Computer games for children with visual impairments

Y Eriksson[1] and D Gärdenfors[2]

[1]Department of Art History and Visual Studies, Göteborg University,
Box 200, 405 30 Göteborg, SWEDEN

[2]Stockholm International Toy Research Centre, KTH,
Brinellvägen 85,100 44 Stockholm, SWEDEN

yvonne.eriksson@arthist.gu.se, *dan@sitrec.kth.se*

[1]*www.hum.gu.se*, [2]*www.sitrec.kth.se*

ABSTRACT

The Swedish Library of Talking Books and Braille (TPB) has published web-based computer games for children with different kinds of visual impairments. As the target groups have very different needs when it comes to the use of graphics and sound, TPB have developed two kinds of games. Image-based games aim to encourage children with partial sight to practise recognising visual objects, while sound-based games also intend to be accessible without relying on vision. Based on the results of two pilot studies, this paper discusses central design issues of the graphical and sound-based interfaces for this type of applications.

1. INTRODUCTION

Today, computer games are integrated parts of children's play activities as well as school education. Contemporary computer games usually feature sophisticated 3D-animated graphics, accompanied by sound effects to enhance the play experience. However, mainstream games are often inaccessible to children with visual impairments.

Children with partial sight frequently have trouble perceiving objects that constantly move around on the computer screen, and objects might be hard to distinguish because a lack of contrast in colours. Furthermore, the continuous noise of a soundtrack can be frustrating when trying to figure out the interface and the elements on the screen. For a blind person, it is practically impossible to play ordinary computer games, as they are based on visual output. To create accessible games for blind children, the games must be communicated by sound only.

For these reasons, TPB, the Swedish Library of Talking Books and Braille has published 13 computer games on their web site, targeted at children with different visual impairments (TPB 2003). The games are small Macromedia Flash™ applications, intended to serve as an introduction to computer games to people who previously have little experience of this type of entertainment. The games are published on the web to ensure that they can be accessed on various computer platforms, given that there is an Internet connection.

As children with partial sight and blind children have very different needs when it comes to the use of graphics and sound, the main aims have been (1) to design computer games that encourage children with partial sight to practise recognising visual objects, and (2) to create games that can be played without any graphics. Therefore, there are both picture-based and sound-based games, where the later category only requires aural attention to be played. The games with pictures are controlled with the mouse. The sound-based games are played with the computer keyboard, since many blind computer users avoid the mouse. The games have intentionally been designed for home computer equipment, so one only needs a standard PC or Mac with a pair of headphones or loudspeakers to play the games.

2. ACCESS TO IMAGES

Many children with partial sight are not very interested in using their sight because of the big efforts and the small rewards involved. Since they easily can misinterpret visual representations, they generally expect little

useful information from pictures. The graphics of traditional computer games usually contain a lot of details to add realism or to make the games more attractive, such as 3D effects and colour nuances. This can distract children with partial sight, since they very easily lose their focus and have difficulties finding the main characters in the games. Therefore, a computer game for people with partial sight has to be designed with clear and simple illustrations, where excessive details are avoided. The TPB games also include slow movements to stimulate the players to look at the graphics.

For a person with limited sight, it can be difficult to get an overview of a computer game situation. With software such as LunarPlus (Dolphin Oceanic 2004) or ZoomText (Ai Squared 2004), computer users can enlarge what is displayed on the screen and read text at a size that they find comfortable. While these applications are convenient for reading, they are not as suitable for watching pictures and especially not animated graphics, since only a small part of the screen can be seen at a time. The TPB games contain illustrations that are created according to the target-groups special needs for high contrast and clear figures. Therefore, the games use vector-based graphics, which also means that the player image can modify the image sizes. The illustrations only show the distinguished features of the objects and characters, so they do not necessarily look realistic in the same way as photographs do.

