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REPMOVES: STORIES THAT A RHYTHMIC INTERACTION DEVICE FOR SENIORS CAN TELL

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ABSTRACT

There is currently an ongoing debate within HCI community regarding the legitimacy of design objects as producers and carriers of knowledge. This paper takes a Research through Design methodological approach to making such an object, RepMoves, with a purpose to explore its use and usefulness and demonstrate how new knowledge can arise while exploring and experimenting with design objects. In this paper, RepMoves is used to address rhythmic and repetitive bodily interaction with music as a welfare technology concept for senior citizens with cognitive difficulties related to the onset of Alzheimer's disease, and in one example, an individual with Parkinson. We show how RepMoves interface was adapted for use in each of these cases, how movements and interfaces were changed, and most importantly, RepMoves' potential to generate knowledge and research opportunities.

KEYWORDS

Research through design, research product, context, rhythmic interaction, generic design, concept design

1. INTRODUCTION

There is an ongoing debate regarding the relevance of Research through Design (RtD) as a research approach within Human-Computer Interaction (HCI), and what kinds of knowledge contributions the approach can offer (Bardzell et al., 2015; Dalsgaard, 2016; Gaver, 2012; Zimmerman and Forlizzi, 2014). The debate has grown out of an increasing integration of design practitioners in the HCI research community and addresses the diverging nature of scientific research and design practice (Zimmerman and Forlizzi, 2014). Some central and interrelated points of discussion are: (i) How can practices of design and making be used as modes of inquiry to produce knowledge and theory?; (ii) How can and should RtD research artifacts be documented in order to communicate the knowledge they produce, contain or represent?; and, (iii) How should RtD artifacts be evaluated, analyzed and critiqued in order to produce relevant knowledge for the HCI research community? As RtD matures as a research approach in HCI, the articulation around how this knowledge production happens becomes central.

Research through Design (RtD) is an emerging approach to HCI research that emphasizes the use of methods, practices, and processes of design as a generative mode of inquiry (Zimmerman et al., 2010). It is a forward-looking and constructive endeavor that seeks to propose alternative futures and explore possibilities through design. Schön (1983) describes the designers' method as that of a 'reflective practitioner', where knowledge generation is an ongoing process brought about through reflection on hands-on engagement with the emerging artifact. Ingold (Ingold, 2013) has also addressed material engagement as the 'art of inquiry' and described it as an essential means of widening the designer's perception of the context. Further, he has coined the term 'correspondence' to describe the designer's (often unique and specific) material articulation of their response to this perception.

While this paper does not aim to settle the above questions, it provides an account of a specific RtD project (or parts thereof), and explores the potential of deliberately open and flexible research objects to produce knowledge in the encounter with specific contexts of use, as well as to open up new questions and lines of inquiry for future research. In doing so, the paper provides a case for exploring and discussing the knowledge contribution of RtD. The design of the research object that we are concerned with in this work, called RepMoves, was not a team effort, but one designer's design work that came about as a response to a particular design research problem, namely: How can interaction design help inspire and motivate seniors to be more physically active? Can interaction design provide generic ways of motivating physical movement that transcend specific use cases? The particularity of the response was based on the designer's specific knowledge, experiences, skill sets, and curiosities. His familiarity with programming, sound design and production and audio-visual interaction design (Rosseland et al., 2014) enabled him to formulate RepMoves as a generic interaction design concept to motivate physical activity through rhythmic interaction with music, and to envision how the concept could be materialized in a research prototype. Accordingly, the RepMoves concept emerged as a personal response, or correspondence, to a certain design research challenge. Nevertheless, the authors have discussed the designed objects, their potential as research objects, and reflections on the knowledge gained through their use in specific contexts.

This paper describes, through three different cases, how the prototypes were used to engage seniors in verbal and material discussions regarding the potential of rhythmic interaction with music as a motivator of movement and physical activity. We show how RepMoves transitions from being a generic concept to becoming a particular research object, or more correctly, a set of research objects that undergo changes and adaptations in order to work as communicative tools in different contexts. They were used as catalysts for discussion and exploration with elderly and their caretakers, as well as other stakeholders and informants around issues of health and welfare for senior citizens. RepMoves became objects to talk about, but also objects to talk *through* and, thus, communicate embodied, non-verbal information during use. The project did not seek to validate a particular design intended for a particular user group, but rather to better understand if and how the concept could become a meaningful future welfare technology for seniors. In summary, the purpose of the present paper is to describe and discuss the new knowledge gained through the use of deliberately designed research objects as a mode of inquiry. The main contribution of the paper is to give a description of a RtD project and discuss its potential knowledge contribution through the lens of the three questions presented above.

The paper is structured as follows: Section two describes the Field practice and research through design, providing background and framing our presentation. Section three is dedicated to a description of the development and rationale behind the RepMoves concept and prototypes. Section four presents our three cases of exploring the prototypes with seniors. In section five, we discuss knowledge production in RtD through the abovementioned questions. Section six concludes the paper.

