Stepstone
- An Interactive Floor Application for Hearing Impaired Children with a Cochlear Implant

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ABSTRACT
This paper describes a novel interactive floor application suited for hearing impaired children with a *cochlear implant* (CI). Existing linguistic learning materials for CI children are restricted to analogue books and CD ROM application in which bodily interaction is rather limited. The paper highlights the relation between language and body movement and proposes interactive floor technology as a foundation for CI children's linguistic learning. The *Stepstone* application described in this paper combines body movement and group collaboration as a mean for practicing and enhancing speech and language skills for CI children in a school environment. Two Stepstone games for CI children are presented: the Stepstone Ling Game helping the children to calibrate their cochlear implants, and the Stepstone Language Game which is a framework for language concept training.

Author Keywords
Cochlear Implant Children, interactive floor, collaborative learning, participatory design.

ACM Classification Keywords
H.5 [Information Interfaces and Presentation]. H.5.1 [Multimedia Information Systems] augmented reality; H5.2. User interfaces.

INTRODUCTION
The Stepstone application was developed in the *iSchool* project under Center for Interactive Spaces (www.interactivespaces.net). The objective of the project was to create a new type of IT-based learning environment for hearing impaired children – especially children with a cochlear implant. Our hypothesis was that a combination of multiple interactions styles (visual, auditory and movement-based) using an interaction floor and tracking technology would create a stimulating learning environment for speech and language acquisition.

Figure 1 CI children using the Stepstone application

The Stepstone application was developed in a participatory design process with both children and their teachers as participants. In some of our design interventions, children were invited to participate as informants [23, 5] and in other sessions we collaborated with the children and their teachers as our design partners [1, 4, 11]. We particularly benefited from three 'Fictional Inquiry' design sessions inspired by Dindler et al [3], Verhaegh et al [24] and Iversen & Brodersen [13]. As propagated in the Fictional Inquiry technique, we established a shared narrative design space between stakeholders in the design process; in this case among teachers, pupils, speech and hearing therapists and designers. The participatory design sessions, in which the Stepstone application was conceptualized and developed is described in Iversen & Dindler [12]. Present paper, however, presents a novel IT supported learning applications for interactive floors in school environments.

The paper addresses cochlear implant children and the lack of suitable learning resources for CI children in school environments. We highlight the relation between language acquisition and body movement as a possible learning resource for CI children in their process of language acquisition. Interactive floors with limb-based tracking are introduced as an IT supported learning platform combining visual, auditory and movement-based interaction. We describe the Stepstone application and provide two game cases for use by hearing impaired children: the Stepstone 'Ling' game and the Stepstone 'Language' game. Finally, a preliminary evaluation of the Stepstone application is provided in the end of the paper. First, we will introduce the Stepstone application by a brief scenario.

THE STEPSTONE SCENARIO

A group of Cochlear Implant children aged 9-12 is studying language concepts and broader language concepts in a school project. The teacher and a group of older students have formulated a learning target aiming at understanding how words are related according to their kinship of broader concepts (e.g. banana, apple and orange belong to the broader concept fruit). Initially, they talk about different broader concepts (furniture, cutlery, flowers etc) and find examples in books and on the internet. Using the Stepstone game construction interface, they formulate different exercises for the interactive Floor. To the question: "Which animals belong to the category of rodents?" the pupils choose a number of correct answers (mice, rats, rabbits, etc.) and a number of incorrect answers (dogs, cows, frogs, etc.). A total of 10 questions constitute a leaning game, which can be played by the pupils themselves or with others at the interactive floor (The Wisdom Well) in the school department square.

They hand in the game that they have made to a group of younger pupils and they play it as a collaborative game with 4 participants (see Figure 1). The questions are given audibly and the participants then choose correct and incorrect answers from the visual areas. The Stepstone collaborative game environment makes them negotiate the correct answers through oral communication. As the CI children use their hands and feet as cursors, they have limited access to their use of sign language. Thereby, they practice their speech and hearing skills in a motivating and collaborative learning environment.

