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Rune B. Rosseland

Design and evaluation of an interactive music system for exercise and physical activity with Alzheimer's patients

Rune B. Rosseland
Department of Informatics
University of Oslo

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Abstract

Elderly people are encouraged to exercise regularly to maintain good health and avoid or slow down the progression of age-related health challenges such as Alzheimer's disease (AD). Despite this, many seniors struggle to find the motivation to adhere to exercise programmes over time. In this qualitative, research-through-design study an interactive music system was tested with AD patients. The purpose was to explore how dynamically adapting musical beat and rhythm can be used to stimulate and motivate physical activity. The system changes the tempo of a piece of music to match the pace of repetitive bodily movements. Findings show that most participants were able to entrain and synchronise to each other's movements through use of the system. Several participants also commented that they enjoyed the experience. Finally, the addition of an interface with nature photos and visual performance and progress indicators suggested possible ways for the system to be redesigned to suit the needs and desires of the participants.

Introduction

The population of Norway is aging as the 'baby boom' generation born in the years after World War II is now starting to reach retirement. Many of these people are expected to live for decades more, well into their nineties or beyond, and it is projected that there will be a significant rise in health challenges associated with very old age. For example, at 65 years one per cent of the population develops dementia, while at 90 years over 50 per cent of the Norwegian population suffers from dementia (Bahr, 2009). Furthermore, dementia may lead to other health challenges related to lack of physical exercise and social isolation, and may thus contribute to a downward spiral of declining health and ultimately early death (The Norwegian Directorate of Health, 2011).

There is an abundance of research to indicate that physical activity and exercise can postpone the onset of dementia as well as slow down the progression and alleviate the symptoms of the disease (Hamer & Chida, 2009; Heyn et al., 2004; Larson et al., 2006). In a randomised, controlled trial Rolland et al. (2007) found that, compared to normal medical care, a simple exercise programme performed for one hour twice a week contributed to a significantly slower decline in the ADL (activities of daily living) score of Alzheimer's disease (AD) patients living in a nursing home. However, recommendations regarding the optimal type and amount of exercise remain unclear (Hamer & Chida, 2009). Nevertheless, any exercise or physical activity is better than inactivity. It is, therefore, crucial to find diverse approaches to motivate elderly people to exercise and stay active.

Music is a promising avenue to explore in this regard. It is extensively used in a variety of exercise activities and has been shown to increase levels of participa-

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tion in group exercise for people with dementia (Mathews et al., 2001). The study reported in this paper explores interpersonal synchrony and entrainment between two participants with AD, aided by an interactive system that synchronises the musical tempo and the tempo of the users' movements. The purpose of this study was to understand whether people with early-stage AD can entrain to each other's movement tempos through the use of an interactive music system and to explore how adaptive rhythmic stimulation with music can be an enjoyable and fun augmentation of repetitive physical exercise. Findings indicate that the idea behind the system has some merit as a motivator for physical activity among seniors with AD. Further research is needed to explore how it can be designed to become a meaningful and natural part of senior citizens' physical activity routines.

The paper is structured as follows: The next section describes relevant background research into music therapy and entrainment. Second, the research method and epistemology of the project are presented. Third, a description of the prototype design and functionality is given, before the evaluation setting, test protocol and data collection methods are outlined. Finally, the findings are presented, followed by the discussion and conclusion.

Background

Music therapy is increasingly recognised as a viable, non-invasive tool for the treatment of dementia patients. Research indicates a positive effect of music therapy on a range of issues associated with dementia, such as behaviour and mood (McDermott et al., 2013; Svansdottir & Snaedal, 2006), anxiety and depression (Guétin et al., 2009), cognitive abilities (Winckel et al., 2004), short-term memory, speech and quality of life (Aldridge, 1994). However, according to a review of 10 randomly controlled trials (RCT) reporting clinical effects of music therapy, the evidence is inconclusive and mostly based on small, short-term trials with limited methodological quality (Vink et al., 2003). There is also a lack of long-term studies, and it is difficult to establish appropriate and reliable outcome measures to evaluate the effects of music therapy (McDermott et al., 2013). Nevertheless, large RCTs may not be the right method for documenting the effects of music therapy on dementia patients: '[P]rovisions of double blinding to treatment or placebo condition are not always practically possible or ethically suitable' (McDermott et al., 2013, p. 781). Based on personal experience, and existing literature, Kvamme (2008) rejects RCTs as a method for evaluating music therapy with dementia patients. She concurs with Ridder (2005) that 'music therapy has positive effects on communicative, physiological, cognitive and social abilities in people with dementia' (Kvamme, 2008, p. 493, my translation). Magee and Burland (2008) also point out that there is a growing demand for electronic music technologies that can be used in clinical music therapy practice.

