Health Improving Multi-Sensorial and Musical Environments

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ABSTRACT
In this paper, we present an interactive multi-sensory environment designed for health promotion. It is the fourth generation in an ongoing research project. We focus on the designed qualities of the environment, and specifically on the multi-sensorial and musical interaction design. We present how we have designed the interactive music and multi-sensorial qualities of the environment, to make them health promoting. We combine knowledge from the field of interactive Music composition, Interaction Design and Tangible Interaction with knowledge from therapeutic disciplines such as Music and Health, Music Therapy and Sensory Integration. We use music and sensory interaction possibilities to evoke the users' positive emotions, to recognise, relate and regulate their moods and feelings. The multi-sensorial environment offers the user possibilities to use their own capabilities and resources to master by experiencing control, coping and advancement. Further, to be able to express themselves through musical and sensory stimulating and aesthetical experiences, and build healing and empowering social experiences and relations.

CCS Concepts
• Human-centered computing~Interaction design • Human-centered computing~Ubiquitous and mobile computing • *Human-centered computing~Accessibility* **• Applied computing~Health care information systems • Applied computing~Media arts • Applied computing~Sound and music computing**

Keywords
Musical Interaction; Multi-sensory environment; MSE; Internet of things; IoT; Health; Tangible Interaction; Sensory Integration; Snoezelen; Music therapy; Music and Health; Music Interfaces.

1. INTRODUCTION

1.1 Music and Health
The health value and effect of music, for a number of diseases, has been well documented, within biomedical and humanistic health research over the last 20 years [1], [2]. Currently we know many ways in which music can empower people and promote vitality and health [3]–[6] from research within fields like *Music and Health, Music and Medicine* and *Music Therapy*. In these fields, they use both traditional acoustic and electronic instruments such as drums, keyboard and guitar. Instruments that give *direct response* on user input. They also use electronic equipment to record and amplify the music and singing. The computer's possibilities to *listen*, *remember* (log), *learn* and respond more "intelligently" (advanced software algorithms), as an actor, are used to a very little degree [7].

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1.2 Sensory Integration and MSE
Sensory Integration and sensorial modulation are different perspectives on understanding a person's management of sensory stimulation, based on occupational therapist Jane Ayres groundbreaking work in the 50-ties [8], [9]. Sensory Integration Therapy and related methods are diverse therapy forms to develop a healthy processing of sensory input, such as emotional regulation, learning, behavior, and participation in daily life.

In the diverse sensory therapy forms, they use different tools, equipment and environments as parts of the sensory therapy. Multi-sensory environment (Snoezelen) is such an environment, and has been used in therapeutic settings for decades in hospitals, care centers and schools [10], [11]. It was originally developed, in the Netherlands during the 1970s by Hulsegge and Verheul, who called it Snoezelen. The Snoezelen term has later been registered as a brand name by one equipment company, so MSE is currently the preferred term [10]. MSEs offer controlled sensory experiences, for people with profound and multiple disabilities, to provide positive changes in moods and emotional states over longer time. MSEs are often equipped with projectors and effect wheels, bubble tubes, simple music instruments, fiber optics, vibrating devices, aroma diffusers and sound equipment [10]. But they very seldom include advanced interactive equipment from an Interaction Design point of view. The interfaces are often just simple switches, and the field has so far a very modest understanding, as we see it, of what computers can do and be for persons with special needs, but using its advanced possibilities as mentioned above [12]. Some projects have been done within the European AAL program to develop technology, mostly based on iPad and Smartphone interfaces to provide health and wellness for people with special needs [13]. Nothing, to our knowledge, combines advanced sensorial stimulating interfaces with advanced music and social sound creating possibilities.

1.3 Interactive Multi-Sensorial Environment
Our research attempts to combine perspective from Tangible Interaction Design and Interactive Music Composition with Music Therapy, Music and Health and Sensory Integration. Based on what possibilities current tangible, mobile, wireless, social and

musical technology offer, our goal is to develop health promoting technology, in a humanistic sense, that focus on peoples own abilities and resources, not their diagnosis and weaknesses.

Drawing from the diverse therapy areas this technology should *evoke* the user's positive feelings and vitality [5], [6], [14]–[20], give them possibilities to *express themselves* in diverse ways and regulate their moods and feelings [25]–[27]. Further, they should offer the users challenges and possibilities to learn and *master* over long time [5], [6], [25], but also to communicate, *participate* on *equal terms* to build and strengthen relations to other people and things [5], [6], [20], [27]. Coming from crafts and culturally oriented disciplines such as Music Composition and Industrial Design, we also want to emphasise the *cultural* and *aesthetic* aspects of the experience [6], [25], [1], [7], [12], [27]. We therefore use the term "multi-sensorial", instead of "multi-sensory" as the occupational therapist do.

2. METHOD

The basis for this paper is the five-year interdisciplinary research project RHYME (www.RHYME.no). The project goal has been to develop tangible musical interactive things (MSE), interactive multi-sensorial environments, for promoting health and life quality for children with special needs and their families [2], [1]. The project is interdisciplinary and a collaboration between the fields of Interaction Design Industrial Design, Universal Design, Music Therapy and Music and Health.

