This is a repository copy of *New musical interfaces for older adults in residential care: assessing a user-centred design approach*.

White Rose Research Online URL for this paper:
https://eprints.whiterose.ac.uk/208271/

Version: Accepted Version

Article:

Taylor, J.R. orcid.org/0000-0002-4435-0657, Milne, A.J. orcid.org/0000-0002-4688-8004 and Macritchie, J. orcid.org/0000-0003-4183-6552 (2023) New musical interfaces for older adults in residential care: assessing a user-centred design approach. Disability and Rehabilitation: Assistive Technology, 18 (5). pp. 519-531. ISSN 1748-3107

https://doi.org/10.1080/17483107.2021.1881172

This is an Accepted Manuscript of an article published by Taylor & Francis in Disability and Rehabilitation: Assistive Technology on 30/03/2021, available online: http://www.tandfonline.com/https://10.1080/17483107.2021.1881172.

Reuse
Items deposited in White Rose Research Online are protected by copyright, with all rights reserved unless indicated otherwise. They may be downloaded and/or printed for private study, or other acts as permitted by national copyright laws. The publisher or other rights holders may allow further reproduction and re-use of the full text version. This is indicated by the licence information on the White Rose Research Online record for the item.

Takedown
If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.

eprints@whiterose.ac.uk
https://eprints.whiterose.ac.uk/

New Musical Interfaces for Older Adults in Residential Care: Assessing a User Centred Design Approach

John R. Taylor, Andrew Milne & Jennifer MacRitchie
The MARCS Institute for Brain, Behaviour and Development, Western Sydney University

Abstract

For older adults in aged-care, group music-making can bring numerous physical and psychological benefits, ultimately improving their quality of life. However, personalising music making to optimise these benefits is often difficult given their diverse ages, experiences, abilities and cognitive motor skills, and their experience with music technology. In this study, we conducted a 13-week group music-making intervention in an aged-care home, using a prototype digital musical instrument that we iteratively refined by following a user-centred design approach from direct resident feedback. The prototype instrument adopted a novel method for errorless learning in music-making settings, which we also refined, by increasing the difficulty level of the instrument's operation. We also assessed the residents' engagement with the sessions by obtaining feedback from caregivers and facilitators. Results show that residents' enjoyment decreased as the complexity (difficulty) of our errorless learning implementation increased. We also found that resident engagement increased when changes to the prototype digital musical instrument were provided, but not when residents were giving feedback. Results also found that participation over the course of the intervention, and the number of songs played during each session also enhanced engagement. Overall, our results show the intervention was beneficial to residents, although we note some areas of enhancement for further interventions in designing prototype musical instruments for group music-making in aged-care settings.

Implications for Rehabilitation

- Older adults positively engage with novel music technology, and do so increasingly over subsequent sessions. Repeated sessions may have the potential to enhance longer-term adoption of technologies as well as any rehabilitative effects of the group music-making activity.

- There is significant potential for residents with different abilities to all make music together, although to maximise the sustainability of the devices, the sessions, and the subsequent rehabilitative benefits, residents must be given the right adaptation for individual interfaces that balances ambition and ability.

- Rapid DMI prototyping positively enhances engagement among older adults, suggesting that in the case of a custom DMI, an upgrade schedule should be aligned with key rehabilitative milestones. Similarly, in the case of pre-developed digital music systems, resident exposure to new features or functionality should be strategically introduced, so as to maximise engagement for key phases of resident rehabilitation.

1. Introduction

Residential aged-care homes provide support for older adults with different ages, experiences, abilities, and cognitive and motor skills. Older adults are more susceptible to experiencing a lower quality of life (QoL) through lack of social connectedness and increased loneliness, which can result in chronic physical and mental health problems (de Jong Gierveld, 1998; Dunphy et al., 2019; O'Rourke, Collins & Sidani, 2018). However, for older adults, there is evidence that music-making has social and emotional benefits (Creech, Hallam, McQueen, & Varvarigou, 2014; Dinh, 2019; O'Rourke, Collins & Sidani, 2018), and that music listening and music instrument learning are associated with better cognitive and motor performance (Garrido, Dunne, Perz, Chang & Stevens, 2018; Schneider, Hunter & Bardach, 2018; Macritchie, Breaden, Milne & Mcintyre, 2020). Furthermore, similar associations have been found in older adults with dementia (Aldridge, 2000; Koger, Chapin & Brotons, 1999; O'Connor, Ames, Gardner & King, 2009; Pérez-Ros et al., 2019; Svansdottir & Snaedal, 2006).

"Receptive" music sessions – where a group listens to pre-recorded music – can improve social interaction and social "connectedness" to other residents (Garrido et al., 2018), while music sessions comprising live musicians (where residents actively participate by singing along), have been found to improve self-esteem and depressive symptoms (Cooke, Moyle & Shum, 2010b; Holmes, Knights, Dean, Hodkinson & Hopkins, 2006). Experimental studies featuring short-term musical instrument training programs, without singing, have suggested there are associated increases in cognitive performance (Buitenweg, Murre, & Ridderinkhof, 2012; Macritchie, Breaden, Milne & Mcintyre, 2020), decreases in loneliness and depression (Joseph & Southcott, 2015; Seinfeld et al., 2013; Zhang et al., 2017), as well as an improvement in motor control for stroke patients (Villeneuve, Penhune & Lamontagne, 2014; Schneider, Schönle, Altenmüller & Münte, 2007). When considering implementing these musical interventions in an aged-care setting, efforts to make the activities customisable (or personalised) to an individual's skills and tastes have seen positive outcomes (Garrido, Dunne, Chang et al., 2017; Garrido et al, 2018; Garrido, Stevens, Chang, Dunne & Perz, 2019). By increasing resident engagement with musical interventions, the rehabilitative effect of music can be enhanced. Unfortunately, it is quite often the case that the associated costs and lack of resources in aged-care homes are barriers to more extensive live (interactive) music experiences (e.g. the cost of different live musicians), short-term musical instrument training programs (e.g. the cost of musical instruments and music teacher/therapist), or the lack of specialised training of caregivers to provide or facilitate music interventions (Garrido et al., 2018). These difficulties arise, in part, from an assumption that, in order to make music, older adults must use traditional musical instruments.