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There are two basic forms of music therapy: receptive and active. Receptive music therapy is based on passive listening to pre-recorded music, while active music therapy relies on the use of instruments and active participation in music-making together with a therapist (McDermott et al., 2013).

Outside of music therapy there is a wealth of evidence to indicate that music can be employed in the promotion of health, well-being and quality of life. In an exploratory study of 22 people with long-term illness, Batt-Rawden and Tellnes (2011) found that a compilation of self-selected songs helped motivate participants to exercise, relieved anger and aggression and transcended pain to the extent that they used the music as a substitute for medication. Rhythmic auditory stimulation (RAS) is a rehabilitation method particularly used with Parkinson's and stroke patients (Leow et al., 2015; Ruotsalainen, 2013; Thaut et al., 1996). As the name suggests, RAS employs rhythmic auditory stimuli in the form of a metronome or rhythmic music to cue and guide repetitive movements and exercise (e.g. walking or moving a limb). Similar to research on music therapy, outcome effects of RAS vary across individuals and studies, but this may partially be because the stimuli used are rarely adapted to individual preferences. It has been shown that familiar music elicits better tempo matching and faster strides than unfamiliar music (Leow et al., 2015). Also, high-groove music and metronome cues lead to better synchronisation than low-groove music, where the beat pulse is less salient (Leow et al., 2014; Madison et al., 2011). Mathews et al. (2001) found that rhythmic music increased participation in group exercise activities for dementia patients. However, the effect varied between participants according to their willingness to participate in social activities.

The concept of entrainment is closely related to RAS. Moens and Leman (2015, p. 86) define entrainment as 'the gradual fall into synchronism of two rhythms, such as when a locomotion pattern gradually falls into synchronization with a musical pattern'. On a more abstract level, humans show tendencies to interpersonal synchrony from birth, and we develop and use these abilities in social interactions throughout our lives (Gill, 2012). Moving in sync with another person is associated with positive emotional effects, empathy and well-being (Gill, 2012).

Phase, period and tempo are central terms in the study of entrainment. Phase refers to the start of a cyclical process (e.g. the onset of a beat pulse in a rhythm or the moment the foot touches the ground during walking). Period refers to the duration of one cycle (e.g. the time from one beat to the next or from one step to another). Tempo is defined by the period and describes how many cycles or periods there are in a unit of time (e.g. beats or steps per minute). Entrainment implies that two rhythmical processes incrementally adapt the period of their cycles to each other. Synchronisation occurs when both processes have the same period and tempo. However, synchronisation can occur in phase or out of phase. In-phase synchronisation implies that the two processes start each cycle at the same time (e.g.

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beat and footstep coincide in time). Out-of-phase synchronisation describes a situation where the two processes have the same period and tempo, but the onset of each cycle happens at different times (e.g. beat and footstep do not coincide in time).

Moens et al. (2010) introduced the D-jogger framework for research into entrainment. D-jogger is a music interface that dynamically selects songs based on walking pace and adapts the tempo of the music (beats per minute, BPM) to the walking pace of the user (steps per minute). Moens et al. (2014) explored different alignment strategies for entrainment using D-jogger. They found that users were better able to maintain a stable synchronisation with the music than to establish this synchronisation from an out-of-sync starting point (Moens et al., 2014). Accordingly, to facilitate synchronisation the prototype tested in this study employed a method for establishing phase and period alignment of music and movement at the start of the interaction. The prototype was based on the same basic principles as the D-jogger system in terms of entraining musical tempo to movement, but it did not automatically select songs based on movement tempo. Also, the prototype differed from D-jogger in that it was designed to detect several different movement patterns, and to allow multi-user interaction.

Research method

There is a tension within design research regarding the diverging nature of design practice and scientific research (Frayling, 1993; Koskinen et al., 2011). Scientific research is conducted in the pursuit of new knowledge and universal truths, while design practice is concerned with the creation of the non-existent and non-universal (Stolterman, 2008). Researchers study the past and the present world as it exists, and attempt to avoid influencing the objects of their study. Designers try to imagine and build possible futures by intentionally affecting and changing the present world. Research-through-design is a research method that attempts to alleviate the tension between design practice and scientific research. It employs methods and practices from design practice in the pursuit of new knowledge.