COCHLEAR IMPLANT CHILDREN AND THEIR LEARNING RESOURCES

Approximately 65 deaf children are annually born in Denmark (as a rule of thumb, one per million of the population of a country are deaf)[1]. An increasingly number of hearing impaired children is offered a cochlear implant (CI), which is a small, complex electronic device that helps to provide a sense of sound. The CI bypasses damaged parts of the inner ear and electronically stimulates the nerve of hearing. Part of the device is surgically implanted into the cochlea, and part of the device is placed externally. CI does not induce normal hearing, but makes it possible to hear sound in the speech area, which makes speech an obtainable objective for most CI children.

Every day, the children with CI run through a sound registration test of their hearing devices. They listen to and register Daniel Ling's[2] 6 sounds: '*mm*', '*ss*', '*sh*', '*oo*', '*ee*' and '*ah*'. The teachers conduct the Ling test. If the child is able to hear the Ling sounds, he/she is able to hear all speech. The process of Ling testing the child is both time-consuming and monotonous, but essential to the child's linguistic learning.

Figure 2 The Cochlear Implant

Current research indicates that children who get the implant at an early age can obtain good spoken skills and thereby participate in traditional education programs. However, the process of developing speech and hearing skills for CI children is comprehensive and depends on the resources provided [21, 18]

In the education of CI children, the Danish educational institutions focus on sound perception and speech production. Verbal communication is frequently the most used mean of social interaction, and if you're not able to speak, your relations to the surrounding society will be reduced. Communication through speech is a strong basis for learning to read and write and through this process to get an education and employment.

CI is a relatively new technology (the first cochlear surgeries on children in Denmark took place in mid-90s[3]) and the research into the pedagogical programs for CI children are currently in progress [21]. Therefore, actual pedagogic interactive materials are rather limited. Existing linguistic stimulating materials are restricted to analogue

[1] www.deaf.dk

[2] www.lingnotes.com

[3] www.decibel.dk

games, books and CD ROMs (e.g. Otto's World of Sounds[4]).

The outcome of CI surgery varies from child to child, depending on their cognitive resources and the supporting resources in their surroundings. There are many combinations of actual age and hearing age (age for receiving cochlear implant) and very few materials combine learning activities of actual age and hearing age.

The communicational problems, that accompany hearing disabilities, cause a risk of the child isolating itself. Group games among children are often at a fast pace and background noise makes it additionally difficult for deaf children to join these group games. Although CI provides a sense of sound, children with hearing disabilities do not get as thorough and varied explanations as hearing children; children with hearing disabilities often miss out on information that is not directly aimed at them, which may result in lack of behavior skills and creates possible social conflicts. Our empirical research/interviews with teachers indicate that children with hearing disabilities prefer functional games and individual sports over social games and team based sports [25].

The relation between language acquisition and body movement

In his social-interactivistic view, Bruner [2] stresses that play has a decisive significance in the construction of social contexts and in that way is the base of social experience in the child's everyday life. Thus, movement based play is an active part of creating potential speech stimulating situations (ibid).

Moser [17] describes that during play, children communicate with each other, and movement based play are often central, when children are active in a social community. Movement-based play often demands different kinds of communication and presuppose interactions between different communication modes, which require a dynamic adjustment of the communication process.

During interview, speech and hearing therapists and psychologists pinpoint that there is a connection between sense perception, motor function and language. This connection is also described in literature [7]. When one or more senses only partly work, it affects the child's possibility of receiving optimal sense impressions, which may complicate the child's development in different areas.

According to neuroscience, there are strong indications that movement and language are based on the same central nervous system related structures and processes, which makes it possible to imagine a positive effect between movement and language based areas [17]. Fredens argues that all movement learning processes are psychomotoric and psychomotorics *is* cognition [7]. Psychomotorics is an expression of a mental process at a cognitive level. Movement and thoughts can be controlled from the same nerve paths in the cerebellum. This led us to the hypothesis that there is a connection between body movement and language development. By stimulating bodily skills (movement), as a supplement to traditional speech and hearing teaching, we could enhance their linguistic capabilities. This hypothesis is inspired by the work of Gardner [8] on multiple intelligences.

