WamBam: A case study in design for an electronic musical instrument for severely intellectually disabled users

Arvid Jense
Eindhoven University of Technology
Den Dolech 2
5612 AZ Eindhoven, the Netherlands
a.jense@student.tue.nl

Hans Leeuw
Eindhoven University of Technology
Den Dolech 2
5612 AZ Eindhoven, the Netherlands
h.leeuw@tue.nl

ABSTRACT
This paper looks at the design process of the WamBam; a self-contained electronic hand-drum meant for music therapy sessions with severely intellectually disabled clients. Using co-reflection with four musical therapists and literature research, design guidelines related to this specific user-group and context are formed. This leads to a concept of which the most relevant aspects are discussed, before describing the user studies. Finally, the plan for the redesign is discussed.

The WamBam has unique possibilities to deal with the low motor skills and cognitive abilities of severely intellectually disabled users while music therapists benefit from the greater versatility and portability of this design compared to other musical instruments.

A prototype was tested with twenty users. Participants proved to be triggered positively by the WamBam, but three limiting usability issues were found. These issues were used as the fundamentals for a second prototype. Music therapists confirm the value of the WamBam for their practice.

Author Keywords
Music interfaces, music therapy, vibrotactile feedback, prototyping, real-time performance, product design.

ACM Classification
H.5.2 [Information Interfaces and Presentation] User Interfaces - Haptic I/O, H.5.5 [Information Interfaces and Presentation] Sound and Music Computing, K4.2 [Computers and Society] Social issues - Assistive technologies for persons with disabilities.

1. INTRODUCTION
Making music can help a severely intellectually disabled person to express himself, to relax, to communicate, to get more self-awareness or just to have fun. [8] Because traditional instruments often don't have suitable affordances for this user-group, it is an interesting design case to create a suitable electronic instrument.

The endless possibilities of electronic sound synthesis are useful to match the unpredictable moods of this user group. The challenge is to contain these possibilities to a comprehensive and expressive interface which is suitable for people with low motor skills.

Music therapists and caretakers are especially open to new tools assist them in their practice or improve the lives of their clients, making cooperation and user testing very accessible.

1.1. Intellectual disabilities
A person is indicated as having a severe intellectual disability when he or she has deficits in intellectual and adaptive functioning to such a degree that attainment of conceptual skills is limited, speech is limited and support is needed for nearly all daily activities. [1] Severely intellectually disabled user's learning level usually stay in the sensomotoric phase of Piaget's developmental model [9], meaning that learning goals are mostly focused on the development of the senses, motor skills, and memory. Specific considerations are:

- Users often lack the intellectual or cognitive abilities to understand instructions; a product has to be self-explanatory and predictable.
- Because of the lack motor skills and unpredictability of the user, a design needs to withstand a high level of abuse.
- A lack of communication skills means that the intellectually disabled user cannot be interviewed, and user research has to be done by careful observation and explanation by a caretaker.

1.2. Music therapy
Music therapy is defined as a "[…] practice and profession in which music is used to actively support people as they strive to improve their health, functioning and wellbeing." [2] Benefits for people with severe intellectual disabilities range from triggering simple emotional responses, to advanced training of cognitive or motor skills. [8] The music therapy sessions performed by the music therapists who were interviewed in this project, however, focus mostly on relaxation and interaction between therapist and client.

Essential in music therapy practice are the musical instruments. Each instrument is different in its sounds, interaction, portability, fragility and usefulness towards different learning goals. To accommodate the diverse needs and unpredictably of their clients, music therapists often take a large number of instruments with them. This can lead to a feeling of being overburdened.

Another issue is the price and fragility of an instrument. Music therapists often need to work with a limited budget or even need to use their personal instruments in their practice. Using high-grade instruments poses risks through their fragility, while cheaper instruments are often less engaging.

The four music therapists interviewed for this project indicated that they need for an instrument that has:

- Low price point.
- High versatility and adjustability for use with clients with a diverse range of limitations and learning goals.
- Engaging yet low threshold interaction.
- Engaging and diverse sounds.
- High structural integrity and cleanability.

2. RELATED WORK

A commercial musical interface is the “Skoog”, as shown in Figure 1. This is a soft cube with five colored areas that can be touched, shaken or twisted to create a sound. They have focused especially on creating musicality and created a musical scoring system which connects to the colors. This product, however, needs an external control and amplification system. The music therapists interview in this research felt that both the price and need for a connected laptop and speaker system are big disadvantages to this product.