2.1 Shapes

When we see an object and identify it as, for example, a vase, a shoe or a dog, it is often because we can recognise its shape. The shape of an object is found in its outline. Outlines do not exist in reality although our brains are constituted so we automatically see contour lines that make it possible to organise our visual perception. This is one of the reasons why we can distinguish objects in the foreground from the background, both in the environment and in visual representations. According to Arnheim (1966), perception of shapes is the understanding of structural features found in, or imposed upon, the stimulus material. When we depict an object, we draw the outlines of it and if the representation is successful it can be identified by others. Even very simplified drawings of an object or a person are easy to interpret if the artist has caught its significant shapes, which is something we can experience in caricatures as well as silhouette cut outs.

The TPB games for children with partial sight feature high-contrast pictures with designs inspired by Gestalt psychology theories. Influenced by Koffka (1934), Eriksson (1995, 1997, 1998, 1999) stresses the importance of outline shape. The shape of an object is dependent of the angle from which it is observed, which is especially noticeable in representations. As shown by Solso (1994), it is much harder to identify a represented object if it is depicted from an unusual angle. For an observer to recognise an object from its outline shape, a representation has to be made from an angle that makes the actual object identifiable. For people with visual impairments it is often hard to interpret tactile as well as visual representations of objects that diverge from the physical form, since the contour of the object will appear very differently from the real object. Therefore, the graphics of the TPB computer games feature objects and characters that are depicted either in profile, *en face* or from above, to facilitate interpretation.

2.2 Colours

Colour plays a considerable role in contemporary visual media. However, when interpreting visual representations, colours are subordinated shape. We identify a picture of a dog because we can recognise it from the significant shapes of its different features, its nose, its body and its legs. It does not matter if the dog is red, green or brown. Furthermore, if we see a figure in the same colour we normally associate with a specific dog, we will not interpret the representation as a dog if its shape is similar to a cat.

Together with light and shadows, colours are often used to create plasticity in paintings or drawings. By manipulating different nuances of a colour, it is possible to add volume to an object on a two-dimensional surface. This has been used by numerous artists and is often applied in mainstream computer games. Eriksson (1999) emphasises that for a person with visual impairment, the colour modulations can cause problems, since the parts with other nuances easily can be interpreted as separate objects. The same issue arises when using shadows and light in images. Fluidised colours can also be problematic, since their luminary quality can obscure the contours of objects. The quality of the contour is crucial for recognising the outline of a shape. The graphics of the TPB games use neither colour nuances nor shadows. The pictures are designed to look flat, so the contour of every object is distinct from the background. In most games, the background is dark, while the objects have light colours. This colour scheme seems to be the most efficient, since it prevents different picture elements from appearing as silhouettes. While a dark silhouette clearly indicates the outline shape, it can prevent a person with limited sight to perceive details within the figure. A dark background makes the player perceive that the backdrop settles while the objects move forward. This is ideal for a person with visual impairment, especially for someone who lacks colour vision.

The notion of contrast between colours usually refers to complementary colours, meaning those found on the opposite sides of the colour circle, such as orange and Klein blue. Contrasts that depend on complementary colours have the same degree of saturation and therefore they can be difficult to perceive for people with colour blindness. For a person who perceives the environment in a grey scale, there is no contrast between colours with the same degree of saturation. As colour blindness is a common effect of visual impairment, the TPB games are made in colour contrast that is based on different levels of saturation.

2.3 Image-based games

The TPB games intended for children with partial sight include jigsaw puzzle games, memory games, action games and play environments where the main objective is exploring.

There are three jigsaw puzzles with different themes. One puzzle starts by briefly showing the player the final picture of a horse before the player can start moving the pieces. The puzzles featuring a snake and a castle do not start by showing the motifs, so the player has to discover the themes by putting the parts together step by step. The puzzle with a castle shows a building with two towers (see Figure 1). While towers are significant features that one generally associates with castles, the motif of the jigsaw puzzle is not understandable for children who lack the knowledge of how to interpret these symbols. Essentially, it is necessary to have knowledge of a specific symbol to be able to interpret its meaning. A clear layout of a picture does not necessary implement an easy interpretation. As discussed by Eriksson and Göthlund (2004) among others, even a picture that appears as very simple is often quite arbitrary.