2. THE FIELD: RTD AND PARTICIPATORY DESIGN

RtD projects are frequently categorized and described through the lenses of the Lab, Field and Showroom practices (Koskinen et al., 2011; Zimmerman and Forlizzi, 2014). The Lab practice, native to Netherlands, combines rich, multisensory design exploration with experimental evaluation in controlled, lab-like environments. The Field practice utilizes design and making as modes of inquiry and exploration in a user-centered and/or Scandinavian participatory design (PD) perspective, where the researchers try to identify design opportunities, together with users, in order to improve products, services or systems. Finally, the Showroom practice builds on the design of critical and speculative artifacts that challenge the current situation.

The project presented in this paper involved elements of all three RtD practices to some extent. However, in this paper, we deliberately stay within the Field practice. Dalsgaard (2016) argued that it is in the encounter between the designed object and a specific application and knowledge domain that new RtD knowledge is produced. Our cases describe how prototypes that were built as part of the Lab practice (described elsewhere, to be published) were brought into specific use contexts in order to initiate discussion and reflection and to generate new knowledge. This paper builds actively on the findings of an earlier paper that offered guidelines on how to engage elderly in PD processes (Rosseland, 2016a). Specifically, the guidelines recommended, among other things, the widespread use of prototypes as ‘things to talk with’ when engaging seniors in PD. Having functional objects to manipulate and talk about relieves senior participants from having to mentally envision intangible concepts and imagined uses, and allows discussions to grow more organically from the nature of the exchange between the object, the participant, and the specific use context. However, we do not consider the current work to be in the PD tradition. A central principle in PD is that participants should be involved from the start in defining the purpose and goal of the project. The elderly participants in this project were not involved until after the first RepMoves prototypes had been built. Our goal was to think generatively rather than user-centered. Nevertheless, the main focus of this paper is the use of open and flexible designed research objects to engage seniors in contextual and material exploration and discussion of RepMoves. Accordingly, the work presented here is certainly relevant for researchers intending to involve seniors in PD processes. Furthermore, the paper demonstrates how the RepMoves prototypes help identify and generate questions and insights that can lead to more user-centered or participatory lines of research.

One of the important inspirations for this project was The Drift Table (Boucher and Gaver, 2006). It is often referenced as an early example of a research through design project that explored the knowledge generating capabilities of intentionally open and generative artifacts placed in a specific context or a knowledge domain. The table was designed to investigate the

concept of ludic engagement at home, to see if a home-based technology built into a coffee table can support curiosity, exploration, and reflection. The many design choices made while building the table helped the authors articulate their understanding of ludic design. This understanding was new and different as it emerged from the actual making of such designed research object. Also, even though the table was still a prototype, it was finished to a much higher extent than customary: "*One of the most important lessons we learned in developing the Drift Table was the value of creating a highly finished, robust prototype. This was crucial in allowing users to suspend disbelief and engage fully with the device over long-term trials, and has also meant that the Drift Table can be exhibited for long periods of time without problem. Such attention to detail and finish are perhaps not normally associated with an experiment or prototype, but there are real benefits to be gained by doing so" (Boucher and Gaver, 2006, p. 4).*

3. A DESIGNED RESEARCH OBJECT: REPMOVES

At its very simplest, RepMoves was the idea of a music player that automatically adjusts the tempo of the music to match the tempo of repetitive human movement. The prototypes offered an interaction form similar to that of a conductor conducting an orchestra. They used a Kinect full-body motion sensor to track specific body parts of users and extract the tempo of five specific movement patterns, illustratively named *conductor, arm swing, body sway, knee bend,* and *knee lift*. The movement patterns were one-dimensional in the sense that each was only tracked along a single dimension (e.g. *conductor* tracked the horizontal position of the hands, *knee bend* actually tracked the vertical position of the head, and *arm swing* tracked the distance between the sensor and each individual hand). All movement patterns were performed in a standing position in front of the sensor, and the system adjusted the tempo of a piece of music to the tempo of the user's movements. Besides body movement, there was no input interface available to the user. All the RepMoves prototypes shared this functionality, and this was the core focus of this RtD project. However, the prototypes also differed from each other in important ways (described below).

RepMoves was conceptualized, and made in line with generic design thinking, see (Wiberg and Stolterman, 2014). Generic design thinking was proposed as a complementary approach to three existing ways of working with design ideas, and for manifesting them in specific designs: concept design, proof-of-concept designs, and design guidelines. Concept design formulates and explores new ideas through sketching and modeling, with the goal of delineating or formulating a new design space. Proof-of-concept designs are largely concerned with building working prototypes of a design idea to prove that it works as intended. Design guidelines provide directions for the designer to ensure that all important and necessary aspects of the design have been duly considered in the design process. "[G]eneric design thinking stands out due to its focus on grouping particular designs and describing the qualities that they have in common on a fundamental level. This is achieved by analyzing, comparing and contrasting designs" (Wiberg and Stolterman, 2014, p. 537). Generic design thinking relates and compares unique aspects of specific designs, or ultimate particulars, to general design classes and concepts. It is suggested that generic design thinking can be used as an analytical tool for evaluating existing designs, as well as a generative method for producing new knowledge through design.