> RtD [research-through-design] draws on design's strength as a reflexive practice of continually reinterpreting and reframing a problematic situation through a process of making and critiquing artifacts that function as proposed solutions. RtD asks researchers to investigate the speculative future, probing on what the world could and should be. (Zimmerman & Forlizzi, 2014, pp. 167-168)

This study is part of a research-through-design project that seeks to explore an imagined possible future where music is used interactively to engage and motivate senior citizens to be more physically active. We initially formulated this possible future as the 'conductor' concept, which describes a situation where the tempo of

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repetitive human movement (the conductor) is used to control the tempo of the music (the orchestra). It was based on the assumption that music motivates movement, and that moving to musical rhythms is an inherently enjoyable activity. The system was envisioned to be used to either musically augment an existing exercise activity (e.g. walking, simple gymnastic exercises, exercise machines, group exercise) or to form the basis for new ways of staying physically active. However, to understand if and how this imagined possible future can be realised, it was necessary to explore the nature of rhythmic bodily interaction with music. Accordingly, an interactive prototype was designed and built to detect the tempo of repetitive bodily movements and to adjust the tempo of music to the movement tempo. The prototype proved the technical feasibility of the 'conductor' concept. Furthermore, it confirmed that the interaction was experientially interesting and warranted further exploration (Rosseland, 2014).

In this study the system was used to explore interpersonal entrainment between two elderly people with mild AD. We hypothesised that the system could help the two participants entrain their movements to each other and to synchronise the movements at a tempo that was comfortable for both of them. The study also sought to understand whether this was an enjoyable experience, and how it could potentially be redesigned to become a meaningful part of the group's regular activities.

The project is epistemologically based in the phenomenology of Maurice Merleau-Ponty, who built his phenomenology of perception on the idea that our knowledge of the world is mediated through and thus predetermined by our bodily capacities. He argued that reality is constituted in the encounter between the lived body and the physical world, thus reasoning that 'the body is our general medium for having a world' (Merleau-Ponty & Smith, 1962, p. 146). Embodiment and skills are central concepts in this regard. Dreyfus (1996) identified two different understandings of embodiment in Merleau-Ponty's work. First, the physical capabilities of our bodies lay the foundation for our abilities to perceive and relate to the world. Our skills and abilities to understand and act upon the world are *embodied* in the relation between the physical capabilities of our bodies and the affordances of the physical world. Second, over the span of our lives we experience and learn how to skilfully interact with the world. This skill development involves an increasingly intimate and embodied understanding of how the world works, an ability to incorporate tools into our bodily practices and an agency to act in the world.

Phenomenology and embodiment are relevant lenses for discussing the design of the 'conductor' concept and prototype. First, the moving body is a prerequisite for music to exist. Without movement the system does not play any music at all. Furthermore, there is a direct link between the frequency of movement and the tempo of the music. As such, the user's movements are constitutive of the perceived reality of the music, while the music reciprocally interferes and influences the movements

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of the perceiving user through variations in rhythm and melody. Thus, a mutually constituting reality, a perceptual loop, is formed between the moving human and the music. Second, the design of the movement patterns (described below) relied heavily on movements that would be intimately familiar to any able-bodied person. This was done to ensure that the movement patterns would be present in the embodied skill repertoire of all senior participants. Also, the movement patterns were implemented in a way that was robust enough to allow for a large degree of personal variation in the range and style of movement.

The prototype

The prototype consisted of three main elements: an optical motion sensor (Microsoft Kinect), a computer connected to an amplified loudspeaker and a Max[1] patch implementing the algorithm for matching the musical tempo to the tempo of human movements. The Kinect motion sensor uses infrared light to detect human bodies and track the position of individual body parts in 3D space. The algorithm in the Max patch was designed to monitor a selection of simple repetitive movement patterns in the incoming position data from the Kinect, and to detect the tempo of those movements. The system would adapt the playback tempo of a pre-selected piece of music to match the movement tempo of the user, thereby ensuring that the rhythmic pulse of the music coincided with the perceived beat points in the movements. In line with the findings of Moens et al. (2014), the system was designed to establish phase and tempo alignment between the music and the movement at the start of the interaction. The user was required to start moving in a comfortable tempo before the music started. The system would use the first 10 movements to determine the tempo and then start the music in phase with the movement.

To avoid degrading changes in the pitch of the music, which inevitably occur when the speed of playback is changed, the audio output was pitch-shifted reversely proportional to the change in playback speed. Thus, the music would play at the correct pitch, independent of playback speed. However, the pitch shift algorithm was not perfect, and rapid changes in playback speed or significant deviations (> approximately 30 per cent) from the normal speed would result in some digital noise and artefacts.