The increased affordability and capability of technology suggests that music-based technology could be designed to overcome some of these existing barriers with traditional musical instruments. Emerging technologies offer a number of possibilities for enhancing music-based activities for older adults (Creech, 2019). Although older adults are generally interested in using new technology to sustain and improve their cognitive and motor control (Heinz et al., 2013), only 16% of music therapists in Australia, Canada, UK and USA self-reported using technology with clients aged over 65, even though 71% of therapists report using technology during general practice (Hahna, Hadley, Miller & Bonaventura, 2012). Staff who work in aged-care facilities, while passionate and well trained in providing care, will likely have different degrees of musical and technological skill and experience. The current state-of-the-art in music-based technologies require a degree of musical experience or technological training such that staff are perhaps not always able to foster an optimum participatory musical environment (Dinh, 2019). An intersection of these barriers is experienced by aged care facilities when trying to choose the most appropriate device for music instrument learning and joint music-making; staff then attempt to balance accessibility for the largest number of residents with potential training and financial constraints (Krout, 2014).

There is a paucity of technology designed to facilitate musical instrument learning and group music-making for aged-care residents with varying cognitive, motor and musical ability. Commercially available music technologies have idiosyncratic drawbacks that preclude their use by certain groups of older adults (for recent reviews and critiques of the technology, see Creech, 2019; Frid, 2018; Topo, 2009; Ward, Davis & Bevan, 2019). User-centred design (UCD), specifically participatory design (PD), is an emergent methodology in product design and development, particularly in aged care, health services and dementia (Ancient & Good, 2014; Dopp, Parisi, Munson & Lyon 2019; Hendriks, Truyen & Duval, 2013; Kopec, Nielek & Wierzbicki, 2018; Müller & Kuhn, 1993; Ward, Woodbury & Davis, 2017) where the end-users, are at the centre of the design process. UCD is an approach to developing interactive systems that take into account users' needs and requirements, iteratively refining the outputs based on their use. In the case of digital musical instrument (DMI) design for playing and learning, the design approach must consider the interaction between the player and the instrument (specifically the human interaction with the controller), and also the relationship between the DMI and the music, or the mapping (Miranda & Wanderley, 2006).

1.1. Aims

In this article, we detail and assess a 13-week (20-session) intervention in an aged-care home in <anon>, which followed a user-centred design (UCD) approach to create novel digital musical instruments (DMIs) for group musical performances and interaction. The DMIs had a variety of different controller interfaces designed to accommodate different cognitive and motor requirements within the aged-care setting and allow residents to experience different types of interaction. By using feedback from residents and caregivers, over a range of music-making sessions, to modify these prototypes, we aimed to enhance the potential adoption and sustainability of the DMIs.

This is one of the few studies where older adults have been involved in a co-design process of digital musical instrument controllers. In our analyses, we seek to ascertain how participants' *engagement* with the session is influenced by the entire intervention as well as by the extent to which they interacted with the different digital musical instruments. Their engagement was assessed with the Music in Dementia Assessment Scale (MiDAS) rating scale (McDermott, Orrell & Ridder, 2015), comprising subscales for participant interest, response, initiation, involvement, enjoyment. The MiDAS ratings were provided by aged-care staff and facilitators before and during or after each session as per McDermott, Orrell & Ridder's (2015) recommended usage guidelines. The degree to which the participants interacted in each session was gauged over two primary measures: i) the change requests logged via verbal feedback during the session, ii) the number of songs played by each participant in the session.

Specific aims were to investigate:

1. Whether participants (n=20) experienced an increase in engagement, as perceived by staff or facilitators, within individual sessions and over the course of all sessions.
2. Whether aspects of participation (songs played, controllers played) affected the ratings of engagement.
3. Whether aspects of the UCD process (e.g. requests made, or changes implemented) affected the ratings of engagement.

The remainder of this paper is organised as follows: Section 2 presents a brief overview of UCD considerations relevant to music controllers and DMIs, particularly user requirements unique to our participant group; Section 3 describes our experimental approach; Section 4 presents the results of our experimentation and associated analytical models; and finally, Section 5 draws conclusions and briefly outlines some areas for further work.

2. Towards A User Centred Design Approach

Participatory design is best described as a design process where the ultimate end-users of a system play a role in designing it (Schuler & Namioka, 1993) and user-centred design (UCD) approaches have been successful in a variety of aged care and musical settings (Franz & Neves, 2019; Jiancaro et al., 2017; Orpwood, 2004; Orpwood et al., 2010; van Besouw, Oliver, Hodkinson, Polfreman & Grasmeder, 2015). Following the framework for UCD activities for developing interactive systems described within ISO 9241-210:2019 (International Organization for Standardization, 2019), we developed our interfaces and controllers using the approach shown in Figure 1.

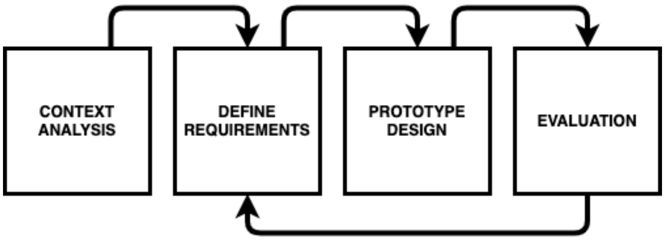

Figure 1. The user-centred design process adopted in this study, adapted from ISO 9241-210:2019.

2.1. Context

In consultation with staff at <anon> (a residential aged-care facility in <anon>), we designed a project in which residents would be given 20 group music making sessions using a prototype DMI comprising a range of different musical controllers. The lead diversional facilitator specified the general aim to have an instrument that would help fully realise the creative needs of all the residents. In the facility there were a mixture of residents with different physical abilities and cognitive abilities (both ranging from healthy to impaired). Musical experience was also mixed, where residents interested in music-making ranged from having no previous experience, to having previously played mainly guitar or piano. The residents were familiar with using iPads for other activities. In terms of experience with existing music technologies, the lead diversional facilitator reported recently attempting to use the Soundbeam (beam controller and single pad-like switches) but had experienced difficulties with latencies in the system. This resulted in the activity being restricted to storytelling with residents interjecting various sound effects using the system, even though they had expressed a desire to play music together as a group.