The project encompasses four empirical studies (see "Generation" 1-4 in Table 1) and three successive and iterative generations of interactive multi-sensorial things (see "MSE" in Table 1) based on participatory action research methods. Its user-oriented research approach includes the users' influence on the development of the prototypes in the project, together with the inter-disciplinary team. Six families and their care persons have volunteered to participate over 5 years. The children with disabilities in these families range from seven to fifteen years old, and vary considerably in terms of behavioral style, diagnosis and resources. All tests were video recorded and observed by the inter-disciplinary research group, teachers and close care-givers during the user tests. Every test period included four actions; We changed the prototypes and setup, from action to action based on the observation, interviews and inter-disciplinary discussion during the test periods. The video and interviews were afterwards thoroughly analysed by the health-oriented researchers in the project [14]–[20].

Table 1. below shows an outline of the RHYME project regarding the main multi-sensory environment (MSE) developed within each Generation (1-4), the *technology* used in each generation, the *data collected* in each action and some *main findings*.

Table 1. The RHYME project structure of Generations, Technology, Actions and Findings

Generation	**MSE** (Year)	Technology	Actions - Data collection	Main findings
1- Basis	**ORFI** (2007) **8** music tunes	MiniMac, Atmel (wireless modules) **I:** Bend Sensors, Microphone **O:** Speakers, LED, Projector SuperCollider Jitter (Dynamic Graphics)	Video observations of use, Questionnaire, Focus Group discussion, Inter-disciplinary reflections formulation of goals for next generation	+ Open to many actions, relations and roles Microphone input important ÷ Too hard to access sensors for some, Need direct response at interaction the place
2- Multi-media	**Wave** (2012) **1** fixed dynamic soundscape	MiniMac, Arduino Mega, **I:** Bend, Touch and Move Sensors, Microphone, WebCam **O:** Speakers, LED, Vibrator/Transducer, Pico Projector SuperCollider, Processing	Research-by-design User-Centered Design, Video observations of use, Questionnaire, Focus Group discussions, Inter-disciplinary reflections formulation of goals for next generation	+ Many ways to express one-self, act, master over time, build social relations. Vibration, base important. ÷ Too heavy and big, and hard to hold for some Too hot and problematic with Pico Projector
3- Mobile media	**Reflect** (2013) **7** music tunes	iPod + J Device (our own designed breakout board) **I:** Bend and Touch Sensors, RFID-Reader **O:** Speakers, LED, Pure Data, Arduino (software)	Research-by-design User-Centered Design, Video observations of use, Questionnaire, Focus Group discussions, Inter-disciplinary reflections formulation of goals for next generation	+ RFID selection of music, lightweight, wireless, evoke feelings and motivate to explore, play with different sounds and objects ÷ Users lack microphone possibilities and visual projection-based stimulation and experiences
4 -Social media	**Polly World** (2015) **50** tunes (user wish)	Wired (MiniMac), iPad Wireless (BeagleBoneBlack) **I:** Bend, Touch and Move Sensors, WebCam, Microphone, RFID-Reader **O:** Speakers, LED, Back Projection SuperCollider, Twitter, HTML	Research-by-design User-Centered Design, Video observations of use, Questionnaire, Inter-disciplinary reflections formulation of goals for future generation	+ Many ways to play, re-gulate feelings, express one-self, act, master and build social relations over time. ÷ Some user groups need longer tunes and daily, rituals. Need washable and lighter textile solutions

3. POLLY WORLD

We have chosen to call the fourth generation of interactive multi-sensorial environment that we present here Polly World. Polly World is the result of three earlier generations of interactive environments we have developed through the project (see Table 1). The findings from testing and development of earlier generations are documented from both the Music and Health fields [14]–[20] and from the design related fields [12, 7]. Polly World combines our findings and knowledge, that we have based on more than 10 years of research. The different parts of the interaction design solutions, such as sensors, sensorial stimulating qualities and music-making possibilities are thoroughly tested in parts in earlier generations [14]–[20]

The multi-sensorial environment Polly World consist currently of one wired and three wireless interactive objects in textile (see Figure 1).

Figure 1. Family playing in the multi-sensorial environment Polly World. © Birgitta Cappelen

The wired one, Polly Land, is size 5 by 5 meter and contains the following sensors and actuators: Five soft and light-responsive touch-sensors (see Figure 2), four soft bend-sensors, one textile embedded web-camera, a microphone, RFID-reader and a back-projection screen. Polly Land also contains several speakers.

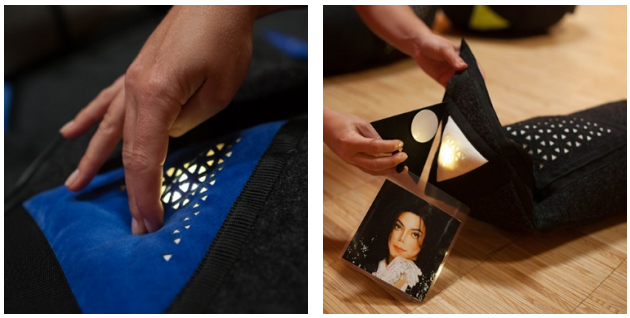
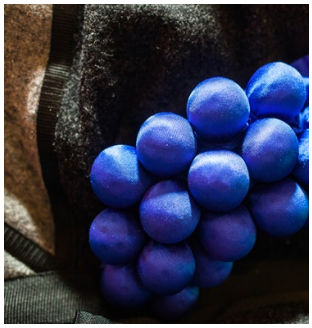


Figure 2 & 3: Soft and sensorial stimulating Touch- and RFID-sensors with light response. © Birgitta Cappelen

We shaped the three wireless objects as archetypical shapes within the therapy field, a ball, a banana cushion and a blanket, which also contains a cushion (www.RHYME.no).

