Accessibility of 3D Game Environments for People with Aphasia: An Exploratory Study

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ABSTRACT
People with aphasia experience difficulties with all aspects of language and this can mean that their access to technology is substantially reduced. We report a study undertaken to investigate the issues that confront people with aphasia when interacting with technology, specifically 3D game environments. Five people with aphasia were observed and interviewed in twelve workshop sessions. We report the key themes that emerged from the study, such as the importance of direct mappings between users' interactions and actions in a virtual environment. The results of the study provide some insight into the challenges, but also the opportunities, these mainstream technologies offer to people with aphasia. We discuss how these technologies could be more supportive and inclusive for people with language and communication difficulties.

Categories and Subject Descriptors
H.5.m **[Information Systems]:** Information Interfaces and Presentation — *Miscellaneous*.

General Terms
Human Factors, Design.

Keywords
Aphasia, stroke, 3D games, virtual environments, accessible interaction design.

1. INTRODUCTION
Aphasia is a language disorder caused by damage to the areas of the brain that are responsible for language. It is most commonly caused by a stroke. People with aphasia have difficulty with all aspects of language: speaking, reading, writing and understanding. The negative impact of this can be immense for the individual, their family and social circle. Aphasia has profound implications for quality of life [11]. Those affected report loss of family roles, friendships and employment [19]. Aphasia affects substantial numbers of people. There are currently about 250,000 people living with aphasia in the UK [21], with approximately 45,000 new cases each year, and an estimated 1 million people with aphasia in the US [15].

With computing technologies, in a myriad of forms, becoming increasingly pervasive and embedded within the everyday lives of many people, it is valuable to consider how accessible these technologies are to people with aphasia. At present, interaction with most computing technology still requires the expression and comprehension of language. Yet many people with aphasia struggle in these areas. For example, they struggle to comprehend spoken and written language, particularly when the material is long or complex [4], meaning that access to technology such as the Internet and recreational computer games is reduced [7] or denied.

In this paper, we report a study undertaken to investigate the experiences of people with aphasia when interacting with state-of-the-art computing technology in the form of 3D game environments. Our aim was to explore both the challenges and the opportunities afforded by these environments for people with language communication difficulties. There has been some previous research that indicates the positive effects of computer games in the rehabilitation of motor performance following a stroke [1, 2 and 8] but we have found no similar work related to the use of computer games specifically by people with aphasia.

The study described here was undertaken in the context of the GReAT project (Gesture Recognition in Aphasia Therapy) [10], an interdisciplinary research collaboration between Human-Computer Interaction (HCI) researchers and Language and Communication Science researchers. The eventual goal of this project is to develop and trial a prototype gesture therapy software package that will support people with aphasia in practicing a number of communicative gestures. The project has a strong commitment to user participation and recruited five people with aphasia to work as consultants. The consultants worked with the project researchers in exploratory evaluations of a range of technologies, including the work reported here, both as a precursor to the design of the therapy package and, more broadly, to help us understand the interaction needs of this user group.

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We firstly summarize related research into the design and evaluation of computing technologies for people who have had a stroke and people with aphasia. Sections 3, 4 and 5 then report the study that we undertook to investigate how people with aphasia interact with game technologies (i.e. the hardware devices) and 3D game environments, thereby providing some insight into the challenges and the opportunities that these technologies offer to people with aphasia. The main findings are organized as a series of "lessons learned", focusing on key themes that emerged from the data. The findings have immediate implications for the design of game environments, suggesting ways in which these mainstream technologies could be more supportive and accessible for people with language and communication difficulties. However, it is our belief that many of our results have broader implications and are applicable not just to 3D game environments but also to other forms of interactive computing technology. They offer insight into effective interaction design for this user population that is of direct relevance to projects like GReAT.