The system was designed to detect five different movement patterns, illustratively named 'conductor', 'arm swing', 'torso sway', 'knee bend' and 'knee lift'. 'Conductor' required the user to swing one or both arms (in parallel) horizontally back and forth in front of the body. 'Arm swing' detected alternating arm swings from front to back. The 'torso sway' pattern tracked horizontal movements of the upper body from side to side. 'Knee bend' required the user to perform repetitive knee bends in a standing position, and 'knee lift' required the user to walk in place by

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alternately lifting one knee while standing on the other foot. All movement patterns had to be performed in a standing position.

The system was not designed specifically for AD patients, and there were no physical therapists involved in the design of the different movement patterns. It was not designed as an exercise or music therapy device, but as a prototype for experiential exploration of bodily entrainment with pre-recorded music. In addition to being within the embodied skill repertoire of senior citizens, the movement patterns were designed because they were conceived of as interesting to explore as well as realistically achievable with the available technical resources and knowledge. Nevertheless, care and consideration were taken to ensure that the movement patterns were easy to perform and did not strain the user.

For the current study, the system was set up to track two users simultaneously in order to explore interpersonal entrainment. The implication of this for the functionality of the prototype was that the music would play at the average tempo of both users. If two users moved in synchrony at the regular tempo of the song, the song would play at that tempo (speed = 1). If user A reduced the movement tempo to half (0.5x), while user B remained constant at 1x, the music would play at 0.75x. If user B then doubled the movement tempo (from 1x to 2x), the music would play at normal tempo (1x). Accordingly, the tempo of the music would always lie between the movement tempos of both users. We hypothesised that this would have an interpersonal entrainment effect on the users, because the music would entice the slower user to increase the tempo, and vice versa for the faster user.

Evaluation

The prototype was tested by a group of seniors with early stage AD. The seniors were still active and participated in a weekly activity group. The activity group was a service provided by a preventive medical centre focussing on nature and culture activities as a way to promote health and quality of life. The staff underlined that although the elderly were active they were not in a position to give informed consent to take part in a study where personal information would be collected. Accordingly, it was agreed that no personally identifiable information or health information would be collected, and that everything had to be done on the participants' terms. In the remainder of this paper fictitious names are used to illustrate how the different participants performed.

The activity group met once a week for four hours, and most of the meetings included three to four supervisors and three to six participants. The meetings were structured into three main activities: walking on trails in the surrounding countryside, lunch and socialising, and a sing-along using a compilation of songs chosen

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by the participants. This organisation provided a familiar and predictable structure for the participants. In agreeing to take part in the study the supervisors underlined that it was important that using the system would not be too disruptive of this routine.

In total, there were five meetings with the group. The first meeting was a pilot session to see whether the participants were able to use the system and willing to take part in the study. Four supervisors and six elderly participants were present. An explanation of how the system worked was given before the system was demonstrated. Afterwards the participants were invited to try the system one by one, while the others watched. They were asked to move in a tempo that was comfortable to them. Four participants tested the system using either the 'conductor' or the 'arm swing' movement pattern. All four were able to perform the necessary movements to control the tempo of the music, and to sustain a relatively stable tempo. Two participants (Per and Marie) played through the songs with only small and gradual tempo variations, while the other two were more explorative in their movements. Jens, who quickly got control of the music with fluid and even arm swings, tried to challenge the system by suddenly doubling his movement frequency, which resulted in a rapid increase in the tempo of the music and ensuing laughter. When Jens returned to a normal tempo, the music followed shortly after and stabilised at his tempo. Peter also managed to get control of the system quite quickly. After a little while, his movements drifted over into dancing and spinning around, leading the system to misinterpret his movements, and the music started oscillating wildly. Similar to Jens, Peter was also able to stabilise the music by returning to the 'correct' movement pattern. During the session the rest of the group were sitting or standing at one end of the small room. Some were clapping or humming and clearly enjoying the spectacle. Two participants seemed less interested and did not want to try.