According to Moser [17], movement based playing can be relevant in developing social skills. As social skills basically are language and communication, the social aspects of play can in itself improve the child's language skills. Accordingly, we developed a second hypothesis, that the social aspect of a collaborative play (itself) might enhance linguistic skills.

As new technologies emerge, the possibility to support and dedicate IT based learning facilities for CI children's training increase. Especially the use of interactive floors with its combination of body movement and collaborative interface seems promising. In the following we will describe existing interactive floors and present the hardware platform for the Stepstone application.

INTERACTIVE FLOOR TECHNOLOGY

Interactive floors have emerged in recent years, and can be divided into two main categories: sensor-based and vision-based interactive floors.

Sensor-based interactive floors are typically utilized in dance and performance set-ups e.g. the prototype Magic Carpet [20] and Litefoot [6]. The prototypes are sensor intensive environments for tracking the movement of feet and in the case of the Magic Carpet the sensor floor has been supplemented with sensor technologies for tracking the movements of the upper body and arms. The Z-tiles concept [16, 22], BodyGames [14] and the LightSpace™ technology[5] are existing interactive floors based on tiles and sensors to provide entertainment environments. In contrast to the sensor-based floors, the vision based floors support a more fluid and natural interaction on a floor surface. iFloor [15] introduces an interactive floor facilitating debate based on SMS and email contributions. A projector mounted on the ceiling is connected to a local computer to provide a display on the floor. The floor interaction works on the basis of a vision-based tracking package [19] analyzing the rim of the interface based on a video feed from a web-cam also mounted on the ceiling. In the iSchool project we wanted to combine the best features from existing sensor-based and vision-based interactive floors in a novel interactive floor setup with vision tracking limb contact points from below the floor surface. We call the interactive floor 'The Wisdom Well' as it was built in a school

4 www.oticon.com

5 www.interactivefloor.com

department square and serves as the hardware platform for the Stepstone application.

The Wisdom Well

The Wisdom Well is built into the physical floor of a school department square. The Well is a 3 m deep hole covered with a projection surface. The projection surface is 3*4 m glass of approx. 9 cm thickness divided into four tiles. The glass surface consist of 8 cm carrying glass, 3 mm Fresnell diffusion layer, and a 6 mm hard protection surface glass. The four tiles are supported at the outer edges and with an internal conic frame resting on a supporting pillar in the center.

The projection is created by four ProjectionDesign F3 projectors with 5500 lumen light power and a resolution of 1024*768 pixels. The projectors are placed vertically covering each their tile of glass. The projectors are driven by a Dell 9150 with a Matrox QID LP PCIe graphics board with four DVI outputs. Each projector is associated with a Logitech Quickcam, tracking limb contact points on the tile covered by the given projector (see Figure 4).

The four Web cams associated with the projectors are managed by a tracking client running on a Dell 9150 that runs the vision software supporting fine-grained tracking of limb positions. The limb-positions are communicated to the application machine feeding the four projectors. The tracking client can be switched to a mode in which it uses a ceiling mounted wide-angel Creative webcam for coarse-grained tracking of body contours from above.

The Wisdom Well supports sound through ceiling mounted Trolltex loudspeakers and a subwoofer placed nearby.