2. BACKGROUND

Previous research into computer game technologies for people who have had a stroke has focused largely on physical rehabilitation rather than communication difficulties. For example, Alankus et al [1] describe the adaptation of existing games to enable practice of nine different types of arm movement. They used Wii technologies and a webcam application that tracked a coloured sock worn or held by the user to effect changes in 3D scenes. They report lessons learned about developing games for this group of users, such as the need to support multiple modes of user input, the need for direct and natural mappings between input actions and effects, the importance of utilising audio as well as visual feedback and of including non-player characters and storylines, amongst others. Some of these lessons are confirmed in the study reported in this paper, although our focus is on people with aphasia rather than stroke itself.

The same team report lessons learned about home-based, repeated game-based rehabilitation from a case study involving a 62 year old woman, seventeen years post-stroke, who played motion-based therapeutic games over a six week period [2]. They found that their video-based game approach improved her motivation to do the therapy and she consequently made significant progress resulting in improved motor control. Additional effects included the fact that the games helped her to channel her frustration.

There are other examples of physical rehabilitation via games following stroke. Jung et al [12] developed a virtual reality game called 'The Reaching Task' which integrated 3D stereo visualization and a tracking system for an interactive virtual environment; users wore active liquid crystal shutter eyewear with an emitter to perceive the 3D stereo effect and distinguish difference in depth among virtual targets which they had to reach for. Flynn et al. [8] describe using the Sony PlayStation 2 Gaming Platform with one individual post-stroke to show the positive motivational element of game playing and how it enabled practice of certain physical movements, which led to some clinical improvement. [23] is a website set up by a physiotherapist and dedicated to rehabilitative games for all sorts of disabilities, including stroke, using the Wii.

Most computer-based applications specifically for people with aphasia are concerned with assisting communication. For example, Daeman et al created a storytelling application in which people with aphasia could create and share their stories from pictures they took themselves [5]. The Aphasia project developed PDA applications for people with aphasia to independently manage appointments and communicate via an individualized store of frequently used phrases. PhotoTalk, another application from the same project, allows people with aphasia to capture and manage digital photographs to support face-to-face communication [3]. A number of therapeutic applications have also been developed, such as SentenceShaper [16], which supports the composition of grammatical language, and AphasiaScripts [13], which provides a platform for conversation practice. There are also a few commercially available communication aid technologies specifically for people with aphasia, such as Dynavox [6], Lingraphica [14] and Touchspeak [22]. The focus of these is on icons and pre-loaded phrases or sentences for mobile devices such as PDAs.

We have found no previous research that is specifically concerned with developing a general understanding of the competencies and limitations of people with aphasia when interacting with computing technologies. Nor have we found any studies that investigate 3D game environments for people with aphasia. The latter is the focus of the study reported here, but we believe that the results contribute towards understanding the interaction needs of people with aphasia more generally.

3. METHOD

We undertook an exploratory study to investigate how people with aphasia interact with and respond to 3D game environments and individual elements of such environments. The study was run as a series of participatory workshops.

3.1 The Participants

Five people with aphasia participated in the study. As mentioned in section 1, these participants were recruited as consultants to the GReAT project. They were recruited on the basis of all being at least several years post stroke, but otherwise representing a range of people with aphasia. They varied in terms of age, gender and the difficulties they experienced with language. (Pseudonyms are used throughout this paper in referring to the consultants.)

Sarah was the youngest consultant. She was in her early twenties, had a stroke three years prior to our study and was able to use one or two words at a time. She understood what was said to her and could read individual words. She was familiar with computer technologies and had an iPhone. She could use only her left hand.

Tanya was in her thirties, had her stroke nine years previously and spoke in short sentences. She could not read or write and sometimes struggled to understand but generally got the gist of conversations. She used Skype regularly and also viewed photos on Facebook. She could use only her left hand.

Ann was in her sixties, had her stroke many years ago and generally understood what was said to her but struggled to speak words. She used a (paper) 'communication book' in which she kept photos and pictures. She was able to use both hands. Ann was not a user of technology.

Tom was in his sixties, had his stroke three years previously and communicated with few words but he drew pictures. He could read clear text and understood what was said to him. He was able to use both hands.

Martin was in his seventies, had his stroke two and a half years previously and could use one or two words at a time but found communicating very difficult. He did not always understand what was said to him. Martin was able to use both hands.