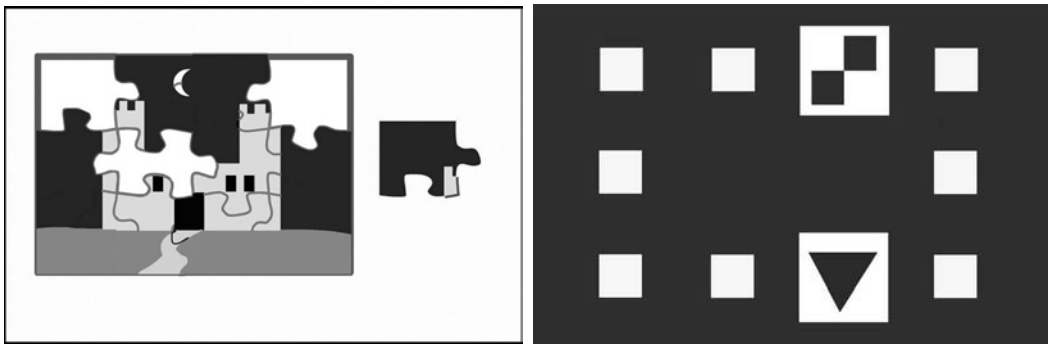

Figure 1. *The castle jigsaw puzzle and a memory game. Graphics by Maria Beskow, courtesy of TPB [TPB 2003].*

The four memory games have different themes, such as farm animals or abstract moving objects. Two of the memory games feature cards with different symbols, such as semi-circles, circles, triangles and squares (see Figure 1). One game has objects with light colours on a dark background, another has dark figures on a light background. The variations in designs are chosen to offer different challenges to the player.

The *Beetle game* requires fast input from the player who tries to stop beetles from eating a cake. The main challenge is to synchronise the movement of the mouse with the movement of the beetle across the screen, as it requires simultaneous awareness of two moving objects.

3. SOUND-BASED GAMES

Most mainstream computer games feature high quality sound effects and soundtracks that enhance the visual animations. However, as sounds mainly are added as embellishments, they do not convey enough information for blind players to be able to understand what happens in the game. Since the sounds cannot be clearly connected to a specific position on the screen, visual information is required to understand where they come from. Furthermore, there often are many characters, objects or events that are not associated with any sound at all.

To make computer games accessible to blind people, one cannot simply add more sounds to existing computer games. Friberg and Gärdenfors (2004) stress the importance of planning the entire game concept around an auditory experience in order to develop a comprehensive sound-based game. Since sounds are very different to graphics with regard to space and time, sound-based game development requires a very different design approach to that of graphical games. In the TPB sound-based games, all the game interfaces, the menus as well as the gameplay, are designed from an entirely auditory perspective.

The sound-based games belong to two categories, the puzzle games *Towers of Hanoi* and *Memory* and the action games *Tag* and *Skybells*. In addition to auditory interfaces, these games feature the same type of high contrast graphics as is used in the other TPB games (see Figure 2). By adding graphics to complement the audio, which is the opposite procedure compared to mainstream game development, the games ultimately feature two complete interfaces. Thus, blind children can play together with friends with partial or full sight, who can choose to use the graphics if they find the sound-based gameplay too difficult.

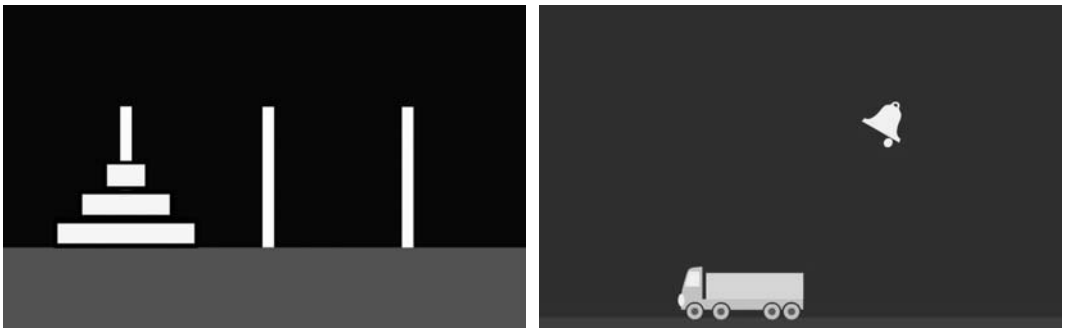

Figure 2. *Graphics from Towers of Hanoi and Skybells. Graphics by Maria Beskow and Annica Norberg, courtesy of TPB [TPB 2003].*