2.2 DMI Design

In this study, we developed prototype *controllers* which receive and transmit gestures made by performers. These may be physical (e.g., a device with buttons that can be pressed) or virtual (e.g., a multitouch interface on an iPad). We also developed the *mapping* of those gestures to musical output, mediated by custom software. We refer to the combination of the controller and the mapping as a *DMI*, or *digital musical instrument*. In order to develop our controllers and DMI, we evaluated the state of the art in music technologies with the criterion of being flexible enough to support varying physical and cognitive impairments. The music technologies we evaluated included DMIs developed in research communities such as new interfaces for musical expression (NIME); human-computer interaction (HCI), for a variety of purposes: from the design of novel music touch interfaces to new digital musical instruments (Nath & Young, 2015; Seymour, Matejka & Foulds, 2017), ranging from music ensemble performance (Takehara et al., 2017) to assistive music improvisation (Challis, 2013).

Our evaluation of different technologies identified some important criterion that a DMI or music controller should have for the end users (older adults) in our project: how *easy* it is for novice players to learn (*learning complexity*), which is important for adoption; how *usable* it is for people with motor or cognitive impairments and how flexible it is in suiting the different abilities of older adults; how *portable* it is to allow for swapping instruments in a group music-making setting; whether the sounds play at the same time as the touch (*latency*) thus avoiding confusion, and; whether it allows for more than one type of interaction (*multi-gesture*; e.g. swiping vs. tapping) to facilitate interest and enjoyment. We also identified some important criteria that a sustainable DMI should have for the stakeholders (the care home) in our project: the *connectivity* to allow connection of different controllers in the future; the *configurability* so that it can be adapted to improvements in user performance; the *cost* of initial purchase, or subsequent upgrade; and ease of troubleshooting, in case the DMI or controller stops working. In the following sections, we shall briefly provide exemplars of currently available technologies through the lens of these criterion. We note this is not an exhaustive list; for a comprehensive review, see Ward et al., 2019.

2.2.1. Special-needs music systems

One popular system in special-needs education is the SoundBeam (SoundBeam, 2019a; Lindeck, 2013), which uses a proprietary beam controller (although wired and the more portable wireless switches can also be used). The SoundBeam has been successful because of ease of learnability of the novel vibroacoustic "beam" controller, although it can be problematic for users with limited movement (Ward et al., 2019). Indeed, our own assessment of the SoundBeam found high latencies (greater than 100ms) when the RF switches were used wirelessly which makes cognitive and motor usability difficult: large asynchronies between tactile and auditory feedback are disruptive to professional musicians during performance (Jack, Mehrabi, Stockman & McPherson, 2018; Pfordresher, 2006). The SoundBeam also needs training for modification and troubleshooting because of the complex proprietary submenus.

2.2.2. Multifunction devices

Tablet computers, such as iPads are versatile music controllers, as music can be performed using purchased or custom-made software, as well as useful complementary tools for informal music learning (Humberstone & Taylor, 2015). iPads have been previously used as music interfaces for older adults: previous research has found tablet computers to increase learning speed; however, those with more severe dementia tended to use less complex apps, and age was negatively correlated with frequency and duration of use (Vahia et al., 2017). In an aged care setting, iPads have been used as a standalone media player (Garrido, Stevens, Chang, Dunne & Perz, 2018); as an interactive device that uses the touchscreen as a controller (Favilla & Pedell, 2014); and augmented with other hardware and used as display and playback device (Seymour, Matejka, Foulds, Petelycky & Anderson 2017). For interfaces that use the touchscreen directly, users may experience a lack of feedback and tactile uncertainty making usability and learning more difficult (Norman, 2002).

2.2.3. Generic MIDI-based controllers

Generic MIDI-based controllers can be customised to control a range of musical parameters, and the costs vary. These MIDI controllers can provide different types of haptic feedback depending on their design: for example, we assessed the Roli Lightpad Block (Roli, 2019), a square hand-held Bluetooth MIDI controller that allows swiping and button pressing with a soft-to-the-touch interface. These can be connected together to form one larger instrument, and they can also be configured to have different numbers of non-physical buttons (the buttons are indicated by under-the-surface LEDs) on each block (e.g. 1, 2, 4, 8, 16). We felt this interface would be portable, easy to use, and could easily be swapped among participants between songs. Other generic MIDI-based controllers, such as Novation's Launchpad (Novation Music, 2019) and Akai's APC Mini (Akai, 2019), have numerous buttons, which can be daunting to older adults unfamiliar with technology (Waycott et al., 2019). In fact, generic MIDI-based controllers provide limited participatory design choices as the hardware is fixed, and so any changes as a result of user-centred design are limited to musical parameter mapping. This in itself could end up being a barrier to musicking and social interaction (Cappelan & Anderson, 2014) and ultimately the development, and adoption of an holistic musical system.

2.2.4. Digital Audio Workstations (DAWs)

DAWs refer to computer software capable of supporting electronic musical instrument performance, together with audio playback. DAWs such as Logic Pro (Apple, 2019a) and Cubase (Steinberg, 2019), are largely unsuitable for an aged-care setting because of their high cost (together with the cost of the hardware to run them), their learning curve (complex settings and submenus), and the difficulty in configuring and troubleshooting. This means that residents are unlikely to use it unsupervised, and specialist training will be required for staff. Although these programs offer accurate timing, connectivity and good choice of instruments/sounds, co-design is limited to content and instrument/sound choice. While other DAWs such as GarageBand (Apple, 2019b) incorporate built-in music lessons, the software can still be difficult to navigate. In contrast, the interactive music performance software Max/MSP (Cycling'74), allows customised musical instrument and interface design which can be tailored for a range of technical abilities, as well as device parameter mapping capable of supporting artistic co-creation (Taylor, 2016), user-centred design (Nath & Young, 2015) and performance analysis (Favilla & Pedell, 2014).