Figure 1. Skoog, by Skoogmusic.com

A number of design guidelines can be distilled from research in musical instrument design for (intellectually) disabled users [3] [4] [6]:

- The main challenge is to create an instrument through which the user will feel that they can express themselves.
- Subtle design decisions such as color can have a huge impact on how the users react to it.
- There should be a clear, sensory-rich multimodal mapping between interaction and reaction.
- The instrument need to be identifiable as a musical instrument.
- The instrument should have a low learning curve for both usage and configuration.
- All musical modalities (rhythm, timbre, pitch and time) should be available for interaction.
- Make sure a satisfactory musical interaction is possible within the first impression.
- Design learning and demonstration material to show the possibilities of the instrument.

3. PROCESS

The design is made specifically for interaction between music therapist and client, as such; a co-design process is used to provide maximum user input. To overcome the lack of communicative skills of the primary user, the ideation phase focusses on just the music therapists; being both secondary users as well as proxies for the primary user. User-tests were done in a later stage to validate design choices.

The *WamBam* concept was formed through interviews and brainstorming sessions with four music therapists. A prototype was made and tested with 20 users covering a wide variety of intellectual disabilities. The user test was analyzed through a “usability problem report” [5] out of which came three main usability problems. Parallel to this, an informal qualitative analysis was done.

Figure 2. Interaction between client and caretaker in the user-test.

4. CONCEPT

The *WamBam*, in its essence, is a versatile wireless self-sounding electronic hand-drum in the shape of a multi-sensory dome, of which an image shown in Figure 3. It is inspired by the hang drum, the Korg Wavedrum and the Omni, which is a special instrument located in the *Klankspeeltuin*[1] at the *Muziekgebouw aan 't IJ* in Amsterdam. The *WamBam* has ambitions to be: an engaging multisensory music therapy activity; a versatile and reliable musical instrument that has the affordances to be used by people with a wide range of motoric and cognitive (dis)abilities; and easy-to-use, affordable and portable in a music therapy practice.

4.1. Shape and interaction

The *WamBam* is a dome about 60 cm in diameter and 20 cm in height and weighs ±2 kg. The brightly colored pads are textured with discernable patterns. When touched, struck or stroked, the instrument makes a sound and resonates. The type of sound, tuning and the sensitivity of the instrument can be configured by the music therapist in an external, wireless interface.

The shape allows therapists and clients to sit around the instrument. It can be placed on the ground, a table, the lap of the client or on a wheelchair table. The WamBam has a high structural integrity and is easily cleaned with a damp cloth.

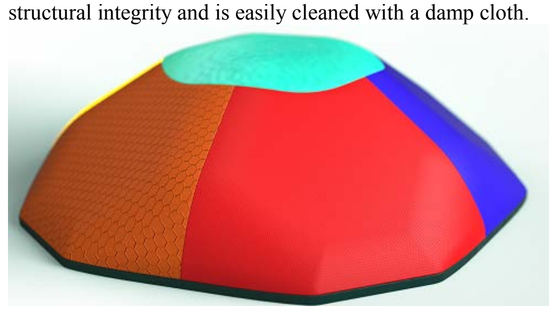

Figure 3. Final prototype concept.

4.2. Vibrotactile feedback

Electronic and acoustic instruments both have their advantages and disadvantages. Where acoustic instruments have a very direct and rich feedback loop in their interaction, the loop is disconnected in electronic instruments, as their sound is heard from a different location than where the interaction takes place. The interviewed music indicated that this is something which can act as a major distraction in music therapy sessions. Research has shown that adding vibrotacticle feedback can improving the interaction with an instrument [7].

Vibrotacticle feedback can be generated with a vibration speaker. This is a speaker which uses an external surface as the speaker cone. A big advantage of this component is that it creates both vibrotactile and audible feedback.

Figure 4. Vibration speaker.

4.3. Sounds

Sounds can be chosen from several variations in the general categories shown in Table 1. These categories are chosen to function in for a wide range of learning goals. A lot of control

[1] http://jeugd.muziekgebouw.nl/informatie/Klankspeeltuin/

is left to the music therapist. For instance, in the *recognizable sounds samples mode*, the music therapist is able to choose sounds which have a special meaning for their client. They could record spoken words from all friends at the daycare, and then play them back at home to their own family members.

Table 1. Categories of sound programs.

Type of sound	Example
Recognizable sound samples	Animal sounds or voices of family members.
Musical sound samples	Snippets of familiar songs or Patatap-like sounds.
Meditative sounds	Hang drum-like or gong-like.
Percussive sounds	Drum kit or different types of short noises.
Melodic sounds	Marimba-like or organ-like.
Chords	Tuned in the primary chords.

5. USER STUDY

5.1. Setup

Twenty users with a wide range of severe intellectual disabilities in two care facilities took part in a user-test. A music therapist put the instrument in the lap or on the wheelchair table of the users. Then she showed him or her how it could make a sound. The music therapist would try different sounds to figure out what the user liked and in what ways the user would interact with the instrument. Sessions took in between two and twenty minutes. The user-test sessions were recorded and notes were taken directly. Afterward, a usability problem report [5] and an informal qualitative analysis were performed.