The wireless objects contain two touch-sensors, two bend-sensors, microphone, accelerometer and a RFID-reader (see Figure 3), all with responsive light. All objects also contain several sensorial stimulation surfaces (see Figure 4) without sensors, light-fields that correlate with the interaction and the speaker output.



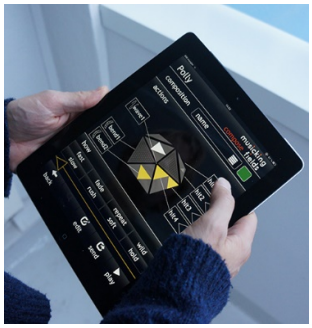


Figure 4 & 5: Sensorially stimulating areas without sensors. Web-based App for distributed GUI interaction over the Net. © Birgitta Cappelen

The Polly World contains 50 different interactive music tunes developed based on users' desires (see Figure 6). When selecting a Scene-card it governs both the music, the dynamic visual graphic on the screen and the color of the light (see Figure 1). Here the user chose the third Scene card "Gimme! Gimme! Gimme" (see Figure 6) by ABBA that has a turquoise card color. It also gives a turquoise dynamic graphic on the screen and all the LEDs in the laser cut textile to be consistent and offer diverse users different sensorial stimulation and focus points sharing the experience of being in the same multi-sensorial environment.

Figure 6: Scene-card with RFID-tag of users' wishes.

Polly World further contains a number of different things, toys and artifacts with RFID-tags, that can be played with (see Figure 7). This gives the user possibility to choose what they like to play with and on, so they feel that they decide what to be included as choir members in the music making, and the expression and complexity of the musicking situation.

Figure 7: Artifacts with RFID-tag to play music with based on users' desires and liking. © Mariko Rhode

Polly World also includes two APPs for distributed interaction through a GUI (see Figure 5) and a high-level Twitter-language to write music compositions (sequences of user interaction) over the net. This makes for instance siblings able to create music in the Polly World, even if they are not at home or prefers to use a screen interface instead of a physical interface for some reasons. Offering diverse users diverse ways (interface medium, sensors, activity level etc.) to interact and participate in the multi-sensorial environment is an important design strategy that we have developed during the 5 years of development of multi-sensorial environment in order to make them accessible and engaging for as many user groups as possible.

4. HEALTH PROMOTING QUALITIES

The goal with the RHYME project and the multi-sensorial environments we have developed through the project is to promote health in a humanistic sense [2], [1]. In our project this represents to design interactive multi-sensorial environments that in diverse ways evoke positive feelings, offer diverse ways to master both musicking and sensorial stimulation. Further, to realise our health and empowering goals, we have seen that it is important to offer the users possibility to participate based on their own interest and in their own way, build different relations, and together experience sense of coherence [14]–[20]. During the four generations of designed things, we have observed many ways the diverse users acted and related to the interactive things and to other users in the environment. We have also seen things that represented problems for the users. Such as sensors that was hard to activate (generation 2 and 3), and lack of voice input (generation 3) and visual output (see Table 1). In the fourth generation we have tried to put together all our knowledge from previous research into the design of Polly World.

4.1 Evoke and Regulate Positive Emotions

When we tested the previous 3rd generation of prototypes, "Reflect" [15], on a diversity of users with complex disabilities and close-others, they expressed that they lacked possibilities to use their voice and get dynamically changing sound, visual and embodied vibration feedback (see Table 1). The users expressed that they wanted to be able to use microphone and effects to fully experience and express themselves [15]. In doing so they compared Reflect with earlier experiences in earlier generations of RHYME prototypes, that included a microphone and multi-sensorial feedback.

Since then we have developed the 4th generation, Polly World, with what we call "scenes", to offer the users just that, i.e. a wide selection of distinctive and expressive multi-sensorial (visual, musical, tangible, etc.) properties. Properties that vary with every of the current available 50 *scenes*, creating a unique set of expressive properties for visual projection, colour-changing LED-lighting and microphone feedback changing dynamically with the user-interaction (see Figure 1 and Scene-card in Figure 6).

In addition, the users chose 50 music tunes to be included in the 50 scenes. The users chose the music through a process where we asked (orally and written) the children, parents, siblings and close-others about their *musical preferences* [25]. Over the course of all four generations we observed how important it has been for users to have "their own music", to be able to relate to the music and recognise, remember it as part of their music culture [14]–[20]. Further, we experienced how their own music often worked as a catalyst for them to get vitalised, act, reach out to others, and create expectations and meaning.

To offer both *familiar*, culturally and *changeable* musical experiences, we therefore have composed each of the current 50 scenes, based on *cultural parts* and *digital parts*. The *cultural parts* are "music elements" of familiar songs as well as familiar physical objects and visuals. We included music elements such as choruses and verses from the music tunes they had chosen. We also composed sounds ("choir-elements") for the objects, toys and instruments with RFID-tags ("tagged-things", see Figure 7). Further, to offer changeable musical experiences, we have included *digital parts*, dynamically rule based music algorithms, making it possible for users to interact with RFID-reader, microphone and bend and touch sensors in Polly in order to change the music, effects, light and visuals. We have selected, edited and remixed parts of the user chosen familiar songs and sounds. We have created rules and programs for the users to re-compose the sounds and songs, to offer the users diverse mastering possibilities, based on the users' interaction and music choices in the environments.