3.2 Participatory workshops

The exploratory study reported here was undertaken as a series of twelve participatory workshops over a six month period. Each workshop had a specific research question to explore, such as which mode of presenting instructions or providing feedback was the most effective. The workshops lasted approximately two hours and each consultant attended seven of these workshops, referred to as sessions 1-7 in the description below. The first workshop was an introductory session attended by all five consultants; subsequent workshops were attended by either 2 or 3 consultants. A speech and language therapy (SLT) researcher and two human-computer interaction (HCI) researchers facilitated all the workshops.

All workshops followed the same structure. Each commenced with some introductory, non-computer-based activity, often in the form of a round-the-table game. The main activity then involved the consultants individually (and sometimes collaboratively) interacting with a 3D game environment or elements of such environments. These activities were videoed for later analysis, yielding rich observational data. Finally, to supplement the observations with the consultants' perceptions, the sessions ended with individual interviews with the SLT researcher. Interviews were supported by the use of paper-based rating scales. Consultants were asked to rate aspects of their experience on a scale from 1 – 5, shown with a thumbs-up sign at one end of the scale and a thumbs-down sign at the other end which they could point to, or pictures which they could rank in order of preference. For example, in session 2 which explored Nintendo's Wii Sports, the consultants were asked about the instructions, the weight and feel of the Wiimote controller, use of its buttons - whether these were easy or hard and what they liked or did not like about them. Visual aids such as the controller itself and screenshots were used to assist with recall and to focus attention. The consultants were also asked to rank how 'fun' they found the session. The interviews were videoed.

All session videos (including introductory activities, main activities and interviews) were reviewed carefully afterwards by one of the HCI researchers and the SLT researcher, and a detailed summary was written for each session. The more quantitative data from the rating activities was also summarized. The reflections in this paper are based on both the observational data and the quantitative data.

3.3 Workshop sessions

The seven sessions attended by each consultant were as follows:

Session 1: Introductory session. First, the consultants were introduced to the project. The consultants and researchers then spent some time getting to know each other through one-to-one discussions focused around a set of pre-determined topics. (Given the language difficulties that all the consultants experienced, the "discussions" involved much gesturing, drawing and referring to physical artefacts such as photos and notes, as well as limited verbalisations.) Name badges were used at this and every subsequent session.

Session 2: Nintendo Wii Sports. This exploratory session introduced the consultants to the Wii 3D environment and avatars (digital characters). The main activity investigated the consultants' interaction with two games from Nintendo's Wii Sports: tennis and bowling. We were interested in how the consultants handled the Wiimote controller (especially in view of movement limitations post-stroke), their understanding of the controls on the controller, their understanding of the mappings between their movement of the controller and the resulting changes on the screen, their perceptions of the different screens, their understanding of instructions, and whether they enjoyed the games or not.

Session 3: Gesture recognition technologies. Many game environments take users' gestures as input (e.g. Microsoft's Kinect) and this session investigated two different approaches to gesture input and recognition. The first was a vision-based gesture recognition technology that used a webcam with OpenCV [18], an open source library of functions and algorithms for real time computer vision including hand-shape recognition and motion tracking. We had trained OpenCV to recognize five different hand shapes, e.g. scissors and stone. The second was the Wiimote again, but this time it was used as an input device in combination with wiigee, an open-source, gesture recognition library for accelerometer-based gestures [24]. We had defined and trained wiigee to recognize four gestures: watch, triangle, an S shape and a tennis serve.