2.2.5. Overview of our prototype system

Ultimately, we opted to develop a series of prototype controllers in our DMI (Figure 1), using custom built hardware (incorporating sensors and an Arduino), with custom music controller software using Max/MSP. This would allow us to rapidly prototype the hardware and software, and change any musical and hardware control mappings between sessions in response to user feedback. We chose to develop our own software for three reasons: i) we needed to consider the software interface and the usability of the software so that it could eventually be delivered by aged-care non-specialist staff, ii) we wanted to be able to modify the content for sustainability and interest during the process, iii) we wished to collect performance data from the controller inputs via our DMI (e.g. timing data, button pushes) so that we might assess each individual's improvement in music performance. Our prototype controllers are shown in Figure 1, and described in more detail in Appendix S1 of the supplementary material online.

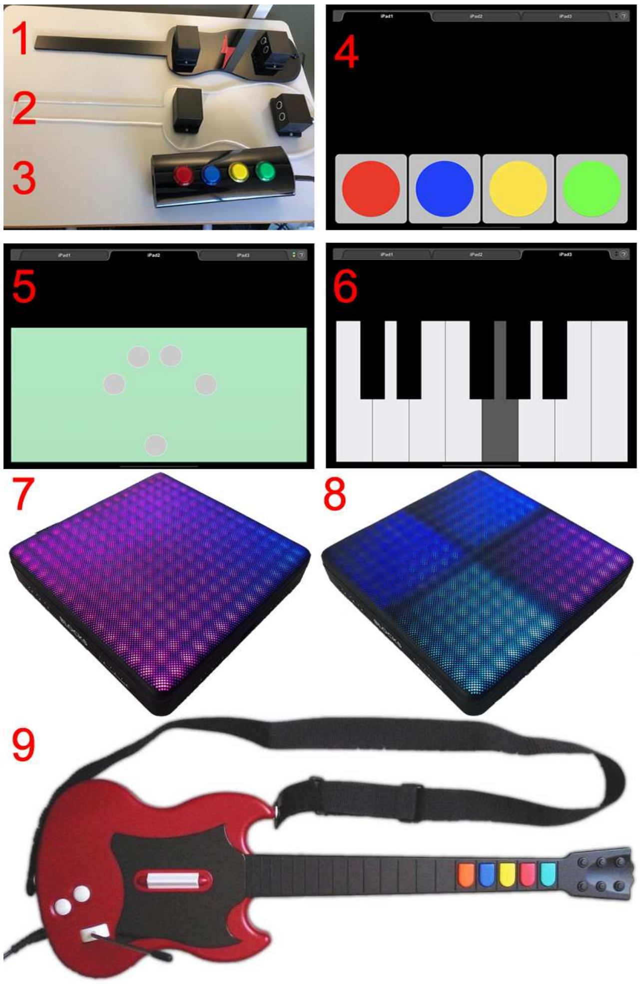

Figure 1. The controllers used as part of our DMI. (1) eBass; (2) eGuitar; (3) eFlute; (4) iPad 1; (5) iPad 2; (6) iPad 3; (7) Block 1, as a single button; (8) Block 2, as four buttons; (9) Guitar Hero Controller. Note that the button colours on the eFlute and iPad are (from left to right): red, blue, yellow, and green.

Miranda & Wanderley (2006) broadly categorise DMIs and their controllers as "instrument-like" (controllers that behave like their real counterpart instruments; e.g. piano/keyboard); "extended" (a real instrument with added sensors); "instrument-inspired" (a device that resembles a real instrument, but behaves differently); and "alternative" (a completely novel controller unlike any real instrument). For practical reasons, we designed or used music controllers to be "instrument inspired" (eBass (Fig 1; 1), eGuitar (2), iPad Piano interface (6), Guitar Hero (9)) or "alternative" (eFlute (3), iPad 1(4), iPad2 (5), Block 1 (7) and Block 2 (8)).

Where possible, we also designed the controllers in pairs, allowing small differences in appearance and response so that we could assess the impact of these differences. For example, the colours, operation and size of the arcade-style buttons on the custom-made eFlute was replicated on iPad 1, allowing us to determine whether residents preferred the tactile feedback on the eFlute over having no tactile feedback when using the iPad. Both the eGuitar and eBass used Passive Infra-Red (PIR) motion sensors, which were identically calibrated and operated as a virtual tripwire: the only difference being the instrument under control. The Roli Blocks had identical tactile feedback mechanisms but were configured so that Block 1 had one button, while Block 2 had four buttons. iPad 2 was a single multitouch green button, and iPad 3 was a polyphonic piano keyboard. None of the iPad interfaces produced tactile feedback. The final pair of instruments was the eGuitar and Guitar Hero guitar. Both had similar functions; both looked like guitars and were designed to be held like a guitar, and although both controlled guitar sounds, the Guitar Hero guitar was operated using buttons, while the eGuitar required no direct physical touch.

2.3. Planned Musical Complexity and Parameter Mapping

DMIs can be controlled using either direct input (e.g. a touchscreen slider whose movement is linearly mapped to musical data such as pitch or loudness) or indirect input (e.g. a nonlinear translation of movement to control data; e.g. squeezing a Skoog (Skoog, 2019)), and influences the physical interaction and musical control of a DMI. Direct input can be problematic for older adults with impaired motor control; conversely for indirect input, connecting the physical movement with the resultant output can be more cognitively demanding for older adults (McLaughlin, Rogers & Fisk, 2009). Striking a balance between the two (especially for a group of older adults with varying cognitive and motor abilities), is important and requires careful design consideration.

For DMI control, performance of difficult musical pieces can be simplified by adjusting the parameter mapping (e.g. the musical functions assigned to particular controls). Our approach considers parameter mapping to be a key determinant of performance complexity and, as such, we make use of the principal of errorless learning. Errorless learning is <can we have a brief definition – there doesn't appear to be one> . It makes use of implicit memory and has been found to be more effective for rehabilitating memory-impaired individuals (Kessels, Boekhorst, & Postma, 2005, Mimura & Komatsu, 2007) than typical learning where learning mistakes can be made. Our errorless parameter mappings operated on both timing and pitch but, primarily on the former. Musical timing is a parameter that i) requires minimal musical ability and training ii) is achievable in residents with physical or cognitive impairment, and ii) could be improved upon in subsequent sessions. Timing also has the benefit of contributing towards a sense of joint music-making. Musical pitch as a parameter that i) caters for a range of people with different musical abilities: its use requires minimal musical ability to use at a basic level, but to use in any advanced form, such as playing sequences of correct notes competently, requires training; ii) could be engaging for residents with physical or cognitive impairment, and iii) could trigger improvements in both control and pitch discrimination over a number of sessions.