5.2. Prototype

The prototype aimed to materialize all basic design features and make them available for practical testing. It functioned as the foundation to test the technology, as well as the sound design. Figure 5 shows the shape and internal electronics.

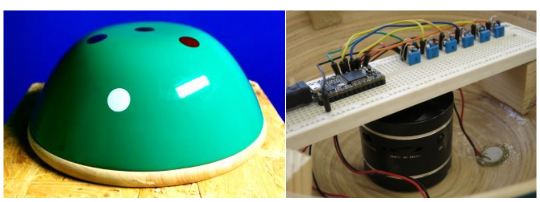

Figure 5. Exterior (left) and interior (right) of the first prototype.

As to easily get a solid, easily cleanable shell, an off-the-shelf salad bowl was used as the basic structure. This bowl had a suitable teal color, which was supplemented by colored circular vinyl stickers at the locations of the pads.

It was chosen to use piezo elements to detect a hit by the user. An advantage is that the elements could be glued underneath the surface of the bowl, greatly simplifying the construction as well as keeping the surface smooth. A disadvantage is that all the pads would respond to any hit and heavy filtering was needed to get the desired response. This caused that each pad was only hittable right on top of the sticker.

The sensors are put through a simple filter and read out by a Teensy 3.1 microcontroller. This device processed the data and would send a MIDI message over USB to a laptop for the actual sound synthesis. The sound was generated from Ableton Live. Most of the sound programs used physical modeling to get a dynamic relationship how hard the pad was hit and the timbre of the sound; making the instrument feel more natural.

An off-the-shelf vibration speaker is used, mounted with a bolt through the top of the shell. This provided maximum vibrational coupling to the device, but it caused the bolt's head to protrude from the top. It was attempted to hide this with a sticker, though this was often mistaken for another pad by the users. The vibration speaker is powered by its own battery and the audio was fed through a mini-jack cable from the computer.

5.3. Results

5.3.1. *Usability issues*

The usability problem report revealed three main problems with the prototype:

- Users often hit too soft, resulting in no sounds.
- Users often hit next to the pads (lack of motor skills), resulting in no sound or an unexpected sound.
- Users don't understand that pads are distinct (lack of cognitive ability), leading to repetitive and non-exploratory use.

These issues often caused users to either use the instrument in a repetitive way without exploration or to get disinterested.

5.3.2. *Reactions users*

The reactions of the users were as diverse as their personalities. Some thought the instrument was absolutely amazing while others were scared and some plainly disinterested. While 15 of the participants initially reacted positively, over half of these got disinterested with the instrument at some point and stopped interacting or even pushed it away. The reasons for this can be found in the unresponsiveness caused by the identified usability issues.

A peculiar reaction was from one participant, who seemed to think the device would hurt him. He would hit the instrument, feel the vibration for a second with his hand palm and quickly retreat while shaking his hand as if he had received a small jolt of electricity. He would repeat this for more than five times. We could not identify what the source of this assumed pain was.

Several users were particularly interested in the vibrotactile feedback. They would hold the instrument with two hands and would hit the device only when it stopped vibrating. They kept playing with the same sound for a prolonged time and reacted disappointed when a sound with a lesser vibrotactile component was put on.

5.3.3. *Reactions music therapists*

While the music therapists were generally positive, they felt like the instrument still needed serious work before they could be able to use it in their practice. They noted the usefulness of being able to switch sounds, but wanted more diversity of sound and more pads. Some of the sounds, like *meditative* got used a lot, while the *melodic* sounds got lesser interest. This might differ for users with a higher level.

A big drawback was that the instrument still had a wire attached to a laptop in the user-test. Combined with the knowledge that this was "just a prototype", the music therapists did not regard the prototype as a full instrument, causing them to stay close to the instructed interaction, instead of daring to look for new forms of interacting.

An idea that got the music therapists excited was the possibility of putting their own recorded sounds on the instrument. They felt this would give the device a serious added value even outside of the context of music therapy.

An interesting suggestion was to add mounts to the instrument through which straps could attach the WamBam on a solid surface. This would allow the instrument to be used even with aggressive or uncoordinated users.

Music therapists suggested making the pads customizable in its graphics to can make the device more personal and to allow to coupling visual meaning and sounds. This could also help in making the instrument more acceptable for picky clients.

Another suggestion was to use lighting underneath the pads as an extra modality, as to trigger the users to touch a pad which lights up.

6. REDESIGN

Taking note of the evaluation from the user-tests, construction of a second prototype was started. The aim is to solve the three main usability issues. This prototype is yet to be tested.