3.1 Positioning sounds

In sound-based games, the player obtains a mental image of all present objects and characters by listening to the sounds that they are associated with. To separate different sound objects spatially, the TPB games rely on stereo positioning, which enables sounds to be spread from left to right. This information is essential for the players' understanding of the game setting. However, as stereo only represents one dimension, it offers a limited space compared to the two dimensions of the computer screen. Just like one visually can simulate depth by graphical trickery, it is possible to imitate more spatial dimensions sonically by head related transfer function (HRTF) techniques. As this requires very advanced sound engines, it is currently not an option when developing web-based games. According to Menshikov (2003), HRTF needs headphones to work well. While headphones can be convenient when playing the TPB games, they are not made obligatory since people with visual impairments might not want to be entirely shut off from the outside world.

The TPB games rely on less realistic ways to convey depth and height. In the Tag game, an illusion of depth is created by alterations in sound pressure. Height is indicated using two different strategies. In *Memory* and *Skybells*, the objects that are higher up are represented by sounds with higher pitches than those of objects below. The *Towers of Hanoi* game relies on a different convention. When checking a horizontal position in this game, the present objects are presented from the bottom and up, so only one object is heard at a time. Obviously, these types of conventions take some time for the players to learn. As it is harder to convincingly communicate spatial relationships with sounds than with images, sound-based games can benefit from being more stylised, with their own, non-realistic game logic.

3.2 Auditory overview

To avoid excessive auditory information, all the TPB sound-based games are designed to stage very few objects, with simple spatial relationships. In the fast-paced games *Tag* and *Skybells*, the game objects are in constant motion, generating continuous sounds. However, in the puzzle games, *Memory* and *Towers of Hanoi*, the game objects are still unless the player activates them, which causes a more static gameplay. In these games, it would be very difficult to distinguish the different objects if they were to emit continuous sounds.

Instead of continuous display, the TPB puzzle games require that the player checks the different positions in the game field to hear the object sounds. Therefore, the sounds always appear in sequence, which relieves the player of having to take in too much simultaneous information. This means that the player must memorise the brick positions when playing the game, or frequently check the different positions. Winberg and Hellström (2000) have created an auditory Towers of Hanoi application that features continuous sounds. While this approach provides a constant overview to the player, the uninterrupted sounds blend into a complex code, which is something the TPB game aims to avoid.

3.3 The sonic palette

Relying on sounds to communicate all aspects of a game, from the menus and instructions to the actual game objects, many types of information need to be presented by different auditory interfaces. There are several kinds of sounds that can be used to convey different types of messages, such as speech, music or "sound effects." The TPB sound-based games use all these kinds of sounds to indicate objects, events and continuous processes within the game environments.

Recorded or synthesised speech is useful when communicating very precise information, such as game instructions and menus. However, inside the actual games, the use of speech is limited, since it generally is too slow to communicate events that occur in a high tempo. Furthermore, spoken messages tend to grow tedious if repeated too often. Neither is speech suitable if more than one message is conveyed simultaneously.

The auditory interfaces of the TPB games are mainly made up from "sound effects," which here refers to sounds that are intended to correspond to the graphics of visual games. These illustrative sounds can be designed in several ways. When possible, it can be useful to represent objects by authentic sound recordings, as they are often easy to recognise. However, since many objects and events do not generate sounds in the real world, several sounds have to be designed from other sources. As it is convenient to design interfaces that build on users' previous experiences, Gaver (1986) argues that "iconised" sounds can be useful in auditory interfaces. "Auditory icons" are sounds that somehow relate to the objects that they represented in the interface. This design approach is used in the TPB *Towers of Hanoi* game, where stone discs make "clinking" sounds, and the wooden poles sound "woody." Like graphics, sounds can be stylised to different degrees. When moving a disc sideways, one hears somewhat cartoonised "swish" sound, which is intended to give the impression of an object being moved, even though stone discs rarely make such sounds.