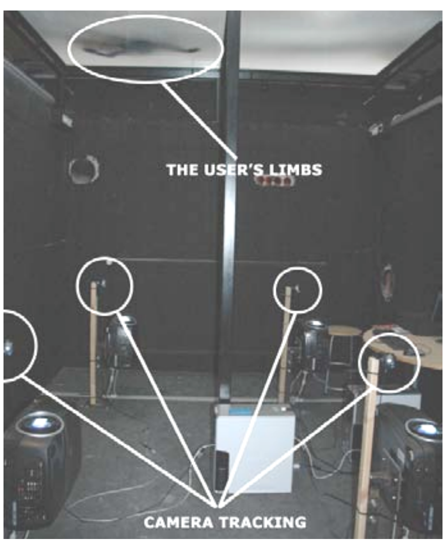

Figure 3 The physical setup of the Wisdom Well, an interactive floor for educational purpose

The start-up/shut-down of computers and projectors is controlled by a Creston control panel on a wall close to the floor. The Creston panel also controls lighting and curtains. Having powered up the Wisdom Well from the Creston panel, it can be fully controlled by body movement on the surface. A traditional keyboard and mouse is located on a nearby shelf ready to be used for editing purposes.

Children with hearing disabilities are in general dependent on technological equipment, not only on their hearing devices, but also on related supplementary materials as FM devices and Micro Links. We have experimented with the opportunity to connect the soundscape of the Wisdom Well directly to the CI devices through FM transmitters.

One of the major findings in the Wisdom Well platform is the use of the basement mounted cameras for tracking the user's limbs and processing them as input to the applications running on the floor. The ceiling mounted cameras (known from iFloor project [15]) are well suited for moving along a ribbon around the projection, but they are not suitable when tracking the accurate position of the user in order to e.g. click a button on the floor. Another issue regarding the ceiling mounted cameras is that users are seen in perspective and not directly from above. This makes it difficult to separate multiple users' contours from each other. However, the ceiling mounted camera set-up is inexpensive and easy to apply for light-weight versions of the Wisdom Well installation [15].

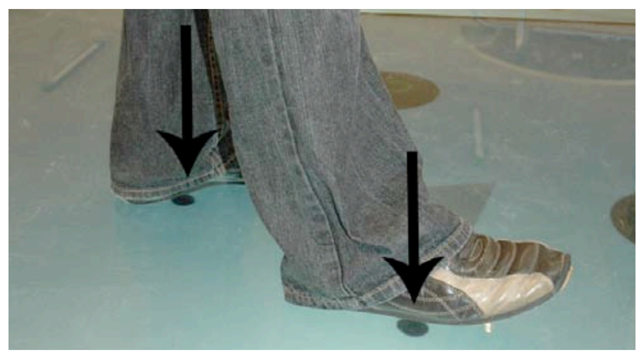

Figure 4 The black dots show the location of the user in the system and can be used as input in applications.

The limb-based interaction technique with tracking from basement-mounted cameras offers a solution to these problems even though it is not as light-weight as the ceiling mounted approach. One of the main advantages in the approach is the elimination of the perspective problem (as mentioned above). The user's limbs are in direct contact with the glass plates and only limbs in contact with the glass surface are tracked from below. The limb tracking occurs when contact points with the Wisdom Well surface create a sufficient contrast from both the projection and the rest of the body. Limb positions are piped via TCP/IP to the applications. It is thus possible to hit a button in an application even though other users are standing close. Since only the center and not the contour of the limbs are being tracked the users are much less likely to disturb other users while interacting with the application. Figure 4 shows a user's feet being tracked on the floor. The black circles indicate the center position of the user in the application and are very accurate compared to the physical location of the user. Tests have shown that at least 40 limb contact points can be tracked simultaneously on the floor though space is limited. The Wisdom Well is further described in Grønbæk et al. [9, 10].

THE STEPSTONE APPLICATION

As a result of our research into CI children's (lack of) learning resources, we developed a dedicated application for the Wisdom Well specially suited for speech and hearing training through body movement and social interaction. We developed the Stepstone application.

Stepstone is a multi-player and collective learning game, where the aim is to answer questions correctly and thereby score as many points as possible over a specified amount of rounds. 1-4 players can participate in the game, which can be played with participants as a group aiming at a collective high-score, as group against group, or as individuals against individuals.