For the music and sounds to *evoke* positive emotions, we have to offer music and sounds the users can relate to and that they know and/or have strong feelings and expectations towards [6]. During the user tests we observed how the users got vitalised and motivated, by replaying the familiar songs they liked [25], [14], [28]. Motivated to interact and control the interface and regulate their emotions.

The 50 different scenes with familiar music from different genres also control the lighting and the dynamic graphics on the projector, and thereby create a suitable visual "set design" (atmosphere) for the song (see Figure 1). The songs the user could chose from include music from different genres, from pop, rock, soul, lullabies, disco, classical, contemporary and natural and industrial soundscapes. This variety is important to offer the users as a possibility to choose between music with different atmosphere and tempo, with the ability to express and regulate a diversity of emotions and feelings, from positive, to melancholic, agitated, calm, etc. [25]–[27, [10].

In order for the songs to work in different situations, we have designed them in different arrangements and different lengths, such as beats, and collections of 5-10 beats, and playlists of whole songs and lists of songs. Further, we have designed rules to control how to put individual parts together dynamically to make the music and the sound develop over time and with the interaction. This makes it possible for persons with different abilities, with and without musical training, to be able to remix his or her version on the fly by interacting physically in Polly World. What version of the rules and the arrangement that is relevant depends on what situation, interaction form and activity level the persons interacting can and want to use. This gives the users infinite mastering possibilities, both musically, sensory and physically.

4.1.1 Play a Jingle

The jingle is the song's "logo" and a recorded cultural part that a user easily can recognise and in a split second creates expectations of what song and artist that will play. To play a jingle, the person interacting uses the scene-card. The scene-card looks like a pocket CD-cover with an additional RFID-tag (see Figure 3) adding a digital interactive layer to the physical thing. A user can activate a *jingle* by selecting a particular scene-card and hold it against a RFID-reader in the physical tangible environment (see Figure 1). The interaction creates an immediate short sound-jingle response. An example of a jingle is the one we selected for the "Disco-scene". The disco-jingle has a very energetic 2-bar long disco shuffle rhythm in a fast 240 BPM tempo accompanied by a funky climbing base melody. A different example is the jingle for the "Woodland-scene" natural soundscape from the woods with the sound of a stare songbird's long melodic calling. A sound that is full of life but still relaxing. Relaxing because chirping songbirds in a sunny and calm nature in our culture is considered pleasant, and creates expectations of sounds of animals living in nature. Yet another contrasting example is the jingle for the "Bad-scene" song by Michael Jackson (see Figure 3). Here we selected, not the musical beat, but the whispering ghostlike Jackson's spoken statement: "He's bad". We selected it to be the jingle because it works like an echo creating expectations about the chorus yet to come. Fans of Michael Jackson know the song and the dance moves in the music video well. It is easy to recognise in Polly

since it stands out as a spoken jingle against most of the other jingles that are instrumental.

4.1.2 Play a Song or a Playlist

When playing in Polly World the user can chose to play a remixed version of a song, a whole song or a playlist of several songs, by selecting one of the related scene-cards (see Figure 6). Users that want to be active tend to prefer the remixed version with 5-10 of a song's choruses. Other users knowing the lyrics tend to prefer the whole song. For some users it is important to hear the whole song in order to get immersed into a feeling and to use the song to *regulate* their emotions. Some users wanted to play a song once. However, most others wanted to play it over and over again, in different sequences, increasing and reducing its complexity over time. Our experiences also lead us to create a dynamic playlist, that the users could edit using an iPad (see Figure 5).

4.1.3 "Choir-Sounds" For Physically Tagged Things

In addition to interacting with the scene-cards, playing songs and jingles, users could also interact with physical objects and toys, with RFID-tags, so called "tagged-things" (see Figure 7). These are culturally loaded objects such as the teddy bear. Objects that often contains values, smells, tangible visual and sound memories. Similar to the scene-cards for musical beats and playlists, each tagged-thing has 2-10 sounds that a user can toggle between when he or she holds a tag against a RFID-reader. We call these sounds "choir-sounds" because the tagged-things with their individual voices make up a choir. Users can activate the choir-sounds. In addition the choir-sounds vary based on rules controlled by the scene (see below under headline "Express Themselves In Diverse Ways").

