How to Design Games for Deaf Children: Evidence-Based Guidelines

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Abstract. The goal of this paper is to present the first evidence-based guidelines for the design of electronic games for deaf children. According to the most recent deaf literature, playing with such games shows positive effects on deaf children's visual abilities and working memory abilities. Our review of deaf literature, briefly sketched in the paper, considers such abilities as well as other relevant findings concerning the needs of deaf children most relevant for the design of electronic games for them. The paper also outlines the latest findings of the DISPLAY project, which builds electronic smart games for deaf children. All such findings are then use to compile the guidelines, which are presented in the third and final part of this paper.

Keywords: evidence-based design, user centred design, deaf studies, games, children with special needs, usability and accessibility.

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1 Introduction

In recent years, more and more attention is being paid to the design of electronic tools (e-tools) for children, and there is a fair amount of work in which designers have started developing design principles for e-tools for children (e.g. in [21,34]). To the best of

our knowledge, however, there is no single collection of principles for the design of e-tools for deaf children. We found a list of suggestions for evaluating e-tools for deaf people [28] and guidelines for captioning for web sites for them [29]. On the other hand, the benefits of e-tools for the deaf population are purported by deaf research studies. In particular, recent deaf studies show how playing video games can have positive effects in terms of visual abilities and working memory of deaf individuals [14;16]. Therefore we set ourselves on such a tack: the main goal of this paper is to present the first evidence-based guidelines for the design of electronic games that are accessible and usable for deaf children.

We start with a compact overview of most relevant deaf studies for deaf individuals, focusing on deaf children. The overview highlights what we know and we do not know from the literature about the characteristics of deaf people and relevant for designing games for deaf children. With the goal of learning more about such an issue, we conducted experiments with deaf children, their teachers and experts of deafness for the DISPLAY European project [23], which is developing video games for improving the reading comprehension of children, like deaf children. In particular, the DISPLAY consortium run field studies with children as subjects and their referent adults as informants. We designed the tasks of the field study with children as paper-and-pencil games, collected the results of the games and also observed children while playing with them. The state-of-the-art analysis and the results of the field studies run for DISPLAY, allow us to compile a set of guidelines for the design of games for deaf children, which is the focus of the third and final part of the paper.

2 Research Findings

In this section, we analyse the most relevant needs of deaf children for playing video-games and, mainly, concerning reading, attention and memory. The needs emerge from an analysis of the deaf literature and recent findings of the DISPLAY project [23]. DISPLAY is developing an adaptive learning system for improving the reading comprehension of primary-school children, hearing and deaf, by means of stories and smart games for reasoning about stories. In order to understand the needs of children for reading and playing with the DISPLAY system, the DISPLAY consortium run studies following the user-centred design (UCD) [18]: the consortium conducted expert-based studies, with experts of the domain or UCD as participants, and user-based studies, in which the

participants were children, hearing and deaf, and their referent adults, like class teachers,

CONSTRAINT	BIB	GL

support teachers and parents. The studies were done firstly for (1) the context of use analysis and secondly for (2) the evaluation of prototypes of the system. The first studies were done for analysing the impact on the design of the system (a) of the characteristics of the users, (b) of the tasks they can perform with the system like playing computer games, and (c) of the environment. The data collection involved 592 7–11 olds across UK and Italy, 70 out of which are deaf, and about 30 referent adults, that are parents of children, class teachers or support teachers. Data collection activities with children were in the form paper-based games, and data collection with adults was done via contextual inquiries, questionnaires or diaries. Direct observations complemented all data collection activities in situ. See [24]. The results were picked up for designing the DISPLAY system, in particular, its smart games and the related interface for playing with them. The resulting high-fidelity prototype, realised in Flash, was then evaluated in the second studies, that is, usability testing sessions of c.a 1 hour each. Tasks with the prototype were analysed in terms of their success and observations allowed us to detect unique usability issues. The results of all the studies of DISPLAY for deaf children are in-line with those found in the literature. Table 1, 2, 3, 4 and 5 recap the findings. Each table is related to specific characteristics (e.g. reading, attention, etc). A table is structured into two main parts: the white part is related to deaf studies; the blue part is for DISPLAY findings alone.

Deaf Studies	-Word recall by deaf seems poor for long words, as well as for abstract, ambiguous or unfamiliar words without contextual clues. -Deaf children's vocabulary skills are better when words have only a single meaning or when they are presented in context. Unfamiliar words or words which have not been specifically introduced to the students cannot be lip-read. -Reading involves using of the centre of visual field to fixate the word for hearing children. Therefore the fact that deaf children pay more attention to items in the periphery could partially cause confusion in the identification of letters and words.	[1;2;7;13; 30;31;35]	3.1.1 3.1.2 3.1.3 3.2.2 3.2.3
	-Deaf individuals seem to have problems with complex sentences, in particular, with cohesive devices and referential expressions. -Deaf students tend to remember disconnected portions of the text rather than the while picture.	[24;25;31; 35]	3.2.1 3.2.3
	-Deaf readers, like good hearing readers, use metacognitive strategies to monitor and maintain comprehension, but are less accurate in their meta-comprehension. -Deaf readers seem to benefit from a"windowed reading'' whereby only limited amounts of text are made available at any one time.	[19;17]	3.2.2 3.2.3
DISPLAY PROJECT	-They prefer reading short texts and books with pictures. -when deaf children are reading books, the teacher often has to recall the attention of the children and indicate the point where they were reading. -Deaf children are likely to have problems with; like cohesion; complex periods and in particular co-references, phonology. -Instructions are not always read; deaf children read them only if they appear before the start of the activity		3.1.2 3.2.2 3.2.3 3.2.4