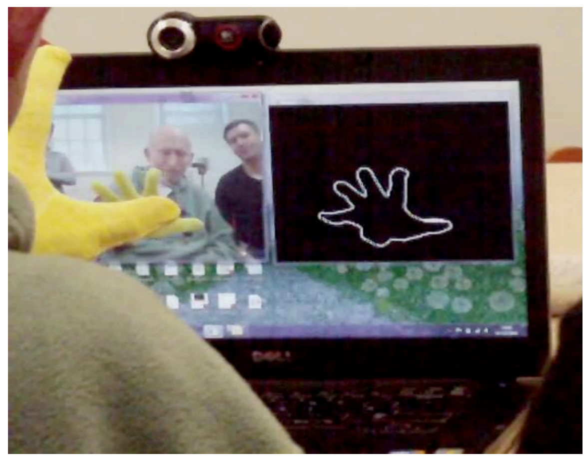

Figure 1. Tom using a vision-based gesture recognition system

The introductory activity involved showing five pictures and teaching the consultants the corresponding gestures. A gesturing game was also played. This served the purpose of showing everyone the gestures to be used and provided a fun and easy way of re-familiarizing everyone (memory being an associated issue for people with aphasia) and getting everyone relaxed. The main activity was making the gestures with the two different gesture recognition technologies (Figure 1).

Sessions 4-7: Explorations of 3D game environments. We developed several prototype 3D game environments using the Unity 3D [23] game development tool and incorporating the vision-based gesture recognition method developed using OpenCV software. Figures 2 and 3 show two of these environments: a town environment and a beach environment.

These environments were used to explore different aspects of interaction. Over several sessions, the participants repeatedly played a game in which a character travelled along a path in a 3D world. At certain points, the character stopped and the participants were presented with instructions to gesture. Making the correct gesture (successfully recognized) moved the game on. We explored different worlds of varying interest and complexity (hills, beach, a matrix, a town, rooms of a house), different methods of presenting gesturing instructions, different ways of giving feedback about the gestures that users had made, different methods and positions for representations of the gestures and pictures of the objects being gestured, different congratulatory messages, motivational scoring, a story line, and less or more control by the user in navigating the character through the world.

Figure 2. The 'town' world

Figure 3. The 'beach' world

4. RESULTS: THE TECHNOLOGIES

We first provide a summary overview of what happened in the sessions, describing our observations and the reactions of the consultants to the various technologies. Then, in section 5, we consider these reactions in terms of the issues they raise. We present these as a number of "lessons learned" regarding interaction design for people with aphasia.

4.1 Nintendo Wii and Wii Sports (Session 2)

All the consultants enjoyed playing the Wii Sports games. Tanya reported afterwards that she would now have the confidence to join in when her nephews played at home, whereas previously she had merely watched them play.

Handling the Wiimote – the weight, the shape, the buttons - was not a problem. With repetition and sufficient time, all the consultants learned to use the buttons, in particular the thumb and finger buttons, in the way the games required. However, sequences of actions, such as holding and then releasing buttons at a certain point, took some practice. Similarly, all the consultants found it much more difficult to hold two buttons at the same time than to use just one button. Two of the consultants needed to be reminded regularly about this, in particular after a short break. In the bowling game, all consultants understood the direct mapping between left and right buttons and the movement of a red line on the screen showing which direction the ball would be bowled, but only Sarah understood how to elicit spin from the same buttons. (Sarah had played the game before). They all liked having their own characters.

The screens for the games were generally understood. The only problem was when we offered Tom and Sarah, who were able to play the tennis game very effectively, a two-person game with a split screen. This was too confusing for both of them. Tanya and Martin only played games where the characters were viewed from a first person perspective. Tom and Sarah did not seem to find first or third person any more or less difficult. Some aspects of the games were too quick for Martin – he needed more time to be able to react.

4.2 Accelerometer-based gesturing with Wiimote and wiigee (Session 3)

Gesture recognition with this technology was unreliable for our purposes, even when the consultants gestured reasonably accurately. This method requires a level of precision and conformity in the way gestures are made. Hence, although holding the Wiimote was not a problem, and holding down the button was not a problem (although most of the consultants needed reminding to do this at some point), the variations in the way individual consultants made the shapes in terms of size, speed and orientation meant a lot of failure and minimal positive feedback; this was very evidently disheartening. For example, at one point, Martin made an S shape back to front after having previously made it the right way round. One of his triangle shapes was only two-sided. Although Tom and Tanya were more consistent in the shapes they made, they too were frustrated and disheartened by the variability of response. All reported this as 'less fun' than the more reliable vision-based technology described in 4.3.