We do not claim that RepMoves in itself represents a generic interaction design class as described by Wiberg and Stolterman. Nevertheless, the project was inspired by generic design thinking, and RepMoves was formulated as a generic concept for how interaction design could contribute to motivating increased and sustained physical activity in a variety of use contexts. We built proof-of-concept prototypes that confirmed that the basic principle was functionally sound (no pun intended) as well as experientially interesting. Further design and development produced different prototypes that all explore different questions, understandings, and applications of the RepMoves concept. Once a sufficient number of design cases have explored this design space, similarities and patterns may help identify relevant design guidelines for a class of interactive concepts that focus on motivating sustained physical activity.

We hope that readers, even just from the description of the RepMoves and what it does could think of many areas of application and many knowledge domains where this can be used and explored. We have tried installing RepMoves on a stationary bicycle in front of a city café (where those using it should try to keep the cycling tempo in order to not irritate other visitors with varying tempo of the music), and tweaking it to work as part of a stroke patient recovery machinery in a hospital setting. Each of these areas of application was interesting in their own right.

4. CASES: REPMOVES FOR SENIORS

We have carefully selected the three cases presented in this section, among several options, to illustrate how failures are not really failures, and successes are not really successes, but indications of what works, or not, in a specific use context. In these cases, different prototypes of the RepMoves concept were used to engage senior citizens and other stakeholders in forward-looking discussions about how the concept could be relevant to their context. The seniors engaged with the material arguments inscribed in the prototypes through bodily, non-verbal interaction. Thus a dialectic exchange took place between the material assumptions and propositions of the designer and the situated reactions of the user. Observing this dialectic exchange allowed the designer, with his extensive knowledge of the functional mechanics of the research object as well as intimate embodied experience of using it, to read and reflect on the responses of the users. The reflections and insights ranged from simple technical issues to potential alternative uses and applications of the RepMoves concept. We argue that the research objects help facilitate discussions, both verbal and non-verbal, about current and future uses of the RepMoves concept. Such discussions would have been impossible to initiate without the designed research artifact.

Each case is divided into two sections presenting (i) the context, participants and prototype and (ii) the designer's observations and reflections during and after the sessions.

4.1 The First Exploration: RepMoves for Parkinson's Sufferers

4.1.1 Context, Participant, and Prototype

Olga (not her real name) lived in a smart home for elderly. We had gotten acquainted with Olga over a longer period of time, observing and discussing her struggles with Parkinson. She

had been suffering from Parkinson's disease for some time and used to receive music therapy as part of her treatment. She considered it to be some of the best and most effective treatments she had ever had. Unfortunately for Olga, the service was discontinued and she was left with pharmacological treatments that partially helped with her symptoms, but also had a range of serious side effects. Furthermore, she felt that she did not get sufficient physical exercise because her medication regime prevented her from being more active. Inspired by research into the use of music therapy and rhythmic auditory stimulation (RAS) (Clair et al., 2012; Repp and Su, 2013; Thaut, 2005; Yu et al., 2011), we were curious whether RepMoves had potential as a musical exercise concept for Parkinson patients. Olga's story led us to think that she would be receptive to the RepMoves concept and that she could provide valuable insights into how it could be adapted for people with Parkinson's disease. We were fully aware that the prototype was not in a state to be used in a comprehensive study with Parkinson patients. However, we hoped that it would be enough to spark an interest in Olga and to allow her to reflect on possible uses of RepMoves for people with Parkinson.

RepMoves was briefly described to Olga as a system that uses a camera-based sensor to detect her movements and to play music that matches the tempo of those movements. It was also explained that this is a prototype and that in working with her, it could be further changed and adapted for her purposes, as well as potentially become useful to other people with Parkinson. She thought this sounded very interesting and agreed to try the system. We made arrangements to meet at a time in her medication cycle when the symptoms of her disease, such as involuntary movements, were subdued by medication.

The meeting was held in a small meeting room in the building that she lives in. At this time, the prototype was in its most basic form: It played music in the tempo of a user's movements. There were no visual aids, interfaces or screens to look at. First, we did a small demonstration of how to use RepMoves. It required the user to perform ten arm swings before it started playing *Bolero* by Ravel in a tempo matching the movements. As the movement tempo was increased or decreased, the music adjusted the tempo accordingly.

4.1.2 Observations and Reflections

After the demonstration, it was Olga's turn to give it a try. She was shown where to stand in front of the sensor and asked to swing her arms back and forth as demonstrated. However, RepMoves did not register her movements. After adjusting and re-starting RepMoves, Olga was asked to start swinging her arms again. At first, it seemed that she did not understand how to perform the movement. She moved her arms in an asymmetrical fashion. Instructions on what to do were repeated, but this did not seem to help. At this point, she was becoming visibly confused and uncertain about the situation. Reflecting on the situation that was unfolding, we realized a critical lapse of judgment in how the prototype was designed: Rhythmic stimulation is used with Parkinson patients specifically to help initiate and sustain movement (which they often struggle with). Our prototype, on the other hand, required the user to perform ten movements *before* the music started playing. We had put Olga in a new and unfamiliar situation and asked her to initiate movement without any form of rhythmic cue or assistance. We, therefore, decided to abort the session. Olga agreed and was content to skip further trials.