For our *errorless timing control*, we composed accompanying musical instruments (parts) to existing songs and muted each part at the end of each bar (while the underlying song continues). When residents pushed a button (or operated a controller) their musical instrument/part would unmute until the end of the next bar, inviting residents to engage with the music, and to learn basic musical measures and timing. This also allowed residents to improve their motor skills and familiarise themselves with the instruments whilst preventing them from making timing errors that might compromise the group music-making output.

At the beginning of our process, we wanted our DMI to be easy to play for older adults with low motor and cognitive ability, by giving residents very little musical control, but also requiring little effort to operate the controllers. We achieved this by allowing instrument control at one-bar intervals. This ensured that repeated and in-time control was achievable among participants with reduced motor control or cognitive function. The motor and cognitive complexity began to vary mildly as we added more musical material with varied tempi, despite the physical interaction of the controller and DMI remaining the same.

As participants became accustomed to the interactions at bar-length levels, we doubled the speed of the interactions by introducing half-bar intervals. This required an increased amount of motor control and, because the intervals between button presses halved, the cognitive and motoric demands increased. We also introduced quarter-bar length intervals, to increase the effort, motor and cognitive demands even further, while maintaining relatively little musical control/ few MDOF.

We also introduced *errorless pitch control* by assigning different sequences of notes (e.g. different melodic parts) to different buttons that could be played together and in tune, while maintaining the errorless timing intervals. For example, each of the eFlute buttons (Figure 1(3)) played different melodies that could be played on their own, or all together in harmony, without being out of time, or out of tune. The errorless pitch control was added to the bar/half-bar/quarter-bar intervals, increasing the motor and cognitive complexity, by introducing some additional musical control/MDOF. We also allowed a "free play" mode, which was not errorless as participants were able to play notes unconstrained, and was designed for those who were comfortable with playing, and able to play, appropriate pitches for the reference material.

2.3.1 User-feedback: mapping and complexity

At points within the weekly feedback from residents, two main requests formed the motivation for adjusting the mapping of the DMI: 1) a request for increased complexity of interaction once the errorless learning approach had been mastered, and 2) the creation of interfaces that bore similarities with other familiar instruments (e.g. a piano). To respond to the first request, as discussed above, we introduced shorter durations (half bar and quarter bar length) between the mute-points used in the errorless timing. This required the residents to tap/operate their controller at 2 and 4 times the speed, respectively. The choice to add shorter durations was a pragmatic one to allow an incremental increase in difficulty (Compared to other methods, such as abnormal divisions, irregular rhythms, extra-metric groupings, which would have been too complex for most participants). In each session, participants were free to decide whether to use the more complex parameter mappings.

Both requests were met with the introduction of a Piano keyboard interface (iPad 3). This particular interface was set up such that both timing and pitch could be controlled independently of both the reference song and the other instruments, essentially removing the errorless learning approach in this particular interface. However, after requests from residents to prevent others from playing "out of tune", we reintroduced errorless pitch performance by transposing the piano notes so that every piano note was in the same key as the reference song at all times. In this scenario the timing was still independent, but the pitch was kept errorless. To respond to the second request, without interfering with the errorless learning approach in terms of individual note timing, we introduced a function that allowed a user to adjust the pitch and timbre in one of the controllers. We did this by introducing continuous pitch control on the horizontal axis (left = lower pitch, right = higher pitch), and filter resonance across the vertical axis (bottom = no resonance, top = high resonance) on iPad 2, which was played horizontally.

2.4. Evaluation

Evaluation of the prototypes within each session was captured via verbal feedback from the participants. During sessions, participants were prompted to provide feedback on any aspect of the session: the controllers; the songs; the structure of the music lessons and; how they felt in general about the process. The facilitators made notes of these comments, and, together with the full transcriptions of the audio recordings, collated the feedback from each session. Weekly meetings between the facilitators and the software and hardware development team facilitated rapid responses to the documented requests. Where these changes could be enacted quickly, new iterations were pushed out for the sessions the following week. Larger changes were planned over several weeks, or coinciding with a break in sessions (see Procedure).

3. Experimental Methods

3.1 Procedure

An initial workshop was conducted at the facility in order to provide information about the project and to staff and prospective participants. This initial workshop facilitated a broad conversation with residents as to what types of interfaces they might like to use. This enabled the initial design of the controllers. The user-design workshop series was planned for two main periods where participants would be offered group music making sessions twice a week: 1) 12 sessions bi-weekly over a period of 6 weeks, and 2) a further 8 sessions bi-weekly for a period of 4 weeks.[1] These two main periods were separated by a period of 7 weeks to allow for major iterations of the controllers and DMI to be carried out. The sessions were run by two facilitators, who were independent Registered Music Therapists, with additional support from staff at the facility.

Our hybrid approach to group music-making using technology included a number of individual music activities, which individually have previously been shown to have positive effects on the quality of life for older adults. For example, our participants were able to receptively listen to music in a group setting, which has been shown to improve social interaction (Garrido et al., 2018); participants were able to sing along with the music which has positive effects on self-esteem and depressive symptoms (Cooke, Moyle & Shum, 2010b); they were able to actively make music by playing the DMI (Creech, Hallam, McQueen, & Varvarigou, 2014; Dinh, 2019), and; we also provided short-term musical instrument training (on the DMIs), which has been shown to decrease loneliness and depression (Joseph & Southcott, 2015; Zhang et al., 2017).

Our novel approach diverges from previous music-based studies because we developed custom music controllers for our DMI, and incorporated errorless learning. We also modified the musical parameter mappings for our DMI to provide a range of different types of errorless interaction, as well as different levels of effort as a result of introducing complexity via increased musical control. We also adopted a UCD process, and involved residents in the development of the DMI in terms of hardware and software changes, and content additions.

3.2. Participants

Twenty participants (75% female, 25% male, age range 65–96) participated in the sessions at some point during our trial, which was held at <anon> residential home in <anon>. The project was approved by <anon> University Human Ethics Committee (approval number: H12931) and participants (and family members, where appropriate) provided informed written consent.