The users, children, parents and teachers have taken part in selecting the objects such as toy cars, small drums, dolls, balls, teddy bears, etc. We have chosen other objects to accompany the different scenes, i.e., the elephant, monkey, tiger and frog soft toys. They are the main characters in the children song "The Animals in Africa" (lyrics Torbjørn Egner, music Aage Stentoft), chosen for the scene with the same name. The four animals in the song's narrative, have been well known to a Norwegian family audience for generations and are still popular. The narrative strengthens relations, memories and emotions that children and parents can have to the song, lyrics and the tangible objects. The users of all ages associate soft toys with personal emotions. It is its teddy bear that a child wants when he or she wants to go to bed, or feel sad and lonely. The teddy, or the soft toy, represents safety and cosiness to the child. It looks cute, small and sad, which evoke a protective feeling. Together, these qualities make it popular for a child to use toys to *regulate* his or her emotions. These are qualities we considered when we added sounds to some 50 different objects with RFID-tags. We based our selection on identity, cosiness, size, colours, sound qualities and associations with a particular scene. One example is the combined soft-toy-dog and slipper that exists in two sizes, both as sounds and physical objects. The biggest dog and slipper also has the deepest base bark sounds with four different 2-5 second long sound samples. The sounds consist of short happy and a little scary growling barks to longer sad, begging and whining wailings. The small dog has 4 high-pitched dog sounds with shorter happy barks and high-pitched begging and sad wailings. Each time a person interacts with the small dog, it is playing a sound with a small dog identity. In order not to repeat and make the sound monotonous a user can toggle between the 4 sounds, which make the sounds vary slightly.

The bongo drum tagged-thing is already an instrument with its own recognisable acoustic sound. Users can have positive memories of movements to rhythms, dance and emotions attached to the drum. In addition to the acoustic sound, the digital layer adds a sound of a short rhythmic beat played on the same drum. The digital recording gives the acoustic drum a context, the short beat. This is a context that can make sense of how to play on the drum. The user can play back 1 of 3 beats while interacting with the attached RFID-tag. For each new interaction a new sound is being played.

4.2 Master and Learn Over Time

The multi-sensorial environment Polly World offers the user many ways to master and learn over time. A user can do so in many ways since everything is open and can be combined with everything, where there are no wrongs in a user functionality sense, only potentially unsatisfactory in a musical or aesthetical sense. A user can develop mastery by choosing, and interacting with the RFID tagged scene-cards (see Figure 3) and fury pompons, representing music elements. Further, the user can enrich the music with choir-sounds, by using and learn to master the tagged-things (see Figure 7) to play on and with, as we describe in more detail below.

4.2.1 User-Remixed Live Music

An alternative to the jingle, pre-remixed and shortened version of the song, the whole song and the song playlist (see Figure 7), is the *improvised user-remixed live version* of a song (compare with songs and jingle in "Evoke and Regulate Positive Emotions" above). A person selects a song using a scene-card. He or she then can interact with one of 6 differently coloured and tagged pompoms to play parts or beats of the song in the scene. It makes it possible for persons that are active to take control and create their own versions of the well-known music.

4.2.2 Dynamically Remixed Music

A shorter variant of the user-remixed live arrangement of each song is a *dynamically remixed*. The dynamic remix offers possible mastering experiences to persons that don't master swift interactions with the pompoms. Instead the Polly algorithms then dynamically change between the 6-10 looping parts in each song and scene. A user can activate the arrangement by putting one of six pompoms with RFID-tags on hold under the RFID-reader. Each time a part ends, it toggles to the next. During tests we have observed how families often use this where a sibling or parent to a child with disability wants to be able to concentrate on interaction-sounds and physical communication with the child. Therefore, by placing the scene-card under the RFID reader, the looping music automatically continues and changes over time as Polly continues to toggle between the sound elements for each song. For the continuity to work, we had to prepare each sound-element in order for it to create a continuous remix. Based on our research [24], [21], we edited it so that it looped smoothly and created a remix together with other sound-elements, with qualities that went well with the chosen genre, such as tempo, number of beats, melody, rhythm and harmony. Some users were motivated to master variation between different sound elements. In Polly we therefore offered a mix between choruses/refrains, verses and breaks. With the dynamically remix a user who couldn't master changing a pompom, and therefore didn't have the ability to change to a new beat and sound-element, could still experience to play a song. In this way the user could still be part of making it shift to a new sound. In this sense Polly World's dynamic remix made the person feel mastery when interacting together with others. During tests we observed how users could learn how to

master to create a live remix by him or her self, and by collaborating with close-others.

4.2.3 Choir-Sound Feedback to Mastery Over Time

We observed how some users became motivated to interact with the tagged-things, tangible toys, tools and instruments. The sounds offered immediate sound feedback. Each sound was edited to start immediately with a sharp attack. Some users were also motivated to build expectation over time. Polly therefore offers a series of sounds to toggle between. For example the harmonica tagged-thing with three different choir-sounds composed of three different parts of the same melody. Different parts create different riffs, that can be experienced as coming from the same song. In this sense the riffs create *continuity* and *variety* at the same time. that we have used to promote both *recognition* and *expectation* through change and variation.

4.2.4 Master the Microphone and Learn Over Time

In the tests we observed how some users, wanted to interact with their own voices and how that created a strong feeling of *mastery*. In Polly World a person can master the soft red microphone, by getting immediate and delayed feedback. The system amplifies the sound directly and the microphone is lit-up in read light, creating a strong visual feedback. Each interaction with the microphone also adds an effect and delayed response. Depending on the scene and the genre of the music it selects Polly adds an effect such as echo-delay, reverb or chorus. The delayed effect response strengthens the feeling of mastery and makes a weak voice sound stronger. The microphone also records sound that can be played back using the movement sensors in the textile arms of Polly. A person can move one arm to pitch-up the recorded voice sound and the other to pitch-down the voice sound. The potentiality to create these effects makes it possible to keep on developing, master and learn new abilities over time.