The participants were asked what they thought of the experience, but Peter was the only one to offer a comment. He stated that he did not believe his movements could affect the tempo of the song. He reasoned that the song had been recorded with a set tempo, and it would be impossible to change this tempo during playback. This was surprising because the tempo varied quite significantly during Peter's session. We tried to explain by referring to how it is possible to change the playback tempo on a gramophone player, but Peter did not seem entirely convinced. Peter's mental model of pre-recorded music obviously did not accommodate what he had just experienced. We also asked the participants to name some favourite songs or artists that we could incorporate into the system for upcoming sessions. However, despite the fact that they had a book of songs that they sing every week, the participants did not make any suggestions. During a later session one of the participants was asked about her preferred exercise activities. She responded, 'I don't have an

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opinion. I just do as I'm told'. This reluctance to form own opinions may also have contributed to the participants' hesitation to comment on the experience of using the system as well as their music of choice. At any rate, we did not expect them to have well-articulated understandings and opinions about the system. We were content and pleased by the fact that the participants were able to use the system as intended. Accordingly, we considered the pilot test a success and agreed to carry on with the study.

Based on the experiences from this first meeting it was decided to conduct the tests in a separate room. In this way, two participants could test the system while the rest of the group carried on with the regular sing-along activity, as this was less disruptive to the normal activity routine of the group and did not lead to participants sitting idle while others tested the system. It also allowed more control over the test environment.

Test protocol

The test protocol was as follows: The supervisors would ask two participants to come to the adjoining room, while the rest of the group started the sing-along session. The participants received a brief explanation of how the system worked and what they were expected to do. The system was then set up to play a specific song and to use the 'arm swing' movement pattern. The participants were asked to stand beside each other facing the Kinect sensor and swing their arms alternately back and forth. The tests lasted for the duration of the selected song. After the music had stopped, the participants were asked to comment on the experience, before returning to the rest of the group.

Songs were selected from the list of songs they sing during the sing-along activity to ensure that the music was familiar to the participants. The songs used during the tests were 'Fly Me to the Moon' by Frank Sinatra and 'Tango for To' ('Tango for Two') by Alf Prøysen (a Norwegian folk singer). Both songs have a tempo of approximately 120 BPM. However, this tempo gives a single beat period of 500 milliseconds, requiring users to perform two arm swings per second to sustain a normal tempo, which is unrealistic to expect an elderly person to do continuously for two to three minutes. Instead, the system was set up to translate a movement tempo of 60 BPM into a music tempo of 120 BPM. Accordingly, to play the song at the normal tempo participants were required to perform one movement per second.

Data collection methods

Two different data collection methods were employed: observations and logging of system data. The author observed the participants as they used the system, focus-

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sing on facial expressions and body language, and on how they performed the movements they were instructed to perform and how well the movements corresponded with the rhythm of the music. Notes were taken from memory after the completion of the day's meeting. During the last meeting an additional researcher was present to observe and take notes during the tests. In addition to observations, the system recorded the duration of each movement cycle in milliseconds (typically in the range 750 to 1,250 milliseconds). The recorded data was used to evaluate the consistency of the participants' movements and how well they were able to entrain to each other.

Findings

A total of nine participants used the system one or more times over the course of four visits (two months), resulting in a total of 12 paired sessions and three sessions with a single participant. Most of the sessions lasted for the duration of the song (two to three minutes), but some were stopped short for various reasons.

Regarding interpersonal entrainment, the sessions can be divided into three categories:

1. Clear entrainment effect (seven sessions). Both participants were able to meet at a common tempo and to sustain a stable music tempo throughout the session.
2. Some entrainment effect (two sessions). Participants were partially able to find a common tempo, but experienced challenges that resulted in fluctuations in musical tempo.
3. No entrainment effect (three sessions). Participants were unable to negotiate a common tempo.

In the following paragraphs example sessions of each of these categories are described, supported with graphs displaying the movement data from those sessions.

Clear entrainment: Peter and Jens performed very stable and fluid pendulum movements with their arms and maintained a music tempo very close to the original tempo during the entire song. At one point Jens stopped moving, looked over at Peter for a short while, before starting to move again, mirroring Peter's movements. The rest of the song seemed to go quite effortlessly. None of them spoke a word during the session. Figure 1 shows the recorded movement periods for both participants (Peter = red, Jens = blue). The x-axis represents movement number, consecutively ordered as they were performed. The y-axis represents the movement

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period in milliseconds of each cycle ('arm swing'). It is clear that both graphs remain very steady around or slightly below 1,000 milliseconds, apart from Jens' pause that lasted for 4,400 milliseconds (the first outlier in the blue graph). After the pause we see that the blue graph returns to the level of the red graph over the following 10 movements. Towards the end of the session Jens made another one-second pause, which corresponds to a reversal of the movement phase and may have been done intentionally to align with Peter's phase.

