NY, USA. ACM.

Valve Corporation (2008). *Left 4 Dead* [Disc]. PC. Washington, United States.

Waller, A., Hanson, V. L., and Sloan, D. (2009). Including accessibility within and beyond undergraduate computing courses. *Proceedings of the 11th international ACM SIGACCESS conference on Computers and accessibility*, Assets '09, pages 155-162, New York, NY, USA. ACM.

Yuan, B., Folmer, E., and Harris, F. C. (2011). Game accessibility: a survey. *Universal Access in the Information Society*, 10(1):81-100.

Zajicek, M. (2003). *Software design for older adults to support memory loss*. INCLUDE 2003 Inclusive design. for society and business.