From the short experience with Olga, it was apparent that we were not equipped to understand the complex dynamic of how her disease affected her abilities to move. In its current state the prototype certainly did not correspond well with her needs and abilities. In order to follow this line of research, we would need to form a larger, cross-disciplinary team

of researchers and medical professionals to develop a RepMoves prototype specifically designed for people with Parkinson and to design and execute targeted studies with Parkinson patients.

4.2 Exploration two: RepMoves for Alzheimer's Patients

4.2.1 Context, Participants, and Prototype

For our next case, we contacted a center working to promote health and quality of life through organizing different nature, culture and health activities as a service to the local community. The center was open to cooperation and facilitated our getting in touch with a group of seniors with early-stage Alzheimer's disease (AD). This was a group of six people, whom we call Walkers. The group met once a week in a cozy cabin in beautiful natural surroundings, with a lake nearby. Each week, the group went for walks around the lake, prepared and ate lunch together in the cabin, and then spent some time singing and talking together.

For this context, it made sense to develop a multiplayer version of RepMoves. The intention with this re-design was to: (i) to explore how this co-operative mode differed from the single player interaction, (ii) to understand whether the system could be used to entrain the movements of two users to a common, shared tempo, and (iii) to explore possible ways of adapting the system to fit this particular use context.

The prototype still had no visual feedback or interface, and focused solely on co-operative interaction with music. The system was described as a music game that played music in response to repetitive movements of the arms or other limbs. It was compared to the way an orchestra conductor uses his arm movements to control the tempo of the orchestra. Several of the participants expressed interest in the project and they seemed to understand the basic idea of using music to motivate and inspire physical movement. They asked questions like: "How does it work?", "Can several people use it at the same time?", "What does the interaction entail for the user?", "Can it be used on the go?". One of the Walkers stated that health and well-being cannot be achieved through medication alone and that it is important to have a holistic approach to health promotion that encourages a healthy lifestyle. Like in Olga's case, we continued with a demonstration of RepMoves. In this case, we showed the *body sway* movement pattern, which implied a swaying or rocking motion of the upper body from side to side. The Walkers saw the person demonstrating the movement swaying from side to side and heard the tempo of the music increase and decrease in response. Several of the participants smiled and laughed and tried to sing along with the music. The participants asked a number of questions post-demonstration, such as: What kind of movement patterns could be used, what songs RepMoves could play, and if it was possible to dance freely to the music.

Over the course of the four consecutive meetings, we observed participants using the system. They did so in pairs, in a separate room, while the rest of Walkers continued their usual activities. Our findings on entrainment from these sessions were described in (Rosseland, 2016b). These sessions were very rich and interesting, and it would have been very useful to be able to record video of the sessions. However, in getting access to the group we agreed not to record video in order to protect the participants' privacy. Instead, a few photos were taken during the sessions, and notes were taken immediately afterward. Also, the prototype was set up to log the movement data from each session, which was useful in the subsequent analysis of the sessions.

4.2.2 Observations and Reflections

Here, we present a selection of observations and reflections made by the designer during and after the sessions with the Walkers. The reflections take the form of annotations, accompanied by short descriptions. Each annotation represented a research and/or design opportunity for us, or someone else who would like to continue these lines of inquiry.

Freedom of movement. Variation in the way the movements were performed was greater than we imagined it would be. The movement that RepMoves was tracking in all sessions was the *arm swing*. This was an appropriate type of movement for the Walkers as it resembles the way the arms swing during walking. The movement pattern, at the system level, was designed to track the distance between the sensor and each hand. It calculated the movement tempo based on timing the moments when hands switched position in relation to the sensor. This allowed for a large degree of freedom to move. Some Walkers used long, fluid movements (which one person commented reminded him of Nordic skiing) while others used more punching motions, or even more of a boxing like, hook motion. In most cases, this 'loose' way of tracking movement patterns along a single dimension worked remarkably well. However, one Walker tended to partially rotate away from the sensor, leading one hand to constantly be in front of the other. Her movements were then misinterpreted, and RepMoves either sped up or slowed down the music in a way that did not match the movement tempo.

Invisible barriers. RepMoves was designed to ignore certain movements, such as very, very rapid ones. When designing the prototype, we had assumed that most seniors would probably not appreciate hearing their favorite song played at 2 or 3 times the normal tempo. We also did not think that they would like to move so fast. However, some Walkers really tried to speed things up and thus, would meet the invisible barrier, which made no sense to them. Such barriers, we learned, should either not be there, or, if they have to be, should be used for some explainable purpose. It was also conceivable that this barrier could be turned into a user-adjustable option, giving the user control over how RepMoves responds to their movements.