Two of the consultants, Sarah and Martin, tried using the Wiimote strapped to their arm in a purpose-built wrist strap as an alternative to holding it in the hand. They found it wobbly and awkward (and it could not be put on one-handed).

4.3 Computer vision-based gesturing with OpenCV (Session 3)

This technology does not use a controller as an input device. Instead, the OpenCV software recognizes hand shapes made in front of a webcam. In order for the gesture recognizer to readily separate the user's hand from other objects in the scene, we had trained it to pick out the colour yellow. The consultants were each given a yellow cotton glove to wear (see Figure 1) which they found fun and, thankfully, were mostly able to put on with ease - even Tanya and Sarah who had to do this one-handed. (We have since devised a very simple technique for putting on the glove one-handed, using a clothes peg and a clip board.)

Gesture recognition with this software was an instant 'hit' with the consultants. They all reported having fun whilst using it. They could see themselves and a contour of their hands, the yellow colour allowing a very clear separation from background details for their own visual feedback (as well as for the software). It is not the focus of this paper to describe the nature of the recognition algorithms we developed, but the fact that they were robust and more 'forgiving' than those described in section 4.2 allowed for greater variation in the way the gestures were made.

4.4 Exploring 3D game environments (Sessions 4-7)

The first time they saw the virtual worlds, Tanya and Sarah responded very positively, noting various features. For example Tanya pointed to tables and chairs outside a café, saying "I like this". Sarah indicated her preference for the beach world on more than one occasion. The other 3 consultants got on with performing the tasks of the game without reference to the background (until asked later in the interviews). We wondered whether this was due to Sarah and Tanya being younger, or possibly the fact that Sarah and Tanya were the most able at gesturing and so needed less concentration on the task, leaving them freer to notice other things. Tom did indicate in the interviews that he was busy focusing on performing the tasks he had to do and had not noticed when the world that he was playing in changed. The observations confirmed this; Ann, Tom and Martin were all very focused on the tasks. It appeared to require a lot of concentration from them. However, all said the game was fun and all engaged well with it.

Sarah and Tanya definitely liked having a character (which Sarah wanted to be female but Tanya did not mind). Ann answered that she too liked the character and did not mind if it was male or female. Martin rated the character at 2 (i.e. he liked it, but not at 1) and Tom said he would be just as happy without a character. He was also troubled by a change in perspective when the character stopped; the scene would change and appear as seen through the character's eyes. This was indicated by seeing the back of his head. 'What?' he asked, whilst pointing.

5. LESSONS LEARNED

The issues identified in this exploratory study can be usefully organized into two main categories: factors that impacted upon the consultants' motivation and enthusiasm for using the technology and factors arising from the design of the technologies that gave rise to specific interaction difficulties.

5.1 Motivation

A successful game is fun; players want to play it. Motivation is crucial for any game or other activity that we want people to engage in independently at home. The following four factors emerged as key with regards to how motivating (or de-motivating) the consultants found the game technologies and 3D game environments.

5.1.1 Reliability

A fun game reliably does what is expected (even when the "expected" is some element of surprise). As reported in section 4.2, recognition of gestures with the Wiimote and wiigee library was unreliable. Even when the consultants made the gestures apparently consistently, the software did not always recognize them and all the consultants reported finding this less fun than using the computer vision-based recognition with the glove. Tanya said at one point that it was a "stupid idea".

It was very obvious that when the consultants did not understand what was happening or why something was (or was not) happening, they quickly became de-motivated. Tom and Tanya expressed this by asking 'Why?' or 'What?' quite vehemently (see section 5.1.3 below on anger and frustration). In session 2, whilst using the Wiimote and wiigee library, all consultants expressed this via some aspect of their body language – slumping or shaking of the head, frowning, shrugging. Some of them then stopped trying.