The Stepstone application functions as a template in which different learning contents can be implemented as required, as well as the graphical environments can be varied (e.g. beach, rain forest, savanna, the city, etc.)

In this specific scenario, the setting is a beach environment with four shores in the corners and in the middle a sea filled with piranhas and stones that the players can step on. The only way to avoid getting bitten is not to step in the water.

Figure 5 Interacting with the Wisdom Well by limb-based interaction

Initially, the players go to the corners of the well to be registered by the system. After a few seconds the game starts and the system ask the first question – either by speech or as text on a nearby Smart Board.

At the same time randomly selected answers appear on top of the stones floating in the water. A part of the suggested answers are "correct" and a part of them are "incorrect" answers. The answers can appear either as images or text.

The players must now select the correct answers by placing their hands and feet on the stones within the given time limit (visualized by movements in the water). Since the amount of correct answers exceeds the number of players, the players will have to use both hands and feet in order to score as many points as possible.

Simultaneous reactions and quick bodily action is required on the floor to answer the challenges in Stepstone. A challenge can be to construct a sentence, recognize and combine a pattern or object, recognize a sound and match it to objects or associations. The hypothesis is that the participants struggle to physically touch the right combinations of stones. This may help them memorize the results, since they were coupled to a fun bodily and intellectual experience.

When the time is up, the selected answers will be evaluated and the player's collective score will be updated. If a selected answer is correct, the team will score a point. Otherwise the team will lose a point and the piranhas will swim towards the wrong answers and consume the stones with their razor-sharp teeth.

Figure 6 The Stepstone game floor

Following the evaluation the players will have to return to their starting points in the corners of the well. After a few seconds the system will ask a new question.

The game ends when all questions have been answered and the collective score will be displayed at the smart board with a funny animation of sea creatures – e.g. a big shark for high scores and a poor creature for low scores.

Stepstone has a game editor in the left sidebar to allow teachers and children, if allowed, to edit the games (see Figure 7). The Stepstone game editor can be accessed on the interactive floor and on a traditional PC. The content is displayed in a tree-view where questions and answers can be created or edited. Games can also be previewed and played using the mouse to test the game play before publishing the game to the floor. The Stepstone editor can be operated either on the floor itself or on a separate workstation.

Thereby, the making of the game is integrated into the game itself. Observing the construction of Stepstone questions and answers seemed to be entertaining in itself and – as proposed by teachers, a learning experience.

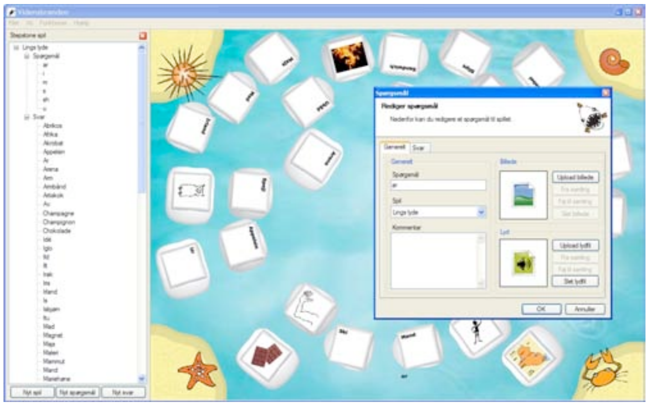

Figure 7 The Stepstone editor can be operated from a standard PC. Content can be edited in game editor.

STEPSTONE LING GAME

Using the Stepstone application, we have created a game particularly for CI operated hearing impaired children. The object has been to provide the children with an alternative and more fun way of testing the Ling sounds, as this daily exercise could be rather boring.

The Stepstone Ling Game consists of two rounds for each six sounds. The answers to the questions will mainly be displayed as images on the stones, e.g. a snake or a sun for the "s"-round.