Paired interaction. The central question in this exploration was whether the RepMoves could be used to entrain and synchronize the movements of two people towards a shared tempo. The tempo of the music was based on the *average* tempo of both users. Accordingly, if two users moved at two different tempos the music would adjust to a tempo in-between both users' tempos, thereby enticing the slower person to speed up and the faster person to slow down. This worked quite well and most sessions demonstrated a clear or moderate entrainment effect. Nevertheless, compared to the single-person mode this two-player mode provided a different experience. Due to the averaging effect of the two-player mode, the music would not directly reflect changes in movement rate of one person unless the other person also made a similar change. In fact, if one user increased and the other decreased the movement tempo (by the same amount), the end result would be that the music tempo would not change at all. On the other hand, if one person made a large and sudden tempo change he or she could potentially disrupt and confuse their co-player, which in some instances led to laughter and foolishness. This seemed to point to a possible alternative direction where the two-player mode could be developed further as, for example, a musical tug of war.

Visual feedback. Another central design decision in this study was the absence of any visual feedback. This was done to ensure that both participants used the rhythm of the music alone to align the tempo of their movements. For the purposes of entrainment, this worked quite well. Nevertheless, observing the participants interacting with the system it was

becoming increasingly apparent that the total neglect of the visual modality, which is so central to human perception, was limiting the experience. The Walkers did not have anything to 'rest their eyes' on, which seemed to make some of them somewhat awkward. In nature, they could rest their eyes on many beautiful things. A natural opportunity was to add a visual feedback, by, for example, photographing the path that they walk along. For the last meeting, we experimented by introducing a slideshow of nature photographs and some graphical performance indicators projected on the wall in front of the participants (Figure 1). This was very well received and suggested an interesting direction for future exploration.

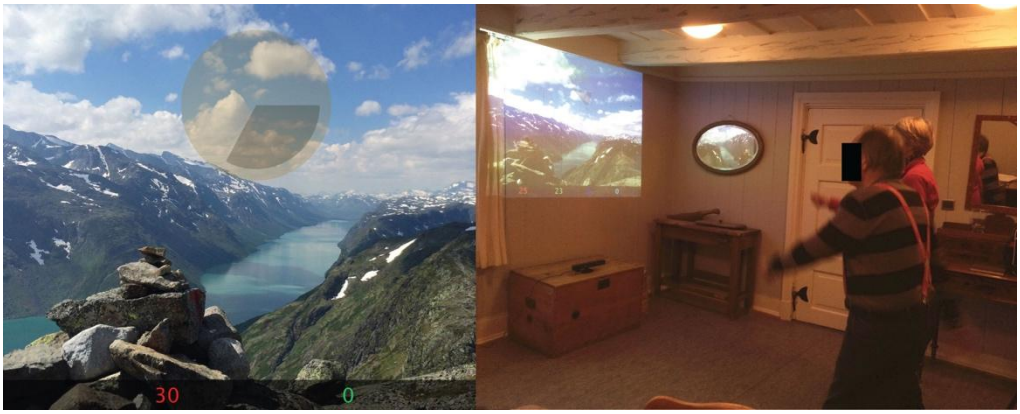

Figure 1, Left: Visual interface with nature photos, a song-timer, a speed indicator, and movement counters. Right: Two Walkers engaged in interaction with RepMoves using the arm swing movement pattern

4.3 Exploration 3: RepMoves for Seniorgamers with Alzheimer's

4.3.1 Context, Participants, and Prototype

The next case was carried out at a daily social club for early stage Alzheimer's patients. The single most popular activity at this club was the *Seniorgamer* virtual bowling sessions. One day each week, the attending seniors were divided into teams of two to four people that competed against each other in a game of virtual bowling on an Xbox 360 game console (using the Kinect motion sensor).

For this exploration, we developed a new and more elaborate RepMoves prototype which included video playback, inspired by the successful introduction of a photo slideshow in the previous case with the Walkers. The videos were shot in a first-person perspective and depicted walks throughout the city where the participants lived (Figure 2). Also, one video was shot walking through the streets of Venice, Italy (Figure 3).

Figure 2. Slide 1 shows the interface for selecting movement pattern. The remainder shows snapshots of a walk over the bridge while listening to "Are You Lonesome Tonight" by Elvis Presley

While using RepMoves, one had a feeling of actually walking the streets. To start, a Gamer would stand in front of the sensor and screen and use a point-and-hold gesture to select one of five different movement patterns shown on screen (the first slides in Figures 2 and 3). At this point, the game would start scanning for the selected movement pattern, and after four movements, play the selected video and music in the tempo of the movements. Points were awarded for how closely the tempo was kept. When a song ended, the video would pause and wait for a new Gamer to select a song and a movement pattern, and then continue. In this way, Gamers could learn to use the system without assistance, and possibly make game rules themselves.