4.3 Express Themselves in Diverse Ways

We observed how the persons interacting in the Polly World multi-sensorial environment could create and express themselves in diverse ways, by playing, dancing, building, moving and using their bodies, etc. They used the tagged-things to play sounds, scene-cards to play music, *express* themselves singing and recording their voices into the microphone and playback the sound with effects.

4.3.1 Choir-Sound Algorithms Enhancing Expression

Further we saw how the users *expressed* themselves by interacting with the tagged *cultural objects* and toys that play back choir-sounds. To motivate persons to be creative and express themselves over longer time it was important to offer inspiring musical variation. The choir-sounds were therefore also activated and remixed using *digital algorithms* that form *dynamically changing* variation rules for each scene. In the scene "Mamma Mia" by ABBA we have designed the rules for each choir-sound that matched a tagged-thing toy to change the pitch so that they play the Mamma Mia melody to the beat. For instance, this made the toy-dog with RFID-tag bark "Woof-woof-Woof-woof", mimicking the melody and rhythm in the phrase "Mamma Mia". For the users playing and creating with the music in Polly this variation were motivating by combining two culturally strong concepts: Combining a familiar *toy dog* and the well-known ABBA song, inviting the user to participate in creating an entertaining *musical-barking-dog*. We experienced that it was motivating for the users because the process of interacting was fun to take part in for the user that mastered while playing both music and with the toy. At the same time it changed dynamically, creating variations. In the scene "The Animals in Africa" we have chosen the sound beat playing based on the character of the tagged-thing the user interacts with. For instance the chorus sung by the deep elephant voice play when a person holds the elephant against the RFID-reader, or the chorus sung by a high-pitched frog's voice when a person holds the frog toy against the RFID-reader. Yet another example is the "Disco-scene" where Polly takes each tagged-thing object's choir-sound and transposes it and plays it back as an arpeggio melody and synchronising it to the disco beat. This enhances the disco rhythm and beat, makes the tagged-thing sound comic and strengthens the users experience of mastering and expressing themselves.

4.3.2 Combine All To Express Oneself

To be able to express oneself, we found that a person that had used Polly World creatively for some time, tended to want to combine different types of actions, digital and cultural parts and objects. During tests we observed how persons combined interaction with the microphone and manipulated the result with the accelerometers, used the scene-cards and the tagged-things, etc. In this way, Polly World could strengthen persons' abilities to keep interacting and to be in a creative flow. A person could for example start by selecting the "Bad-scene " song by Michael Jackson, putting the scene-card on-hold, so that it played continuously looping parts. The person then could continue by toasting and making rap-sounds in the microphone and play back and cut-up the sound by moving the accelerometer-arms and adding a dynamically changing pitch-up effect. The person could keep rapping new sentences into the microphone. Further, he could repeat and develop the beat by changing between the tagged pompoms playing different parts of the song and selecting the tagged-thing dog to "comment" on the rap with the dog's chorus-sounds.

4.4 Build and Strengthen Relations

We experienced users playing together in Polly World, strengthening relations to others and to the things in the environment. A quality of Polly World is that it offers diverse possibilities for persons with different abilities and different activity preferences (active, calm, social, alone, etc.) to play together and share a common experience. We have seen how a multitude of possibilities (many sensors, music-tunes, chorus-sounds, tactile, visual and tangible feedback, dynamically changing algorithms, etc.) available at the same time, motivate *collaborative interaction* and activities among a *diverse group of users*.

4.4.1 Collaboration With Multi-Sensorial Interaction

An example that we have observed during tests is how two users play together using the microphone and the movement-sensors in the arms of Polly World. One person can lie down and talk and sing into the microphone, while the other is very active moving the arms to play back the sound and changing its effect, pitching down or up depending on what arms he or she chooses. We have experiences how the person at the microphone often starts to alter the vocal input when hearing the manipulated answer made by the other person.

4.4.2 Sound-Element Editing For Relation Building

We have edited the sound-elements in the scenes to *strengthen relations* and collaboration in three ways. Firstly, we have edited the musical elements to support smooth interaction, where elements and choir-sounds succeed each other, without hick-ups, with loop points, transitions, and mixing levels that are musically satisfying [24]. These are *musically satisfying* interaction sounds

in the sense that they are *dynamically changeable* by the user over time, and goes *musically well together* rhythmically, melodically and harmonically in accordance with the genre. Secondly, the sound-elements vary sequentially on a horizontal layer. A layer that is built up from verses, refrains, cadenzas, riffs, bird singing, call-and-respond, etc. Thirdly, sound-elements vary on a vertical layer as an ensemble. An ensemble forming layers of different voices, that in turn form chords or arpeggios on top of each other. One example is how the base and the drums in the disco beat is combined with a layer of choir-sound creating an arpeggio on the top. Or as the sound-elements in the natural soundscape "Woodland" form an "ensemble" in a mix of high-pitched birdsong combined with a background of wind and base thunder, and a layer of close-up water drops.