In each round the Ling sound will be transmitted directly into the hearing aids of the children. The teacher has the possibility to increase the background noise in order to increase the difficulty of the task. Additionally the teacher could let the children speak the sounds out loud. The exercise of letting the children pronounce the words in stead of using sign language is helped along the way by the game play – using the children's hands as cursors to answer the questions proposed by the system, the children are obliged to use spoken language as means of communication.

STEPSTONE LANGUAGE GAME

As introduced in the beginning, another example of a game created in the Stepstone environment is the Stepstone Language Game. On the basis of CI children's special needs as described previously, the game is focused on:

- Synonyms/antonyms
- Language concepts and broader language concepts
- Prepositions
- Position of articulation (lip, tongue, palate)
- Distinction between resembling words/sounds

The Stepstone Language Game consists of 15 rounds, which randomly combines these five learning themes. The introduction is an example of one round of the game. Another is a round based on synonyms to "happy". The sound "happy" is transmitted directly into the cochlear implant of the participating children and following they have to mark the correct areas on the game platform (e.g. pleased, glad, satisfied) and avoid marking the in-correct (e.g. tired, angry, small).

PRELIMINARY EVALUATION OF STEPSTONE

The Stepstone application was released for prototypical use in December 2006. Thus, a full-scale evaluation of the application is not yet accessible. During the first months of the design project, participant observations of children's interaction in the Stepstone learning environment were conducted. Preliminary analysis of the observations brought about some directions for further study:

- The physical setting at the department square of the school including the large projection surface sets the scene for co-located collaborative gaming environments. Even though the Stepstone game is intended for a fixed number of participants (e.g. two or four) up until 30 children were incorporated in the game play as supporters and participants.
- Children help each other throughout the game, negotiating game elements with each other to increase their common score. Thereby, the collaborative co-located setup initiates knowledge sharing and communication among the pupils.
- The fact that the children are able to construct their own games adds a dimension to the gaming experience. Preparing a game can be equally entertaining as playing the game. Moreover, the Stepstone game editor has enabled the pupils (and teachers) to dedicate the assignments in the Stepstone application to a specific learning task.
- Children are able to interact with the Wisdom Well platform using body movement as the only mean of interaction.

Finally, the CI Children were generally motivated by the use of bodily interaction and described the social games as 'fun', 'motivating' and 'a good playground for learning activities'.

FUTURE WORK

We have developed a novel application for hearing impaired children. However, the CI children can also play the games with hearing children. This makes the Wisdom Well a gathering point for all the pupils at the school. Giving the deaf and hearing impaired children the chance of hearing the questions as well as the hearing children gives them equal conditions when playing the games.

In our future work, we will look more into entering in background noises to the Stepstone application. This way the teachers or the children can adjust the level of noise when hearing the questions and it partly compensates for the missing auditory sense in relation to hearing children.

However, we still lack a thorough evaluation of Stepstone learning potential in order to confirm or deny the hypotheses on improving language skills by using movement and social interaction.

CONCLUSION

This paper has introduced the research into the Stepstone application as a platform for collaborative learning games for CI children. Preliminary studies indicate that the Stepstone application accommodates CI children in several ways:

First, the Stepstone application set a stage for social learning activities which lead to communication among the participants through movement based activities. The games are a way of improving speech skills, whether it concerns concrete sound/speech training according to a bottom-up method or the natural "free" dialogue according to a top-down method.

Examples of bottom-up: playing Stepstone is an obvious way to train vocabulary through games. The Stepstone Language Game is an example of this kind of training, in which the exercises practice concepts, synonyms and antonyms, syntax, position of articulation and distinction between resembling words/sounds. The Ling game is another example of daily hearing training. Top down dialogue is a natural part of the game, based on the fact that the participants obtain a total score during both Stepstone Ling Game and Stepstone Language Game. Thereby they have to communicate with each other to mark the correct answers.

The Stepstone application makes it possible to combine actual age and different levels of linguistic skills as teachers and pupils fill in learning contents themselves in the applications. Finally, the Stepstone application creates a basis for applying multiple senses simultaneously: auditory, visually and movement based.

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