Another approach to auditory interface design (Brewster et al, 1992) is to use abstract musical sounds to create auditory messages. This type of auditory symbols, also called "earcons," show little or no resemblance to what they represent. This means that earcons can be used to indicate any phenomenon, generating pleasant, musical interfaces. The main drawback of earcons is that they can take a long time to learn, as they are more arbitrarily linked to the real world than "auditory icons." In the *Memory* game, a type of "earcon" created by pitched percussion instruments is used to represent different positions in a grid of cards. These sounds were chosen because the action of checking positions is not clearly associated with a sound in the real world. Other examples of events that are musically illustrated in *Memory* are the rewarding sounds played when finding a pair of cards or winning the game, and the error alert sound heard when attempting an impossible move

There are endless possibilities to combine the auditory interface design methods above. One reason for this is that it is possible to listen to a sound in many ways. Influenced by Schaeffer (1966), Chion (1994) divides human listening into three modes: casual listening, semantic listening and reduced listening. Casual listening applies when listening to the source of a sound, attempting to understand what caused it. Semantic listening is used when understanding auditory codes such as speech or Morse code. Reduced listening is used when listening to qualities of a sound without considering its source, such as when appreciating music by listening to its pitches, harmonies and rhythms.

As Chion (1994) claims that it is possible to apply more than one listening mode simultaneously, it is possible to design sounds that are both iconic and musical the same time. Friberg and Gärdenfors (2004) suggest a system that illustrates the various auditory interface design approaches according to Chion's three listening modes. In analogy to a system used to describe visual cartoons by McCloud (1993), a triangular model can be used to indicate the different ways in which sounds can be designed (see Figure 3).

This triangular sonic palette demonstrates the range of different sound design strategies that can be used when developing auditory interfaces. The TPB games are not limited to speech, the "auditory icon" or "earcon" design approaches. Instead, they use a sonic palette that spans between voice, authentic sounds and musical sounds.

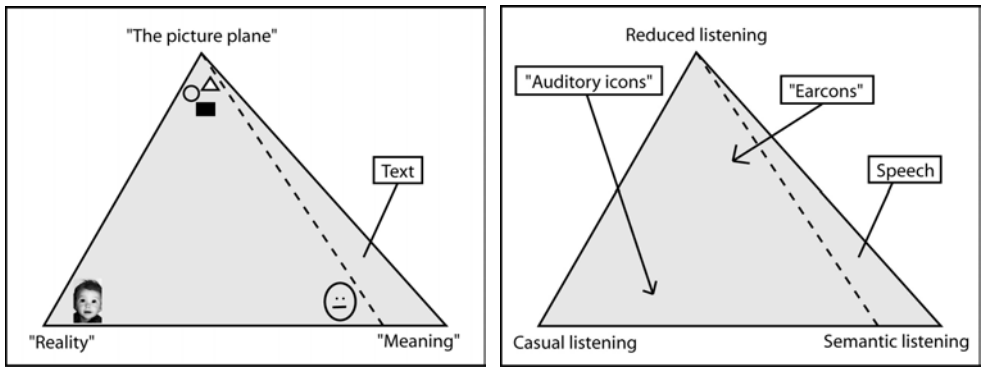

Figure 3. *McCloud's triangle of visual representation and a corresponding triangle for sonic representation. Graphics courtesy of Friberg and Gärdenfors [2004], after McCloud [1993].*

4. TEST RESULTS

The TPB game project has involved two pilot studies: with five children, between 6 and 12 years old in 2001, and four children between 9 and 12 years old in 2003. The first test focused on the image-based games. To be able to analyse how and if these games work for a child with limited sight, we made an eye tracking study. All the children in the group have heavy nystagmus, a constant, uncontrolled eye movement that is very common among people with partial sight. It has been discussed if nystagmus leads to limitations in the ability to interpret visual information, especially when it is represented by images. However, we found that the children had no problem playing the computer games and that they could coordinate the movement of the mouse with what they saw on the screen. This was clear in the *Beetle Game*, in which it is important to react quickly with the mouse to smash a beetle before it takes a piece from the cake.