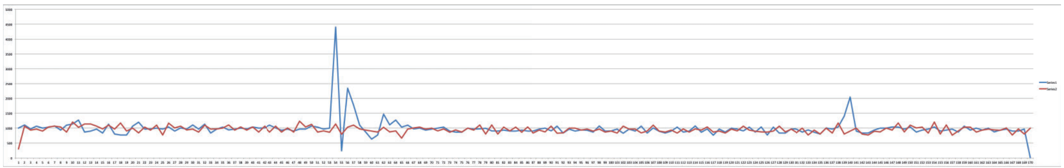

Figure 1

In another session Jens and Marie also achieved clear interpersonal entrainment (figure 2). The system had been set up to store the beat period of the music as it changed based on user input, which is the third black graph in figure 2. It is evident that all three graphs follow each other closely, apart from one point in the middle where the music slows down momentarily before returning to normal (as indicated by the spike in the black graph). The change in music tempo seems to have affected Jens to slow down correspondingly (indicated by the spike in the blue graph).

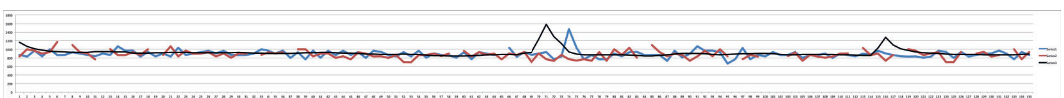

Figure 2

Some entrainment: Figure 3 shows the data from a session with Per and Jens (blue and red graphs, respectively). During the session a clear difference in movement pattern was observed. Jens' movements seemed fluid and controlled, while Per's movements were more asymmetric (i.e. each arm followed different trajectories) and less fluid. They were able to maintain a relatively stable music tempo, but with fluctuations within a tolerable range. Nevertheless, as the graphs show, there are relatively big and irregular fluctuations in consecutive movement periods, particularly in Per's graph (red).

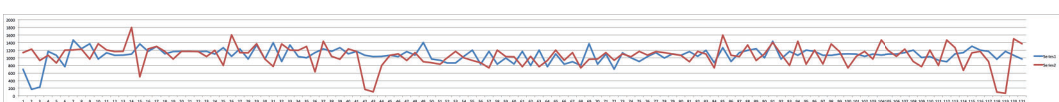

Figure 3

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No entrainment: In three sessions the participants were unable to synchronise and entrain to each other's movements. However, the inability to entrain was caused by either system bugs, incorrect user positioning or a bad shoulder that restricted arm movement.

There were several indications that the participants enjoyed the activity. For example, in some cases participants were observed skipping and dancing back to the rest of the group after finishing a session, as well as humming the melody of the music. There were also sessions where the participants either hummed along with the melody or attempted to sing the lyrics. When asked what they thought of the experience, several participants commented that they thought it was fun. However, getting them to elaborate further was difficult without putting words in their mouth. When asked whether this was a silly and nonsensical system, Per protested and underlined that he enjoyed the experience.

We made some additions to the system for the final meeting. During previous sessions it was noted that participants seemed a little confused about where to look during the sessions. A couple of participants also commented that they did not know where to look, which was a very reasonable comment as the participants were facing an empty grey wall during the tests, without any form of visual focal point. For the last meeting a visual interface was introduced to give the participants something to focus on as well as provide a minimum of feedback regarding performance and progression. The visual interface (figure 4) was projected on the wall in front of the participants and included:

1. A slideshow of nature photographs from Jotunheimen National Park.
2. A counter that counted the number of movements each participant performed.
3. A pie chart that slowly filled up to indicate the progression of the song (i.e. a slice of a pie chart that grows into a complete circle).
4. Another (complete) circle to indicate the current tempo of the music. This circle was centred on the same point as the pie chart and grew (faster tempo) and shrunk (slower tempo) proportional to the speed of the music.

The intention with the interface was to provide an enjoyable focal point to look at as well as to provide the participants with some information regarding their performance. When presented at the last meeting, the interface was very well received, and several participants commented that they thought the photos were beautiful. It is hard to say whether the visual performance indicators (points two-four above) were useful, but comments and questions suggested that at least some of the participants were paying attention to them.