Figure 3. Slide 1 shows the setup interface with the five movement patterns. The rest show the progression of a walk through Venice, Italy

The prototype with its features was demonstrated. It was explained that the pace of music and video would be linked to their movements. The fact that they were familiar with the Kinect tracking technology made it easier to start describing the system. Stopping the movements would pause the video and music, and resuming movement would resume playback. One of the participants asked if several people could use it simultaneously. We explained that this was not possible with this prototype, but that it certainly was an option if

they wanted to try it at a later stage. The participants then tried the system, one by one. Contrary to the case with the Walkers, this was a social setting, with all the Gamers (5-8 people) present for the duration of the sessions. This led to loose discussions crisscrossing the room as different people tried the system. We were unfortunately not able to record any video due to privacy issues. This was a big drawback as it was impossible to capture all the reactions and reflections through observations alone. A research assistant took observational notes throughout the sessions, which were transcribed and expanded upon by the first author immediately after the sessions. Some of the participants were enthusiastic and explored the system creatively by testing different ways of moving. Others seemed more awkward or disinterested. Also, as we started to explore different movement patterns, some of the seniors had problems performing certain movement patterns, leading the system to intermittently pause and restart playback, which confused the users.

4.3.2 Observations and Reflections

At this stage, the prototype represented a much more targeted proposal for how RepMoves could be applied to a specific context than any of the previous prototypes. Accordingly, a wide range of more and less well-founded assumptions and arguments were inscribed into the prototype. As with the Walkers, the reflections are organized into annotations with accompanying descriptions.

Invisible barriers. In this prototype, a new invisible barrier had been designed into the system, namely, the pausing of video and music when the user stopped moving. We explained and demonstrated this to the participants as an intentional feature. The idea was that they would have to move in order to see the video and hear the music. Several of them tried it out themselves during the sessions and were fluidly able to start and stop the video and music. However, some of the participants did not understand, or were not able to perform the chosen movement pattern, which in some cases caused the system to misinterpret their movements as non-movement, and intermittently and arbitrarily stop the playback. This led to confusion and in some cases a complete breakdown of the interaction.

Freedom of movement. Several participants explored, intentionally, different variations of movement within the same movement pattern. For example, while interacting with the system through the *conductor* movement pattern, one of the seniors switched from a side-to-side movement of the hands to a circular movement in front of his body. Because the conductor movement pattern only tracks the hands along the horizontal plane and ignores any vertical movement, the circles that his hands were making were captured by the system as a straight, horizontal line. Accordingly, the system was able to accommodate his explorative movements and accurately synchronize the music and video to the tempo of the new movement trajectory.

Triggering memories. A new and clear effect of the system was that it initiated thoughts, reflections, and memories. Several of the songs triggered discussions and memories of going dancing in their youths, of listening to music on the radio, playing records, as well as reflections and opinions regarding the life and fate of Elvis Presley. The videos also had the effect of triggering discussions and reflections related to the places they depicted. One man, in particular, was very excited about the video from Venice, where he had been many times. He proudly proclaimed that he was familiar with the area where the video was shot and continued to elaborate on his connections to the city.

Virtual tourism. The combination of videos from their hometown with the video from Venice video brought home the potential of RepMoves to serve as a virtual tourism device. Several of the participants expressed excitement about the opportunity to have virtual walks in

foreign countries and other places they would have liked to visit or re-visit. We suspect that having access to a large number of videos from around the world could provide motivations for many hours, days, and weeks of physical activity through such a device.

People are different. Seniors are not a homogenous group, and the fact that they all share a diagnosis does not mean that they have converging interests and opinions. A few participants were very positive and enthusiastic about the system, most were mildly interested, and yet another few played along but demonstrated through body language and comments that they would rather do something else. There was also a somewhat different attitude among the participants from the first to the second meeting.

Single-player in a social context is not ideal. The tests with the Gamers seemed to suggest that single-player interaction in such a social setting was not ideal. As each interaction lasted for two to three minutes, the rest of the participants were left to watch and wait. After the initial excitement wore off we observed a few of them closing their eyes and even taking a nap as they awaited their turn. However, we do not put too much emphasis on this fact because the same participants were also observed taking short naps in between turns during the bowling game. Nevertheless, we concluded that some form of a multiplayer option would be preferable in such a social context.

Supervisors' role. Our experiences with the group during the two visits underlined the importance of the supervisors to the successful execution of a gaming session. During previous visits we observed that the supervisors were responsible for setting up the bowling game with all the necessary options, divide the participants into teams, call out whose turn it was to play, keep score, and declare winners. The only thing the seniors did was get up from their chair when they were called, walk over to the spot in front of the sensor, throw the ball, and go sit back down. During our tests of the RepMoves system, we did not have the same routine and authority as the supervisors to instruct the participants, which resulted in a somewhat messier and more confusing experience for the participants. It was clear that for this group it was important to have a clear and predictable structure to the game, and that if the RepMoves system would have to be further developed to fit this context, the supervisors would need to be more closely involved in facilitating the game.