5.1.2 Feedback and reassurance

One of the sessions with the 3D game environments was devoted to investigating the best method of presenting instructions from within the game. We presented instructions for five gestures (previously unseen) in a number of different ways that all included a picture of the object together with either: a video of a speech and language therapist (SLT), a cartoon avatar of the SLT, a video of a disembodied gloved hand, or a video of a contoured hand. These were presented randomly. The consultants were asked to copy the gestures as and when instructed. The researchers observed the activity but did not participate to avoid influencing the consultants' behaviour.

Initially, all the consultants copied quite well, though sometimes looking confused, sometimes hesitant. However, very quickly, the gesturing of some of the consultants deteriorated. They became frustrated, unsure whether what they were doing was correct or not. At one point, when one consultant in particular became upset and gave up, we interrupted the session and the SLT researcher presented the gesture in the same way as in the video, but face-to-face. As the consultant attempted to copy the gesture, the SLT researcher provided additional instructions such as, 'now lift your little finger'. The consultant was looking intently at the SLT's face, receiving feedback from her facial expressions and whether or not she chose to correct him. His anger and frustration were instantly defused. This incident exemplified the importance of reassurance and feedback and how de-motivating it can be when it is not there.

Similarly, in other sessions, before we had correctly adjusted the timing in the games between the recognition of a correct gesture and the story moving on, the consultants were unsure whether or not they had done it correctly. They looked to us for reassurance, querying or uttering 'Oh!'

We determined that it was insufficient for the game simply to move on after the user had taken some action, hence *implying* that the task in the game had been completed correctly (and this is how interaction proceeds in many game environments). In contrast, very definite, positive feedback - either visual or auditory - was also required.

5.1.3 Anger and frustration

Anger and frustration are natural side effects of not being able to communicate. Some of the consultants would become quite overtly frustrated when things did not work as expected or things happened that they could not understand. For example, this frustration was triggered by sudden changes in perspective, or by unexpected changes in the position of things on the screen (see section 5.2.4). At such points, one must assume that if they were playing the game at home, they would have simply given up. In our sessions, with full and patient explanations from the SLT researcher, understanding was achieved and the consultants were happy to continue with the session.

This indicates the importance of ensuring that games incorporate an appropriate level of challenge. Certain kinds of interaction design (see section 5.2) can in themselves pose challenges for people with aphasia in addition to the challenge of the game itself. More general design principles here are that there must always be a way of escaping from the game world and of obtaining help.

5.1.4 Positive effects

Playing games and achieving a result is rewarding. All the consultants enjoyed playing the games and noticeably gained confidence from participating in the sessions. As mentioned earlier, after the session with Wii Sports, Tanya commented that she would now be able to join in when her nephews played; previously she had just watched. Sarah and Tom particularly liked playing competitively against each other. The 'fun' rating that each consultant gave at the end of every session was consistently high.

As described in section 4.4, the consultants who found the games easier were more open to noticing the different game environments and commenting on features such as tables and chairs, or hills. Whenever a new environment was introduced, Tanya and Sarah in particular, pointed to features and made comments such as, '[I] like that'. Alternatively, Sarah said the matrix world was 'boring'. Liking the world appeared to increase the level of motivation with the game. However, those who had to concentrate more on performing the tasks in the game environments, such as Ann, Tom and Martin, did not comment on the worlds until they were more familiar and confident with what they needed to do.

Tom was very enthusiastic about playing tennis on Wii Sports. He indicated by making a tennis serve movement and pointing to himself, that he used to play before his stroke. Although he struggled at times to co-ordinate and remember the two simultaneous actions required when using the controller (see section 5.2.5) he was evidently motivated to keep trying and definitely enjoyed himself. He enjoyed the bowling less, whereas this situation was reversed for Martin (for reasons explained below).

5.2 Interaction

The following five issues relating to interaction with the game technologies and environments emerged as particularly important.