Table 1 Reading

TABLE 2. VISUAL ATTENTION

CONSTRAINT	BIB	GL

Deaf Studies	-Deafness leads to changes not in all aspects of vision but specifically in visual attention and alterations of attention abilities. -Deaf individuals seem better in certain aspects of visual perception and specifically at allocating visual attention to the periphery of the visual field. -Deaf signers seem to be more distracted by peripheral events and hearing individuals are more distracted by central events.	[1;2;5;7;17;36;37]	3.2.2 3.2.3 3.3.1
	-Young children have more difficulties for serial recall and take more time for recovering attention	[14]	3.2.2
	-Deaf individuals are better than hearing individuals in orienting visual attention from one location to another, and are more affected by the presence of distractors, that is, they are less good in selective attention, whereas no difference was found in divided attention that is the ability of processing multiple stimuli in the visual field.	[6;7]	3.2.3 3.3.1 3.3.2 3.3.3
	-In deaf individuals the ability to discriminate very small differences in direction of motion is altered and more deaf subjects discriminated gross differences in direction as leftward vs rightward.	[12]	3.3.3

TABLE 3. FOCUS AND SOCIAL INTERACTION

CONSTRAINT		BIB	GL
Deaf Studies	-The majority of deaf children have problems in focusing their attention	[4]	3.4.1 3.4.3
	-Few mothers declare that they have problems in eliciting and maintaining eye gaze and joint attention with their deaf children.	[38]	3.4.2 3.4.3

	-Deaf children tend to be more impulsive and lack of inhibition and suffer for increased distractibility.	[8;39;40]	3.4.1
DISPLAY PROJECT	-Deaf children is distracted more easily and should always be called his/her attention with signs. When deaf children are reading books, the teacher often has to recall the attention of the children and point to where they were reading. -Deaf children tend to have diminished attention time. -If the teacher uses pictures or games the deaf child is more stimulated to perform reading tasks. -They are more alert of being treated differently and suffer from it. The older they become, the more frustration-prone they grow. -Def children devote less time to cooperative activities and significant more time to solidarity activities.		3.3.2 3.4 3.5.3 3.5.4 3.5.5 3.4.3 3.5.1

TABLE 4. MEMORY

CONSTRAINT		BIB	GL
Deaf Studies	-Reading ability is closely linked to overall short-term memory performance. This seems lower for individuals, so is long-term memory.	[9;11]	3.1 3.2
	-Deaf children surpass hearing children in short-term memory tasks for complex figures, except when the task involved serial recall. -Deaf people are accredited to rely more heavily on visuo-spatial short-term memory codes. Deaf subjects have deficits in recall for linguistic stimuli, printed words and pictures but not in recall of non-linguistic stimuli such as unfamiliar faces and spatial arrays of lights.	[9;10;12;14]	3.3.1 3.3.3 3.4.3 3.5.3 3.5.4

	-Deaf individuals may be a disadvantage on linguistic tasks that involve serial recall but they seem to be better in tasks that involve temporal order.	[12;32] [6;9]	3.3.1 3.5.4 3.5
DISPLAY PROJECT	-Deaf children show to better recall images than texts alone. -Since their first impact is with the physical aspect of a person, they tend to remember this better. Often, they refer to person by signing physical characteristics of the person.		3.2.2 3.4.2

TABLE 5. TYPES OF PLAYS

CONSTRAINT		BIB	GL
Deaf Studies	-In a variety of problem solving and other academic tasks, deaf students have been found more likely than hearing age-mates to focus on individual item information rather than relations among items.	[16;43]	3.5.2 3.5.5
DISPLAY PROJECT	-Deaf children generally prefer -Individual plays -Human avatars -Plays where they can make lip-reading -Plays with more visual and less sound components.		3.5

3 Guidelines for the Design of Usable Games for Deaf Individuals

There are many studies about design principles for technology artefacts for hearing children, but not for deaf children. In this section we state the first guidelines for designing computer games that are accessible for deaf children, and that arise from the research in deafness reported above. We clustered the guidelines into the following 5 main areas that are explained below.