5. DISCUSSION: REFLECTION ON ACTION

"It was this meticulous attention to how people worked with iFloor that pushed it beyond mere design. The study produced data that were used in many different ways, not just to make the prototype better, as would have happened in design practice" (Koskinen et al., 2011, p. 2).

We hope to have shown, through the cases described above, how material and contextual explorations of an interaction design concept can lead to a wide variety of insights and knowledge relevant to the HCI community. Here, we reflect our process through the lens of the three questions described in the introduction.

(i) How can practices of design and making be used as modes of inquiry to produce knowledge and theory?

We would like to point to three different stages of our process that we think were instrumental in defining the kind of knowledge it produced: concept design, building material arguments and proposals, and contextual exploration. Although this paper mainly focuses on

the third stage of contextual explorations, we offer some reflections regarding the two preceding stages and their significance for the outcome of the project. First, our exploration revolved around one simple concept, rhythmic interaction with music. The concept had been formulated with the specific intent of motivating sustained physical activity. However, it was not conceived of as a finished product for a specific use case, but rather as a generic interaction design concept that could be applied to a wide range of different physical movements and activities. This was arguably one of the most defining decisions of the project as it set the direction of the inquiry without specifying details.

Second, the actual making and extensive testing of the prototypes during development provided countless insights, understandings, and new questions regarding the RepMoves concept and its potential future uses. Throughout this process, the prototypes were inscribed with the designer's questions and proposals regarding potential applications of the concept in the service of motivating physical activity in seniors. As such, the prototypes represented relatively complex arguments in material form. This process also provided the designer with intimate knowledge of the inner workings of the prototypes, as well as extensive embodied experience of using it, both of which were critical during the third stage: the contextual explorations with potential future users.

During this third stage, we were able to engage seniors with Alzheimer's disease in both verbal and embodied discussions and explorations of the RepMoves concept, which would have been impossible to achieve without the research prototypes. Some of our assumptions that had been inscribed in the prototypes were praised, confirmed or accepted by the seniors, while others were overlooked, rejected, or discussed how they could be changed. Furthermore, we were able to explore and understand how a range of contextual, personal and social factors could influence the future adoption of the RepMoves concept in specific contexts. For example, in the case of both activity groups for Alzheimer's patients, it was obvious that the role of the supervisors would be critical to the successful and meaningful adoption of the such a system. Finally, it was clear that while some participants were very positive and enthusiastic about the system, many others were less interested, indicating that it was not for everyone.

(ii) How can and should RtD research artifacts be documented in order to communicate the knowledge they produce, contain or represent?

This was a very challenging project to document for two distinct reasons: The nature of the prototypes and the need to protect the privacy of the participants. The prototypes were very difficult to document through still photos, particularly the ones that did not provide any visual feedback. A series of images could give some indication of how the users moved over time, but they would give a very poor representation of the interactive experience. The last prototype involving the use of video was more easily represented in photos, as we have done above, but it does not come close to any faithful representation of the interactive experience. We have recorded video of people interacting with the prototypes in other contexts, and have seen how rich and informative they are for in-depth analysis of the interactive sessions. The project would have benefitted greatly from being able to record video of the sessions with the senior participants, but alas, due to privacy constraints it was not possible in any of the cases presented here. In the future, we will make determined efforts to find ways to record videos of the interactive sessions with users while ensuring that participants' privacy is protected.

The project was well documented through the code history of the prototypes. The code files contained an abundance of information about the project that was very useful in tracing the evolution of the project and different lines of inquiry within it. They provide a detailed timeline for the whole project and have, combined with field notes and other forms of notes

and sketches, been instrumental in the evaluation and analysis of the project. We see annotations as an appropriate method for extracting, organizing and categorizing the knowledge contained within this body of documentation.

(iii) How should RtD artifacts be evaluated, analyzed and critiqued in order to produce relevant knowledge for the HCI research community?

Looking back at our project, we would like to think that it demonstrated some of the generative and explorative potential of deliberately open research artifacts as a method of inquiry. Accordingly, it is appropriate that the project is evaluated and critiqued for its ability to open up new design spaces and avenues of further research. We also feel that it is relevant to critique and discuss the concept-driven nature of the research, our ability to turn the concept into good research artifacts, our choice of participants and use contexts to explore, and our ability to ask the appropriate questions and propose coherent arguments through our research prototypes. The project may also be critiqued for its ability to document the process as well as the different research prototypes.

However, as Bardzell et al. (2015) point out, it is not the sole responsibility of the designer to identify the knowledge that RtD objects produce. They argue that the HCI research community needs to establish a communal practice of *critical reception* of designed research objects in order to collectively evaluate and discuss the kinds of knowledge they provide. This, they argue, will distribute the responsibility of identifying RtD knowledge contributions on the entire community and lead to the development of a hermeneutic community that is competent and able to 'read' designs like the art community is able to read a Rembrandt. "[In] order for the object to 'appear', it needs to enter a qualified and engaged dialogue with an interpretative community" (Bardzell et al., 2015, p. 2101). However, in order to enter this dialogue, it needs to be accessible to the research community. Pierce (2014) argues that although the research artifact in RtD is seen as constituting, containing and constructing knowledge, hardly anyone within the research community have access to these artifacts. The principal form in which the research community can evaluate and critique the knowledge produced by RtD research artifacts is through verbal descriptions in research papers. Thus, the material artifact and the written research paper co-constitute knowledge for the research community. Accordingly, it is through meticulous and conscientious documentation, description and presentation of the artifacts in research publications such as this that the RtD artifacts can enter a critical dialogue and produce knowledge for the research community.