In signing up to participate, residents were made aware that they could attend as many or all of the sessions as they wished. Attendance was monitored as a proxy of engagement with the process[2] with the number of sessions attended varying with each participant (M = 4.5, SD = 4.16, min = 1, max = 13). Four participants attended more than ten sessions during the process.

[1] The second period experienced a delay in completing the sessions due to an influenza lockdown at the facility.
[2] Although illness and other reasons not to attend were not captured by this process.

3.3. Materials

3.3.1 DMIs and equipment

Following an assessment of existing controllers, and DMIs (see Section 2.2), we opted for a selection of custom-built prototype controllers and commercially available instruments. The commercially available instruments comprised: two Roli Light Blocks and two iPads (using Cycling'74s MIRA app; see Figure 4) and a Guitar Hero controller (introduced in later sessions) were connected to a MacBook Pro using Bluetooth. The custom-built prototype instruments comprised an eFlute (with four arcade style LED backlit momentary push buttons), an eGuitar, and an eBass (both of the latter used passive infrared (PIR) motion sensors configured as a tripwire that could be triggered using a strumming action). The buttons and PIR sensors on the prototype instruments were powered by an Arduino Mega, connected via USB to a MacBook Pro. Performance data from all instruments were musically mapped and captured using Max/MSP which also controlled the audio playback of popular songs. Audio was played back via a JBL Charge+3 speaker using the line input.

3.3.2 Songs

Initially, two reference songs were chosen by residents and staff prior to the commencement of the sessions, and more were added upon request throughout the process. Table 1 shows the complete playlist of reference songs as was accumulated by the end of the whole process

Artist	Song title
Doris Day	Que Sera Sera
Bing Crosby	You Are My Sunshine
Perry Como	Catch a Falling Star
Peter Dawson	The Road to Gundagai
Laurie London	He's Got the Whole World in His Hands
Elvis Presley	Wooden Heart
Louis Armstrong	What A Wonderful World

Table 1. All reference songs used during the process.

Each reference song contained full instrumentation and vocals. We composed custom melodic instrumental parts as an accompaniment (and in harmony) to each song, and assigned to each controller (e.g. guitar parts for the eGuitar etc.). Each such melodic part lasted the full duration of the reference song so that, whenever the instrument was unmuted, it was in time and playing an appropriate pitch. To allow for pitch control, we composed multiple instruments parts so that multiple instrumental parts could be assigned to each controller to allow for either harmony or melodic change. Participants collectively chose the order of the songs to play with and chose the DMIs they wished to play. The number of songs played in each session, and the number of controllers any one participant chose to use were then subject to change depending on the participants' requests. For each instrument, performance data were captured comprising, timing, inter-onset-interval (IOI), button ID, and in the case of the multitouch iPad screen, the number of fingers used and the coordinates of the fingers relative to the screen. However, these data are outside the scope of this article.

3.3.3 Measurements

The Music in Dementia Assessment Scale (MiDAS) was used in order to collect measures of the five key areas of Interest (in the music), Response (to others), Initiation (e.g. actively verbally requesting things or sharing stories), Involvement (e.g. in the instrument playing) and Enjoyment (of the session) (McDermott, Orrell & Ridder, 2015). These individual paper-based MiDAS ratings were made on five separate visual analog scales (VAS), each of which was a continuous 100mm line without intervals. The two extremes of the scale were labelled "none at all" and "highest".[3] Both staff and facilitators judged the maximum of each VAS score (i.e. "highest") based on the best possible outcome for the individual in question, rather than a pre-set value that is the same for every individual. Administering the MiDAS involved receiving completed scales from both the facilitators conducting the session, and a caregiver (in this case a staff member). The facilitator completed the MiDAS scale twice as per McDermott, Orrell & Ridder's (2015) recommended use: once for the beginning of the session (pre-session) during the first 5 minutes, and once in-session, during the most clinically significant 5 minutes, as judged by the facilitator within their therapy process for each client (without stopping the session). Staff also completed the MiDAS scale, again as per McDermott, Orrell & Ridder's (2015) recommended use: twice but pertaining to different timepoints than the facilitator: once for before the music session (pre-session) and once for after the music session (post-session). This is done to a) confirm the extent to which any changes are noted outside of the context of the session (i.e. whether the rating is 'in the moment', or whether it would last longer than the length of the music making session), and b) to minimise bias since the staff worked closely with the residents on daily basis, whereas the facilitator did not. We obtained an overall measure of participant "engagement" in each music session by calculating the mean score for each MiDAS rating in each session. The five MiDAS rating scales (and our calculated mean values) are the dependent variables modelled in the forthcoming analyses.

Each of the sessions was recorded through video and audio; primarily so that resident feedback and specific requests could be documented and rapidly translated into iterations of the controllers and DMI, software and song content. This documentation of requests based on the audio-visual recordings was conducted by the facilitators running the sessions.

3.4 Data Analysis

We performed multilevel Bayesian regression to analyse the data using the R package brms (Bürkner 2018), which provides a high-level interface into the Bayesian MCMC sampler Stan (Carpenter et al. 2017). A total of three models were run. The first model tested whether the facilitator's in-session MiDAS ratings were higher than their pre-session MiDAS ratings, and whether the staff member's post-session MiDAS ratings were higher than their pre-session MiDAS ratings. The second model was used to establish whether MiDAS ratings were associated with: session number (i.e. did the ratings generally improve or get worse over the 20 weeks); the number of songs performed by each participant; the complexity of the mappings used in that session. The final model also explored whether MiDAS ratings were associated with developments requested by participants, and changes made by the project team in response to those requests. Before detailing the results of each of the models, we now briefly summarise the dependent variable (how the MiDAS ratings were quantified) and the predictors of that dependent variable. We then outline how to interpret the models' coefficients (due to the family and link functions used in the models), and how we estimate the strength of evidence for each coefffient (effect) using the Bayesian approach of evidence ratios.

3.4.1 Dependent Variables

The five individual MiDAS ratings were measured from the markings on each rating scale, to two decimal places (0.00–10.00). Although staff were asked to complete a MiDAS rating prior to, and at the end of, each session, this ended up being a burden on time when they needed to be caring for residents, and so we did not collect data from staff for a number of sessions (12/15).