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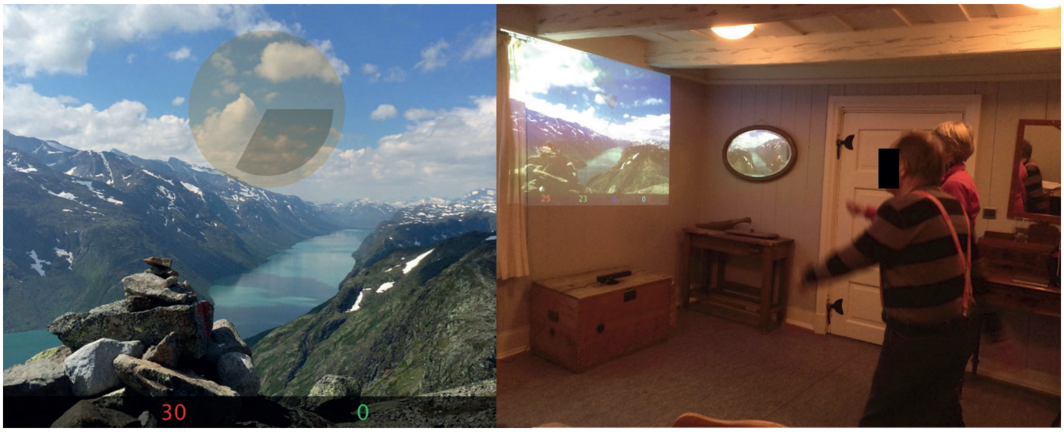

Figure 4

The introduction of the visual interface also sparked an impromptu brainstorming session with two of the supervisors. A relevant question that surfaced was whether the system could be developed into a virtual walk simulator. We hypothesised that it could be used as a substitute for the regular walking activity during the upcoming winter months, when snow and ice would make it challenging and dangerous for the participants to walk outside. Sequences of photos could be arranged sequentially to create virtual walks in different environments, accompanied by music. One supervisor also asked whether it was possible to play a video and to control the playback speed of the video with the same mechanism that controls the music. He was thinking of one participant who had a particular interest in extreme sports such as mountain climbing and skydiving, and whom he thought might enjoy watching videos of such activities through the system. The use of video was briefly explored in an earlier version of the prototype and is certainly technically possible. These ideas will be explored further in future work.

Discussion

It is clear that the system had an entraining effect on the participants. In nine of the 12 sessions the participants were able to fully or partially entrain and synchronise each other's movements to the tempo of the music. In the remaining three sessions entrainment was precluded by technical complications with the system or physical challenges of the participants. It is reasonable to assume that a more technically robust system would have yielded a higher entrainment effect.

As recommended by Moens et al. (2014), the system implemented a method for facilitating initial synchronisation by ensuring that the music would start playing in the same phase and tempo as the users' movements. When used by a single user, this worked remarkably well. The music would start playing at a tempo and beat phase that more or less matched that of the user, allowing him or her to continue in

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approximately the same tempo. However, in this study the system was used to synchronise music tempo to the average tempo of *two users*. This implied that, unless they were already in sync with each other during the first 10 movements, the music would start playing in a tempo in-between the participants' tempos. This was intentionally not explained to the participants, as we were interested in seeing how well the system and participants were able to entrain and synchronise to a common tempo.

In most cases, the participants would start their initial movements in a relatively similar tempo, in which case the music would start at a tempo close to both participants and allow them to synchronise through slight adjustments. However, in a few sessions the participants started the initial movements with significant tempo differences, which resulted in some confusion when the music started playing at a different tempo. This corresponds well with the findings of Moens et al. (2014) that users were less able to achieve synchronisation with the music from an out-of-sync starting point. Nevertheless, the participants and system were usually able to mutually adapt and synchronise at a common tempo within five to 10 seconds. The dynamically averaging music tempo had a clear entrainment effect on the participants by inviting the faster participant to slow down and the slower participant to speed up. The entrainment effect may also have been enhanced by the fact that the participants could peripherally see each other's movements. They were several times observed looking sideways at their co-participant before adjusting their phase and tempo to match him or her, suggesting that they partially relied on the movements of co-participant to set their tempo.

Given the lack of recommendations regarding the optimal type and amount of exercise for dementia patients as pointed out by Hamer and Chida (2009), it is crucial that any exercise programme for dementia patients be tailored by physical therapists to suit individual needs and capabilities. As there was no physical therapist involved in this study, it made sense to focus our design efforts on how interaction design could help motivate and facilitate exercise and activity in general, without limiting the scope to the needs and abilities of individual patients or patient groups. Accordingly, we based the system design on the fact that exercise, on a general level, involves repetitive movements. This was conceptually linked to qualities of music and rhythm, which also display repetitive characteristics. This combined perspective enabled the design of an algorithm that is neither tied to specific movements or exercise scenarios nor to certain songs or types of music. We see this as an advantage of the proposed design. It can be adapted by physical therapists to a variety of activities that involve repetitive movement, and the user is free to choose his or her favourite music which, according to Leow et al. (2015), better facilitates tempo matching than unfamiliar music. Thus, the benefits of physical exercise

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can be combined with the benefits of music therapy. Furthermore, it can be applied to both preventative and rehabilitative exercise scenarios.