6. CONCLUSION

We hope this paper has demonstrated the generative potential of research through design, and the wide variety of knowledge such projects can produce. By making open and flexible prototypes based on a generic concept of rhythmic interactions, and immersing them in different contexts, we have tried to see what kind of new knowledge and insights emerge. The prototypes, or more precisely, research artifacts were used in three different situations with seniors, individually or in groups. We conclude that at the point of encounter between a research object and a new context of use, insight and knowledge emerge. In line with low fidelity prototypes, these objects also pose more or less open lines of inquiry. Insights gained by engaging in such a process are both numerous and valuable.

REFERENCES

Bardzell, J., Bardzell, S., Koefoed Hansen, L., 2015. Immodest proposals: Research through design and knowledge. *In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, pp. 2093–2102.

Boucher, A., Gaver, W., 2006. Developing the Drift Table. *interactions* 13, 24–27.

Clair, A.A., Lyons, K.E., Hamburg, J., 2012. A feasibility study of the effects of music and movement on physical function, quality of life, depression, and anxiety in patients with Parkinson disease. *Music Med. 4*, 49–55.

Dalsgaard, P., 2016. Experimental Systems in Research Through Design. *In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, CHI '16*. ACM, New York, NY, USA, pp. 4991–4996.

Gaver, W., 2012. What Should We Expect from Research Through Design? *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '12*. ACM, New York, NY, USA, pp. 937–946.

Höök, K., Löwgren, J., 2012. Strong concepts: Intermediate-level knowledge in interaction design research. *ACM Trans. Comput.-Hum. Interact.* TOCHI 19, 23.

Ingold, T., 2013. *Making: Anthropology, Archaeology, Art and Architecture*, 1 edition. ed. Routledge, London ; New York.

Koskinen, I., Zimmerman, J., Binder, T., Redstrom, J., Wensveen, S., 2011. *Design Research Through Practice: From the Lab, Field, and Showroom*, 1 edition. ed. Morgan Kaufmann, Waltham, MA.

Pierce, J., 2014. On the Presentation and Production of Design Research Artifacts in HCI. In Proceedings of the 2014 Conference on Designing Interactive Systems, DIS '14. ACM, New York, NY, USA, pp. 735–744.

Repp, B.H., Su, Y.-H., 2013. Sensorimotor synchronization: A review of recent research (2006–2012). *Psychon. Bull. Rev. 20*, 403–452.

Rosseland, R., 2016a. Involving Senors in the design of home based welfare technologies: a review of existing research. *In Proceedings of the International Conference on Interfaces and Human Computer Interaction, IHCI 2016*, pp. 12–20.

Rosseland, R., 2016b. Design and Evaluation of an Interactive Music System for Exercise and Physical Activity with Alzheimer's Patients. Sound Eff. *Interdiscip. J. Sound Sound Exp. 6*.

Rosseland, R., Berge, S., Culén, A.L., 2014. Publicly Displayed Interactive Installations: Where Do They Work Best? *In Proceedings of the Seventh International Conference on Advances in Computer-Human Interactions, ACHI 2014*, pp. 1-8.

Schön, D.A., 1983. *The reflective practitioner: How professionals think in action.* Basic books.

Stappers, P.J., 2007. Doing Design as a Part of Doing Research. *In Michel, R. (Ed.), Design Research Now, Board of International Research in Design.* Birkhäuser Basel, pp. 81–91.

Thaut, M.H., 2005. *Rhythm, Music, and the Brain: Scientific Foundations and Clinical Applications.* Routledge.

Wiberg, M., Stolterman, E., 2014. *What Makes a Prototype Novel?: A Knowledge Contribution Concern for Interaction Design Research*. *In Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational, NordiCHI '14*. ACM, New York, NY, USA, pp. 531–540.

Yu, W., Vuong, C., Ingalls, T., 2011. An Interactive Multimedia System for Parkinson's Patient Rehabilitation. *In Shumaker, R. (Ed.), Virtual and Mixed Reality - Systems and Applications, Lecture Notes in Computer Science*. Springer Berlin Heidelberg, pp. 129–137.

Zimmerman, J., Forlizzi, J., 2014. Research Through Design in HCI. *In Olson, J.S., Kellogg, W.A. (Eds.), Ways of Knowing in HCI*. Springer New York, pp. 167–189.

Zimmerman, J., Stolterman, E., Forlizzi, J., 2010. *An analysis and critique of Research through Design: towards a formalization of a research approach.* ACM Press.