As two of the three usability issues dealt with users missing the pads, this prototype was made into half a truncated icosahedron instead of a dome. The separated surfaces should make it clearer in which way the active areas are separated. The shape was made by laser-cutting MDF, which was glued and painted.

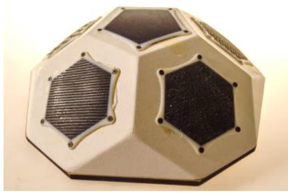

Figure 6. Exterior of the second prototype.

The piezo sensors of the previous prototype only responded to medium to hard hitting on the exact location of the pad. This required too much motor skill for some users. An alternative was found in using velostat force sensors. With these sensors, even a soft touch can be detected. A disadvantage is that the sensors need to be placed on top of the surface of the structure. The pads consist of multiple sensitive areas, enabling the detection of stroking, pushing and hitting.

To improve tactile and explorative qualities, each pad would get a specific pattern. These pads were 3d printed in a soft rubber material. It is expected that the extra tactile modality of these pads will also have a positive influence on the ability to play the instrument intuitively.

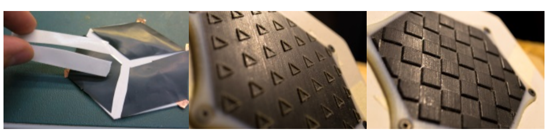

Figure 7. Velostat sensor (left) and variations in tactile patterns (right).

7. DISCUSSION

7.1. Design evaluation

The WamBam prototype was received well; users got engaged with the instrument and music therapists found the instrument to be useful in their practice. Still, more iterations are needed before the WamBam could be deployed in the field. As a first step, the three main usability issues need to be fixed through a new prototype and more user studies.

While designed with severely intellectually disabled persons in mind, there is no reason that the WamBam wouldn't be suitable for other user-groups. Maybe with some variations in color or shape, but with all the same technology, this instrument could be seen as a serious musical instrument.

Other researchers and designers could benefit from using a similar approach as this project, when designing for a difficult user group. It allows for the finding of real needs through interviews, while assumptions are quickly dealt by quick through testing.The design guidelines identified at the beginning of this paper could be applied to similar projects.

8. FUTURE WORK

With the three usability issues identified, the next step would be to test the second prototype and see how the interaction changed. The use of multimodality should be a focus in these tests; do the users react to tactility and sound? Is adding another modality, such as light, beneficial? Or is it better to keep the focus on one modality?

Interface design fell outside of the scope of this paper, but is essential for the adoption of the WamBam. Once the technology and interaction of the basic design have been defined, the focus can shift towards the interaction on the music therapist's side.

An interesting point from the interviews with the music therapists which did not get explored yet, was that they felt there was a need for an instrument that was usable by their clients without a therapist being present; as a way to continue the positive effects of music therapy outside of session time.

9. ACKNOWLEDGEMENTS

All the participants of the user-tests.

Music therapists Lizzy Dinghs, Sasja van der Oord, Josephine te Pas and Annemiek Vink for helping in the research, ideation and user-testing phases of the process.

Losserhof and Jelle's mother for allowing and hosting the user-testing sessions.

The employees of TU/e /d.search lab for supporting the construction of the prototypes.

References

[1] American Psychiatric Association, "Intellectual Disability," in *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition: DSM-5 [5 ed.]*.: American Psychiatric Publishing, 2003, 33-41.

[2] Australian Music Therapy Association. (2012) What is Music Therapy? [Online]. http://www.austmta.org.au/content/what-music-therapy

[3] B. J. Crowe and E. Ratner, "The Sound Design Project: An Interdisciplinary Collaboration of Music Therapy and Industrial Design," *Music Therapy Perspectives*, vol. 30, no. 2, p. 101, 2012.

[4] A. Hunt, R. Kirk, and M. Neighbour, "Multiple Media Interfaces for Music Therapy," *IEEE Multimedia*, 2004, 50-58.

[5] D. Lavery, G. Cockton, and M. P. Atkinson, "Comparison of evaluation methods using structured usability problem reports," *Behaviour & Information Technology*, 1997, 246-266.

[6] M. Luhtala, T. Kymäläinen, and J. Plomp, "Designing a music performance space for persons with intellectual learning disabilities," in *International Conference on New Interfaces for Musical Expression*, Oslo, 2011.

[7] M. T. Marshall and M. M. Wanderley, "Vibrotactile Feedback in Digital Musical Instruments," in *Conference on New Interfaces for Musical Expression*, Paris, 2006.

[8] T. Meadows, "Music therapy for children with severe and profound multiple disabilities: a review of literature," *Australian Journal of Music Therapy*, vol. 8, p. 3, January 1997. [Online]. http://www.thefreelibrary.com/Music therapy for children with severe and profound multiple.-a0189828370

[9] J. Piaget, *The Psychology Of The Child*. Paris: Presses Universitaires de France, 1969.