[3] See https://vbn.aau.dk/ws/portalfiles/portal/316447795/Music_in_Dementia_Assessment_Scales_MiDAS_.pdf for an example MiDAS rating scale (University of Aarhus, Denmark).

Rating diff. In the first model, we are specifically interested in the difference between the post-session MiDAS rating (or in-session rating) and the pre-session rating. For this reason, the dependent variable for each VAS scale – denoted *Rating diff* – was that scale's post-session (or in-session) rating minus that scale's pre-session rating. This difference score, which is in the interval [–10, 10], was then normalized to the interval [0.0001, 0.9999] by multiplying by 0.4999/20, then adding 0.5.

Post-session rating. In the second and third models, the dependent variable was only the post-session rating or in-session rating (in the interval [0, 10]) and this was normalized to the interval [0.0001, 0.9999] by subtracting 5, multiplying by 0.4999/10, then adding 0.5. For brevity, the resulting variable is denoted *Post-session rating* whether the rating occurred post-session or in-session.

3.4.1 Predictors

Session number is the number of the session (an integer from 1 to 20), which has been linearly transformed to have a mean of zero and a standard deviation of 1.

Songs played is the number of songs played by the participant in the session (an integer), which has been linearly transformed to have a mean of zero and a standard deviation of 1.

Complexity The complexity levels used by each participant (per song, per session) was captured, where 1 = no complexity, 2 = half-bar complexity, 3 = quarter-bar level complexity. To account for participants playing multiple complexity levels during a single session, we calculated the median complexity level per participant per session resulting in four different median values: 1, 1.5, 2, and 3. These medians were used as monotonic predictors (a monotonic predictor is ordered but the distance between the levels is not fixed) in our Bayesian models so that we could assess the effects of the different complexity levels.

Pre-session rating. In the latter two models, the pre-session rating was also included as a covariate. In each session, we expect a participant's post- or in-session ratings to be strongly associated with their pre-session ratings (as they rate the same thing but at different time points); an advantage of including the pre-session rating as a covariate rather than regressing on the difference between the post-session (or in-session) and pre-session ratings (i.e., *Rating diff*) is that the former allows the rating's increase to vary across differing pre-session ratings (Gelman & Hill 2007).

Requests all is the total number of requests related to software, hardware, and content made by participants for each session, across all sessions.

Changes all is the total number of changes related to software, hardware, and content completed by the developers for each session, across all sessions.

We also tried a model with a predictor coding the number of times each DMI was played per session per participant. But we found this overfitted the data (as assessed by cross-validation) and do not report on this further.

Participant. In all models, the intercept was allowed to vary, as a random effect, by participant.

3.4.2 Model Family, Link Function, and Effect Size

As mentioned above, the MiDAS ratings, after normalization, are appropriately modelled as beta-distributed variables. We used the logit link function to transform the linear predictors' scales to the unit interval. This means that the interpretation of the models' coefficients becomes multiplicative and nonlinear: an effect β of a given predictor implies that a rating of r_0 becomes $r = \frac{r_0 \exp(\beta)}{r_0 \exp(\beta) - r_0 + 1}$ when that predictor increases by 1 unit. For example, given a unit increase in a predictor, a "small" effect of 0.1 changes a medium rating of 0.5 into a rating of 0.525; a "moderate" effect of 0.5 changes a rating of 0.5 into a rating of 0.622; a "large" effect of 1 changes a rating of 0.5 into a rating of 0.731.

3.4.3 Strength of Evidence and Hypothesis Testing

To ascertain evidence in favour of an effect, we use Bayesian evidence ratios: for an effect whose posterior has a positive mean, it is the posterior probability of that effect being greater than zero divided by the posterior probability of it being less than zero; for an effect whose posterior has a negative mean, it is the posterior probability of that effect less than zero divided by the posterior probability of it being greater than zero. We interpret evidence ratios greater than 10 as being sufficient to warrant further discussion.

4. Results

4.1. Model 1: Evaluating participant engagement in music-making sessions

In order to evaluate the success of the individual music-making sessions in engaging the participants, we assessed whether residents saw an improvement in their MiDAS scores. We conducted multilevel Bayesian regression intercept-only model on the post session ratings minus the pre-session ratings – i.e. on the difference between the pre-session and post-session (or in-session) ratings (see *MiDAS diff* as defined in 3.4.1 above). These results are shown in Table 2.

Staff/ facilitator	**Post-session MiDAS rating increase**	**Hypothesis**	**Est.**	**Est. Error**	**CI Lower**	**CI Upper**	**Evid. Ratio**	**Post. Prob**	
Staff	Mean	Intercept > 0	0.07	0.14	-0.16	0.29	2.61	0.72	
	Interest	Intercept > 0	0.06	0.12	-0.12	0.25	2.51	0.72	
	Response	Intercept > 0	0.07	0.14	-0.16	0.29	2.4	0.71	
	Initiation	Intercept > 0	0.09	0.13	-0.12	0.32	3.58	0.78	
	Involvement	Intercept > 0	0.09	0.15	-0.17	0.34	3	0.75	
	Enjoyability	Intercept > 0	0.09	0.18	-0.19	0.37	2.58	0.72	
Facilitator	Mean	Intercept > 0	0.22	0.08	0.09	0.35	332.33	1.00	*
	Interest	Intercept > 0	0.11	0.03	0.06	0.16	>1999	1.00	*
	Response	Intercept > 0	0.12	0.03	0.07	0.18	>1999	1.00	*
	Initiation	Intercept > 0	0.14	0.04	0.08	0.21	665.67	1.00	*
	Involvement	Intercept > 0	0.17	0.03	0.12	0.23	>1999	1.00	*
	Enjoyability	Intercept > 0	0.11	0.04	0.04	0.17	165.67	1.00	*

Table 2. Results of Bayesian regression with the formula *Rating diff* ~ 1 + (1 | *Participant*). Note that Est. = Estimate; CI = 95% Confidence Intervals; Evid. Ratio = Evidence Ratio; Post. Prob. = Posterior Probability. '*': The posterior probability of the hypothesis exceeds 95% (an evidence ratio of 19).