5.2.1 Controlling the pace

The pace of interaction with the 3D game environments was a theme that emerged from many of the sessions. There is a general expectation that people with communication difficulties will need extra time to interact with computers and play games. This was certainly true in some cases. For example, we observed Martin struggling with the pace of balls in the tennis game. However, interestingly there are also times when they may want things to move faster. For example, Tom thought the character walking between gesturing points took too long in the 3D worlds. Similarly, when playing Wii Sports, he thought the clapping and cheering when a point was scored was a distraction. He was much happier once told that by pressing the thumb button, he could cut short the celebratory feedback and allow the game to continue. Sarah already knew to do this. Martin and Ann however, seemed content to use such episodes as 'breathers' between tasks. The design principle here is that control is important; players should be able to pace the game themselves. When that control is not provided, the interaction can be incredibly frustrating.

5.2.2 Reminding

A key deficit in aphasia is the loss of access to words [17] and in some cases this is accompanied by difficulties with other symbols [20]. The consultants therefore needed regular reminders of people's names, how to use buttons and how to make gestures. The 'round-the-table' games, away from the computer, that started each session were very helpful in serving this purpose.

When playing the gesturing game in our 3D game environments (sessions 4-7), there were a couple of occasions when Ann took time with a particular gesturing task and then forgot what she was supposed to be gesturing. This led us to keep a constant visual reminder on the screen of where the player is in the course of the game. This is, of course, consistent with general HCI design principles about making the state of the system visible to the user, but it is a principle that is sometimes deliberately flouted in game environments.

In the Wii Sports session, most of the participants (except Sarah who had played before) needed repeated reminders and explanations, especially when complexity of the task increased. The consultants found it challenging to remember the sequences of button presses that were sometimes required to trigger an action in the game world. For example, when more than one button on the controller had to be pressed simultaneously, or when more than one move was required in a sequence such as holding the finger button, moving the controller and then letting go.

In general, it is important for aphasic users that instructions and required action sequences should be short and straightforward. Where feasible, compound action sequences should be replaced by single actions, such as only needing to press one large and obvious button, for example to both start a game and to respond within it, and that help be available at all levels.

5.2.3 Mapping and consistency

People with aphasia often find it hard to deal with abstract information [9]. The mapping between input actions and their effects on the screen therefore needs to be intuitive. In the Wii Sports bowling game for example, it was possible to alter the angle of the ball by pressing on 'left' and 'right' buttons on the controller. These buttons were obvious and, because of their positioning on the controller, their use was intuitive. A red line showing the angle shifted left or right on screen simultaneously with the user pressing the relevant button. The consultants found this easy to use. However, using the same buttons to spin the ball was not intuitive and proved too complex for most of the consultants. Likewise, when playing tennis, several of the consultants had difficulty remembering the combination of button presses required; there was no intuitive mapping between the buttons and their effect on the environment and no prompt on the screen. A similar finding is reported in [1].

Perspective also proved to be an issue in the games. Initially, when the character stopped in the 3D game environments and an action was required, the perspective would change and the environment would appear as if seen through the character's eyes. This confused several of the consultants. Some of the Wii Sports tennis games do the same. It appeared that it was the change in perspective that was confusing. There was no overall preferred perspective; it was consistency that was required.

Consistency in general was another aspect of the 3D environments that was very important to the consultants. They became familiar with the position of certain things on the screen, how instructions and feedback were represented, and how tasks were to be performed. When we explored alternative screen positions for objects (such as pictures of a target gesture), the main message that came through from the consultants was that they just needed these to be consistently in the same place.

5.2.4 Complexity, distraction and 'noise'

In general, the lighter the cognitive load in performing a task, the better it was for the consultants. For example, simply using a gloved hand to gesture was better than having to remember to simultaneously hold a button down on a controller such as the

Wiimote. In addition, keeping the screen (and 3D environment) relatively empty and navigation as simple as possible, was also effective in enhancing interaction. These are general guidelines for good interaction design, but they are especially important for people with aphasia who can be easily overwhelmed by too much complexity. In particular, including verbal or textual information is especially difficult for people with language and communication difficulties. Additional support can be made available [7] but there is also a conflict between offering support and this too being a distraction.