3.1 Words on the Screen

According to the literature review, unfamiliar or ambiguous words, without contextual clues, are problematic for deaf children and words that have not been specifically introduced to the student cannot be lip-read. Moreover, if deaf readers

have an alteration in their visual selective attention, they could have problems in identifying the letters of a word and in creating representations that preserve both the correct letters and their correct spatial arrangements. Therefore texts should use familiar and unambiguous words, paying attention to neighbouring words that influence where the reader will fixate their attention [GL 3.1.1]. If unfamiliar, ambiguous or abstract words are used then their meaning should be easy to be inferred from the surrounding context [GL 3.1.2]. As explained in the literature review, word length matters, thus words should not be too long [GL 3.1.3].

3.2 Other Characteristics and Position of Text

Reading problems, issues with attention and memory suggest several guidelines for how texts should be positioned in screens for playing games. This is particularly true for instructions for playing games; accessible instructions accelerate the time to perform the playing task. Firstly, according to what in Sect. 2.1, any explanatory text, as in instructions, should use short and simple sentences, without complex referential expressions [GL 3.2.1]. For instance, deaf children will have problems to resolve who "her friend is" in the sentence "One day Ben and Sophie visited the biggest swimming pool in town with their Mum and her friend from work". Moreover, given the visual attention orienting and selective skills of deaf learners, the game should use visual clues or animations for directing the attention of the child on relevant textual information [GL 3.2.2]. Moreover, relevant textual information like instructions should occur in a separate dedicated part of the screen, with a small amount of information because deaf children may have problems with longer fixation and slower reading times and, in general, they perform better if limited amounts of text are made available one at a time [GL 3.2.3]. Instructions should better be placed before the start of the game, as suggested by our usability studies [GL 3.2.4].

3.3 Characteristics and Positions of Other Objects on the Screen

According to the literature review of this paper on attention, young children have more difficulties for serial recall and take more time for recovering attention. This means that younger learners may need fewer choices than older children in games. More in general, using the same items in the same position and order in the interface should aid the

recall of deaf children [GL 3.3.1]. On the screen, there should not be distracting stimuli for the peripheral visual field of view because deaf individuals are more distracted by peripheral events. On the edge of the screen, the interface should have objects and motion stimuli that do not distract the children from their main task [GL 3.3.2]. Deaf individuals are better than hearing in their ability to orient spatial attention especially at reorienting it from one location to another. More deaf subjects discriminate gross differences in direction as leftward versus rightward. This means that the interface of the game should use the motion of objects only in relation to the main task for the children [GL 3.3.3].

3.4 Interaction and Feedback

In general, children are impatient and need immediate feedback: they expect to see the results of their actions immediately; if nothing happens after their input, children may repeat their action until something does occur. Deaf children are problems to focus attention for too a long time in a reading task or demanding playing activities. In general, a child should not be left idle in front of the screen for too long a time without any stimulus or feedback. The game for deaf children, thus, could have vibration or motion feedback for directing the attention [GL 3.4.1] of the learner towards specific targets, e.g., the correct or wrong resolution of a game. However, one must be careful where to place the animation on the screen because it might adversely affect their focus attention. Since deaf children are more impulsive, the type of feedback must be calibrated on the target deaf children [GL 3.4.2] so as not to be frustrating or irritating. While hearing children can listen and answer simultaneously within the game, deaf children must interact with one task at a time, e.g., the game should propose a reading task and a resolution task in separate moments [GL 3.2.3] .

3.5 Game Genres and Avatars

According to the literature review, possibly due to difficulties in communicating and socially interacting with nearby peers, deaf children prefer single-player games [GL 3.5.1]. In our usability study with deaf and hearing children, we observed that all our children's preferences were for playing with consoles (about 27% of preferences). All children prefer doing specific activities always in the same place. The majority of deaf children prefer playing with consoles alone and prefer games with movement [GL 3.5.2]

(e.g. balance board of WII or kinect of XBOX). Therefore they need sufficient space to move freely while playing. Deaf children often fail to respond with gestures or signs when their eyes are attracted by the objects in motion, due to their difficulty with divide attention. While hearing children can listen and answer simultaneously within the game, deaf children must interact with one task at time. Moreover deaf children suffer from increased distractibility and have different attention needs according to the literature. Therefore the duration of the game should not be too long and composed of a single task at a time [GL 3.5.3]. However, since deaf children are easily irritated, the timing of games should be calibrated on the target deaf players [GL 3.5.4]. Deaf children perceive immediately when they are treated differently, the older they grow and the less impatient they become. Thus, the game should pay special attention to the age of the child, e.g., the genre of texts and pictures should be age-appropriate [GL 3.5.5]. Several studies show that children who played action video games showed enhanced performance on all aspect of attention. Moreover, from our own usability experiments with deaf and hearing children, it turns out that playing with video games takes a large part of the deaf children's day, and is preferred over other daily activities (e.g. TV, reading). So the training with games like action games may be used to enhance deaf children's skills, in particular, for improving their performance problem solving strategies [GL 3.5.6], possibly enhancing their working memory. According to our studies, human-like avatars guiding through games [GL 3.5.7] were the most appreciated.

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