Surprisingly, the children found the horse jigsaw puzzle harder to play than the *Beetle Game*. They said that the time that the motif of the puzzle was displayed before the game starts was too short. To solve this task methodically, and not by chance, one has to remember the outline of the horse, and one must be able to associate the different details on the pieces with a specific part of the total image. This can be difficult for children with visual impairments, since they often only can observe a limited part of the screen at a time.

The second user study showed that blind children found the sound-based *Memory* difficult to play. Three out of four children could not manage to figure out the organisation of the cards on the screen. The one who succeeded had played the game earlier together with her father and, with his help, created a mental map of the surface.

Skybells, like *Memory*, is space related in the sense that the player has to understand that the bells and the stones fall in four different horizontal positions. Some children had difficulties both in perceiving the stereo positioning and in understanding how to avoid the stones and to catch the bells. The children found the game much easer to play when using headphones instead of loudspeakers, which indicates that headphones are more reliable when conveying differences in stereo positioning.

One child with limited sight, who after a careful explanation could play Skybells quite well, found it much more difficult when he was asked to use his sight. As his sight is very limited, and since he first learned the game from its sounds, he got confused when exposed to the visual and auditory information simultaneously. In this specific case the pictures and the sounds did not complement one another for the child.

Only one child in the second pilot study was totally blind. So, as a second trial we asked the children to play the games using their sight. One of the girls, 12 years old and classified as blind with an almost non-existing sight, made a better result with the sound-based *Memory* when using the graphics.

The *Towers of Hanoi* game proved to be a great challenge for the children, especially those who do not have access to the visual representation of the objects and have to rely on sound only. To be able to solve the problem, the player has to understand the spatial relationship between the objects before it is possible to start moving the discs. No child under 9 years has been able to complete the *Towers of Hanoi*. As the game rules are quite sophisticated, all children need careful instructions before being able to solve the game.

Tag is an action game that requires skill when controlling the game with the keyboard. One of the children in the second pilot study had a motor problem that lead to difficulties in managing the keys. Still, he

found the game very stimulating and it will work as a platform for practising and challenging the limitations of his motor skills.

5. CONCLUSIONS

The game project by TPB has shown that it is possible to create fun computer games for children with partial sight or blindness. In general, the response to the TPB games has been very positive, which indicates that several of the design hypotheses may be adequate. The fact that most children with partial sight, nystagmus and even one child classified as blind could play the image-based games signifies that the visual designs of the TPB games are successful.

Still, several issues remain unsolved or little explored, especially regarding the sound-based games. It is difficult to communicate static overviews of several objects with sounds. Sound, just like text, is limited when it comes to conveying unchanging environments. Visual game interfaces offer the player a continuous overview that makes it possible to investigate environments at random. Pictures are also exceptional when it comes to conveying spatial relationships between different objects.

The pilot study indicates that, when it comes to sound-based games, it is easier to play action games such as *Tag* than a static puzzle, such as *Memory*. This is probably due to the lack of overview offered in the sound-based puzzle games. Therefore, it is very important to provide clear instructions for games that require a spatial understanding to be solved. For younger children, instructions have to be introduced by a person. It is not enough with a pre-recorded verbal instruction that accompanies the game.

The game elements developed in the TPB project can be used to develop larger and more advanced computer games for people with visual impairments. Several ideas have already been used successfully in other game projects, such as TiM (Friberg and Gärdenfors 2004). Still, the main challenges when creating sound-based games remain, mainly regarding how to design interfaces that efficiently utilise the spatial and temporal characteristics of sound. Headphones seem to be advantageous when understanding the positioning of sounds, however they cannot be the only output option since they shut off the player from the outside world.

It seems that even children with very limited eyesight intuitively find it easier to interpret visual images than auditory representations. This might be because they, like most people, more often are exposed to conventional visual symbols than to non-speech auditory interfaces. When designing computer games that rely on non-speech sound, there is a lack of conventions on which the auditory interfaces can be based. While Western culture has a rich tradition of visual iconography, there is no well-established auditory counterpart. Without an established canon of auditory icons, players of audio games today need elaborate instructions before they can start playing.

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