For example, certain clues, such as seeing a picture of the target gesture whilst making their own gestures, were helpful for some of the consultants. However, Tanya, one of the more competent gesturers, found this a distraction (because she did not need it). Ann, Tom and Martin, however, found the additional clue a great help. So what is a distraction for one individual is not necessarily for another.

Therefore, another design implication to result from these observations is that the system should provide the facility to switch certain support materials on and off, ideally whilst simultaneously trying to comply with another general principle of having no more than two (for our consultants) elements on the screen requiring attention at any one time.

5.2.5 Individual differences

In general, people vary in what they want from a game, what they like and how long they take to process what is required of them. So, while the preceding discussion has focused on issues experienced in common by the consultants, there were, of course, many individual differences. Effective and motivating interaction design must be sensitive to these also. For example, Sarah was the only consultant who persistently expressed a preference for a female avatar. This could have been because she was already familiar with games such as Wii Sports where a character can be created in one's own image.

Another case was reaction time. Martin, for example, understood exactly what he needed to do in the WiiSports tennis game, but could not react quickly enough, whereas the other consultants did not experience the same difficulty. The bowling game, on the other hand, was paced appropriately and gave him sufficient time to respond.

People with aphasia have very individual difficulties with language and these extend to their experience with interactive computing technologies. They may well change over time. The requirement to handle these variations, as well as to respond to personal preferences, means that it is crucial that many aspects of systems should be tailorable to reflect an individual's preferences and abilities. Similarly, as discussed in section 5.2.4, the level of support needed to perform a task will vary. Alternative levels of support should be available at all levels of the game.

6. CONCLUSIONS

People with aphasia can feel isolated and excluded from technology. Yet our study clearly demonstrated that the consultants were able to have fun and gain confidence whilst playing games in 3D environments. We said in the introduction that our aim was to provide some insights into the challenges and opportunities for people with aphasia interacting with 3D games. We want to suggest ways in which these mainstream technologies could be more supportive and accessible for people with language and communication difficulties. In summary, our exploratory study has led us to the following suggestions:

- Characters, story lines, patterns of navigation or of progression, feedback, etc, all need to behave reliably and consistently. Items on the screen should appear in consistent locations. All aspects of the game and the 3D environment should conform to players' expectations.
- Non-textual, visible reminders are important. For example, to show the current state of interaction, to show the player where he/she is in the course of the game.
- Positive, explicit feedback (visual and auditory) is crucial for maintaining confidence and motivating the player to continue. The player needs to be reassured that what he/she has done is correct.
- 3D game environments for people with aphasia should contain minimal distractions, allowing them to focus on the primary game task.
- Players should be able to progress through a game (or any other application) at their own pace, which means that they can speed up, as well as slow down, the course of the game. This needs to be achieved without adding complex layers of navigation.
- The mappings between input actions (e.g. using controls on hardware input devices or gestures) and effects within the 3D environment must be direct and intuitive. Compound sequences of actions should be avoided.
- Players have very individual preferences which should be catered for. For example, the capability to select characters of different genders, and game worlds that contain different elements to reflect the user's individual interests.
- Similarly, there should be the facility to change certain settings, for example, to accommodate different reaction times.
- Additional support should be available, but it should be possible to switch this off. Supports that are not needed are a distraction.
- It should be possible to escape from the game world and get help at any time by one simple action.
- Verbal instructions should be kept to a minimum.

In conclusion, the study reported here has focused on developing an understanding of the interaction needs of people with aphasia, attending to issues related to the challenges they face in using language rather than challenges arising from other post-stroke deficits such as movement limitations. Through a series of workshops, we have investigated how people with aphasia interact with 3D game environments, considering where interaction design is effective and where it is less so. The findings are making an important contribution to the design of the gesture-based therapy tool for the GReAT project, providing a solid foundation for our design decisions. However, reflecting upon the principles for interaction design given in the list above, we would argue that these results are not limited to 3D game environments but have broader applicability. These principles offer insights that should help enable effective and accessible interaction design for this user population with all manner of other applications, and, in so doing, enhance and enrich lives.

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