5. REFLECTIONS

During the Polly World *project*, we have experienced situations that would not have been possible to anticipate without a thorough user-involvement, with repeated actions over long time. Six families is not a high number, but to work closely and repeatedly with a very diverse group of users and their close-others, has given us an understanding of both *diversity* and *complexity*. Diversity, because of the wide user group consisting of children with severe disabilities and their parents, siblings and personnel at school, that performed a wide range of situations and relations over the 5 years of collaboration [14]–[20]. We also gained an understanding of the *complexity* and cultural variation of a multi-sensorial interactive thing. Qualities that are needed to offer diverse user group possibilities to express themselves, master and regulate emotions, collaborate and create relations to each others.

Reflecting over the development we did during 5 years and 4 generations of technologies in order to promote health (see Table 1.), the most obvious changes were that we had to *increase* the number of *multi-sensorial possibilities* (cultural, expressive, musical and physical) over time. For instance, when we in the 3rd generation didn't include a microphone, that we had in the 1st and 2nd generations, the users expected to find it, and were disappointed when they didn't. It had become part of the users *expressive* voice-body-music *resources*. When including the microphone again in Polly World, pairing it with a new movement sensor/accelerometer, it lead to the development of a range of creative expressive modes and actions that surpassed our wildest imagination [21]. Otherwise silent and shy users now started to shout and sing into the microphone, creating sounds and vibrations that changed with dynamic algorithms that mediated their expressive resources. The possibility for the user to continuously record, change and replay the sound with the movement sensors, increased the body-voice connection [27], motivated the user to master, create and self-regulate. Further, Polly became an *arena* for communication [20] between *two users* with different abilities. For instance in the 2nd generation multi-sensorial object Wave (see Table 1). Here one user, lying on top of the vibrator, interacted and recorded sounds with the microphone-arm. The other user interacted with the movement-sensors-arms, continuously replaying and pitching up and down recordings of the first user's voice [14]. In Polly World we have expanded these body-voice interaction possibilities by offering not one, but four multi-sensorial things, to use together. In Polly the possibilities to express and create therefore increased even more as the communication was two-directed, where everybody could record and playback sound. What happened when four users accessed and controlled all input sensors and output, in their individual object, was that they continuously vitalised themselves and simultaneously inspired each other to act. They started to explore, mastered more, got more creative and increased interactions with each other in an infinite loop. We experienced how users during this process created something *new*, as they started to use their microphone-arm to record the other person's music [21]. We also saw how they continued to manipulate the recorded sound with the movement sensors, creating and expressing sounds that were never heard before.

We observed how users got motivated to master when selecting and playing with a familiar song they liked. We designed the "scene-card" solution (see Figure 6) as a hybrid of two physical cultural artifacts that were well known to the user group: soft and square plastic covers for compact discs with pictures and title of familiar music artists, and communication cards from the tradition of Augmentative and Alternative Communication (AAC). We were very surprised over the amount of diverse ways that different persons would *actually use* the scene-cards. For instance, to repeatedly interact with a scene-card to play a song's jingle over and over, in order to master and create, as on an instrument. Other, put the scene-cards under the RFID-reader to play continuously so they could dance without further interaction. On users' request, we increased the scenes from 8 songs in the 3rd generation, to 50 in the 4th generation. We anticipated more engagement because more people would find music and soundscapes of their liking. We couldn't have known that this expansion in number of scenes would lead to completely *new ways of playing together* and socialising with each other for people with disabilities and without, *new expressions* combining different songs in the four different Polly objects [21].

The large number of *culturally well-known* things and musical tunes, in combination with the *dynamic musical algorithms* that change with the users actions, resulted in experience of *mastering over long time*. The editing of the music tunes into parts and the algorithms for creating sequences and layers, are unique in that they are based on knowledge about empowering and health promoting qualities in Music Therapy and Music and Health [3]–[6], [27]–[29]. They are also based on observations of use from the 1st to 4th generation [7], [12], [14]–[20], [22]. Comparing with simpler switch-oriented systems [12], [7], we can see that this combination of knowledge from Music, Health and Tangible Interaction have been necessary to develop the multi-sensorial complexity we created. It is a very complex task to develop the music algorithms to be compatible with the tangible interaction possibilities that create variation over time. Further, it takes time to follow up on the fantastic innovative actions and ideas that the divers user group contribute with, when they spend time in Polly World. It truly works when users find new ways to act that we haven't yet thought about and that they can make their own.

6. CONCLUSIONS

In this paper, we have presented an interactive and musical multi-sensorial environment, developed for health improvement for children with special needs.

We have presented how we have designed the interactive environment in order to offer the user health promoting qualities such as to: Evoke the user's positive feelings and vitality; Regulate their moods and feelings; Express themselves in diverse ways in the interactive environment; Master and learn over time; Build and strengthen relations to other people and things.

In the paper, we have focused on the musical and *sensorial* aspects of the interaction design. We have shown how we have constructed the design *of layers and parts* to offer the users many and *diverse sensorial experiences to vary and master over long*

time. Some parts, such as the songs and the physical toys, are *cultural and familiar objects* that therefore create *expectations*, *recall* memories and feelings. Some parts are digital and algorithmic to increase possible *motivation curves*, *playability* and *learning* over long time. The interactive environments therefore consist of a structure of cultural parts and objects such as familiar music elements and artifacts, and digital layers of software and hardware components. The cultural and digital composite structure becomes an empowering and healing social arena that connects diverse users together, in a creative multi-sensorial community.

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8. REFERENCES

[1] Bjursell G., Vahlne Westerhäll, L. (eds.). 2008. *Kulturen och Hälsan*. Stockholm: Santérus,.