From an embodied skills perspective, the interactive mechanism does not prescribe bodily skills and abilities of individual users. Rather, it allows the user, in consultation with a physical therapist, to select movement patterns that are familiar and suitable to his or her bodily capacities as well as useful as physical activity. The prototype provided a selection of five simple movement patterns with varying difficulty ('conductor', 'arm swing', 'torso sway', 'knee bend' and 'knee lift'). These were used because they were assumed to be known to the user group and would allow the users to rely on their existing embodied skills rather than to develop new skills. The study confirmed that all participants were able to use the system when they were asked to perform a movement pattern that they were able to perform (e.g. 'arm swing'). In fact, there was hardly any need to explain or teach the participants how to use the system at all. They were just told to stand in a certain spot and to start swinging their arms back and forth, and henceforth no further instructions were given. Considering the amount of difficulty many senior citizens experience when trying to use modern digital technologies that are touted to be intuitive and user-friendly (e.g. smartphones, tablets, websites), we find it encouraging that patients with early stage AD were able to use the system with minimal instruction.

Apart from 'arm swing', some of the participants also tried to use other movement patterns such as 'conductor' and 'knee lift'. Predictably, it was quite clear that 'knee lift' was significantly more challenging than 'arm swing' and 'conductor', as it challenges balance, strength and coordination to a much larger extent than 'arm swing'. Several participants were unable to perform 'knee lift' due to various restrictions in their bodily capacities for movement. Nevertheless, the more able-bodied participants were able to control the music by walking in place.

Some participants' comments also suggested that it was boring to perform the same movement for the entire song, and that they would have liked more freedom of movement. Despite this, it is reasonable to assume that, based on observations and comments, performing the same movements without musical accompaniment would have been more boring. Furthermore, the different movement patterns did allow for a range of variation in style of execution, within certain limits. However, to avoid experimentation with movements that would preclude our investigation of interpersonal entrainment, the potential for variation in movement style was not explicitly communicated to the participants. They were simply told to swing their arms from front to back. We did observe a few different styles across participants, and the system was able to accommodate these. Nevertheless, each participant maintained a fairly consistent style of movement.

From a music therapy perspective, the system may best be described as a hybrid between receptive and active music therapy. It resembles active music therapy in

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that the users actively engage in the generation of musical output through repetitive movements. On the other hand, it resembles receptive music therapy insofar as the musical content is pre-recorded and the users are left to 'passively' hear the music as it is. We believe this balance between the two forms may be useful in terms of engagement and motivation. It allows users to select music that they enjoy and engage with both rhythmically and emotionally. It also reduces the potential (self-inflicted) pressure of having to make beautiful music. At the same time, the adaptive tempo of the music allows the users to deviate from the normal tempo of the music, according to their preferences and capabilities, without losing the pacing effect of the musical rhythm.

The present study is not suited to evaluate potential effects of music therapy on health challenges related to dementia. However, as described above, it was clear that several participants showed improvements in their mood after using the system. This is in line with McDermott et al. (2013, p. 793), who found 'consistent evidence for short-term improvements in mood following music therapy'.

Even though the tests went quite well and showed that the participants were able to entrain to each other through use of the system, it was not until the introduction of the visual interface during the last session that the system garnered enough excitement among the participants and supervisors to indicate a viable way forward.

Limitations and future work

This was a small, qualitative study with few participants. As such, it does not provide any clear or quantifiable effects on engagement, well-being or motivation to be more physically active. However, it opens up for future research in any of these directions. In addition, it also revealed possibilities for studying how diverse visual elements (e.g. photos and video) affect the participants' experience and motivation to use the system. Finally, on a more theoretical note, the study raises interesting questions regarding how human-technology relations influence peoples' lives and experiences. Future work will conduct a post-phenomenological analysis to explore the particular human-technology relations that exist, and emerge, in the interplay between the system and its users.

Conclusion

In this study an interactive music system was tested with AD patients. The purpose was to explore how dynamically adapting musical tempo can be used to stimulate and motivate physical activity in seniors with early-stage AD. The findings showed that most participants were able to entrain and synchronise to each other's move-

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ments through using the system. Several participants also commented that they enjoyed the experience.

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Notes

1 Max is a visual programming language and integrated development environment (IDE) for interactive and audiovisual programming: https://cycling74.com/products/max/

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