[2] Blaxter, M. 2010. *Health*. Polity.

[3] Bruscia, K. 1998. *Defining music therapy*. Gilsum, N.H.: Barcelona Publishers.

[4] Bruscia. K. 1987. *Improvisational Models of Music Therapy*.

[5] Rolvsjord, R. 2010. *Resource-Oriented Music Therapy in Mental Health Care*. Barcelona.

[6] Ruud, E. 2010. *Music Therapy: A Perspective from the Humanities*. Barcelona.

[7] Cappelen B., Andersson, A.-P., 2011. Expanding the role of the instrument, *Proc. NIME2011*, Univ. of Oslo, 511–514.

[8] Ayres, A. J. 1974. *The Development of Sensory Integrative Theory and Practice: A Collection of the Works of A. Jean Ayres*. Kendall/Hunt Publishing Company.

[9] Dunn, W. 1997. The Impact of Sensory Processing Abilities on the Daily Lives of Young Children and Their Families: A Conceptual Model, *Infants Amp Young Child.*, vol. 9, no. 4.

[10] Fowler, S. 2008. *Multisensory Rooms and Environments: Controlled Sensory Experiences for People with Profound and Multiple Disabilities*. Jessica Kingsley Publishers.

[11] Pagliano, P. 1999. *Multisensory environments*. London: David Fulton,.

[12] Cappelen, B., Andersson A.-P. 2012. Musicking Tangibles for Empowerment, *ICCHP 2012, Part I, LNCS 7382*, Berlin, Heidelberg: Springer-Verlag, 254-261.

[13] ACTIVE AND ASSISTED LIVING PROGRAMME | ICT for ageing well. 2016.

[14] Stensæth, K. 2014. 'Potentials and challenges in interactive and musical collaborations involving children with disparate disabilities. A comparison study of how Petronella, with Down syndrome, and Dylan, with autism, interact with the musical and interactive tangible "WAVE".', Stensæth, K. (ed.), *Music, Health, Technology and Design*, NMH-publications, . Vol. 8, 67-96.

[15] Stensæth, K. 2014. 'Come sing, dance and relax with me!' Exploring interactive health musicking between a girl with disabilities and her family playing with 'REFLECT' (A case study). Stensæth, K. (ed.) *Music, Health, Technology and Design.* Vol. 8, Oslo: NMH-publications, Series from the Centre for music and health, 97-118.

[16] Eide, I. 2014. 'FIELD AND AGENT': Health and characteristic dualities in the co-creative, interactive and musical tangibles in the RHYME project. Stensæth, K. (ed.) *Music, Health, Technology and Design.* (Vol. 8) Oslo: NMH-publications, Series from the Centre for music and health, 119-140.

[17] Stensæth, K., Ruud, E. 2014. An interactive technology for health: New possibilities for the field of music and health and for music therapy? A case study of two children with disabilities playing with 'ORFI', Stensæth, K. (ed.) *Music, Health, Technology and Design.* Vol. 8 Oslo: NMH-publications, Series from the Centre for music and health, 39-66.

[18] Ruud, E. 2014. Health affordances of the RHYME artefacts. *Music, Health, Technology and Design*, Stensæth, K. (ed.) NMH-publications, Series from the Centre for music and health, Vol 8. 141-156.

[19] Stensæth, K. 2013. 'Musical co-creation'? Exploring health-promoting potentials on the use of musical and interactive tangibles for families with children with disabilities. *International Studies on Health and Well-being, 8*.

[20] Stensæth, K., Ruud, E. 2012. Interaktiv helseteknologi – nye muligheter for musikkterapien? *Musikkterapi*, *2*, 6-19.

[21] Cappelen B. Andersson A.-P. 2016. Embodied and Distributed Parallel DJing. Petrie, H. et al (eds.). Universal Design, UD2016, University of York, *Studies in Health Technology and Informatics, Vol. 229*. IOS Press, Amsterdam, 528-539.

[22] Andersson A., Cappelen B. 2014. Vocal and tangible interaction in RHYME. *Music, Health, Technology and Design*, Stensæth, K. (ed.) NMH-publications, Series from the Centre for music and health, Vol 8. 21-38.

[23] Cappelen B., Andersson, A. 2013. Towards an Empowering Tangible Interaction Design for Diversity. *Proc. Include 2013*, Hong Kong. ISBN 978-1-907342-70-7.

[24] Andersson, A-P. Cappelen, B. 2008. Same But Different, Composing for Interactivity, *Proc. AudioMostly08*, Luleå Univ., Interactive Institute, 80-85.

[25] Kvamme, T. 2013. *Glimt av glede. Musikkterapi med demensrammede som har symptomer på depresjon og angst*. Norwegian Academy of Music.

[26] Austin, D. 2001. In Serach of the Self: The Use of Vocal Holding Techniques with Adults Traumatized as Children', *Music Therapy Perspective*, vol. 19, no. 1, 22-30.

[27] Loewy, J. 2004. Integrating Music, Language and the Voice in Music Therapy, *Voices*, *vol. 4, no. 1*.

[28] Rolvsjord, R. 2006.Therapy as Empowerment, *Voices*, *vol. 6*.

[29] Stige, B. 2002. *Culture-Centered Music Therapy*. Gilsum, N.H.: Barcelona Publishers.