For the facilitator's in-session ratings, we found very strong evidence to suggest an improvement over the pre-session ratings in all areas of the MiDAS ratings (including the mean ratings), particularly noting the evidence for increases in interest, response, and involvement. For the staff, however, we found negligible evidence that the MiDAS scores increased over each session; this may be due, in part, to the pre-session ratings already being practically at the ceiling (note in Fig. 4 that the staff's median ratings are above 9.5 for every item).

4.2. Model 2: Evaluating participant engagement and participation in music-making sessions

Our UCD approach meant that there were incremental changes in content and DMI functionality over the course of all 20 sessions; furthermore, any benefits arising from the intervention may accumulate. For these reasons, we constructed a model to determine if there was any cumulative effect of the sessions on engagement. This same model also included indicators of participation (how many songs or DMIs a participant played, as well as the complexity of those DMI mappings) as predictors of engagement. We ran a single Bayesian beta regression for each in-session MiDAS item score. The resulting models' estimated effects are summarised in Table 3. Here we report only the effects for which the evidence ratio is greater than 10 (i.e., the evidence is "strong"). A full summary of all effects is provided in Appendix S6, in the Supplementary.

MiDAS Item	Hypothesis	Est	Est. Error	CI. Lower	CI. Upper	Evid. Ratio	Post. Prob	
Staff Mean	Session No. > 0	0.27	0.15	0.03	0.52	29.16	0.97	*
Facilitator Mean	Session No. > 0	0.18	0.04	0.11	0.25	>3999	1.00	*
	Songs Played > 0	0.10	0.04	0.04	0.16	332.33	1.00	*
Staff Interest	Session No. > 0	0.29	0.13	0.07	0.51	62.83	0.98	*
Facilitator Interest	Interest (before) > 0	0.65	0.19	0.35	0.97	>3999	1.00	*
	Involvement (before) > 0	0.49	0.18	0.20	0.79	172.91	0.99	*
Facilitator Response	Session No. < 0	-0.10	0.05	-0.18	-0.02	63.52	0.98	*
	Response (before) > 0	0.39	0.14	0.16	0.62	399.00	1.00	*
	Initiation (before) < 0	-0.32	0.10	-0.48	-0.15	799.00	1.00	*
	Involvement (before) > 0	0.29	0.18	0.00	0.58	19.10	0.95	*
	Enjoyment (before) > 0	0.21	0.12	0.02	0.40	24.16	0.96	*
Facilitator Initiation	Session No. < 0	-0.10	0.06	-0.19	0.00	20.62	0.95	*
	Interest (before) > 0	0.40	0.24	0.01	0.80	21.10	0.95	*
Staff Involvement	Session No. < 0	0.29	0.16	0.03	0.56	29.13	0.97	*
Facilitator Involvement	Session No. < 0	-0.11	0.05	-0.20	-0.03	55.34	0.98	*
Staff Enjoyment	Session No. > 0	0.33	0.15	0.09	0.58	67.18	0.99	*
Facilitator Enjoyment	Session No. > 0	0.16	0.06	0.06	0.26	209.53	1.00	*
	Enjoyment (before) > 0	0.27	0.13	0.06	0.48	79.00	0.99	*
	Complexity < 0	-0.36	0.16	-0.65	-0.04	65.67	0.99	*

Table 3. Results of Bayesian regression with the formula *Post-session rating* ~ 1 + *Session number* + *Songs played* + *Pre-session rating* + *Complexity [monotonic]* + (1 | *Participant*). Note for the mean ratings we used only the Pre-session mean rating. Also note that we have included all effects with evidence ratios greater than 10; Est. = Estimate; CI = 90% Confidence Intervals; Evid. Ratio = Evidence Ratio, Post. Prob. = Posterior Probability. '*': The posterior probability of the hypothesis exceeds 95% (an evidence ratio of 19). For full results see Appendix S6 in the Supplementary.

The model summarised in Table 4 shows strong evidence to suggest that the number of songs played (*Songs Played*) has a large effect on the facilitator's ratings of overall participant engagement. For the individual MiDAS items, there is no evidence that *Songs Played* has an effect on any of the facilitator's other MiDAS item ratings. Table 4 also shows strong evidence that *Session No.* has a positive effect on both the staff and facilitators' mean MiDAS ratings. For the individual staff MiDAS ratings, evidence suggests a positive effect of *Session No* on ratings of interest, involvement and enjoyment. On a per-session basis, for each additional session attended, there was an increase in the MiDAS interest and enjoyment ratings of up to 50%. In contrast, for the facilitator's MiDAS ratings, the evidence suggests there is a positive effect of *Session No* on enjoyment, but not for interest. For facilitator ratings of response, initiation, and involvement, *Session No* had moderately negative effect.[4] We also found very strong evidence that complexity has a negative effect (-0.35, CI -0.66 to -0.05), where this effect refers to the change in *Post-session rating* associated with changing from median complexity 1 to median complexity 3 (42% of this total effect accounted for by changing from median complexity 1 to 1.5; 31% by changing from median complexity 1.5 to 2; the remaining 27% from changing from median complexity 2 to 3.

4.3. Model 3: Evaluating the user-design process

We then investigated whether the UCD process affected participant engagement; specifically, to determine whether the inclusiveness of our approach, as well as the rapid response in software and hardware developments to such feedback, improved the post-session engagement ratings. An overview of the weekly number of change requests made by participants, and development changes made by the project development team is shown in Appendix S4. Because participants were unlikely to articulate specific technical requests for functionality, we coded the participant feedback created into three areas, based upon the whether the request required modification to the software, the hardware, or the musical content (see Appendix S2 and S3). Because the changes and requests were often made/deployed together, a correlation matrix (Appendix S7) of the individual requests and changes found correlations above 0.80 between hardware and software changes and requests. Thus, any model using the individual predictors would not adequately distinguish between the individual effects of these predictors. Consequently, the model to answer this is presented in Table 4. For our analysis we used the same predictors (*Session No.*, *Songs Played*, *Complexity*, and *MiDAS pre-session mean ratings*), and added the total number of changes, and total number of requests made by residents, irrespective of whether the change or requests was software, hardware or content-focussed.

[4] We had hoped for a positive predictive influence of DMI use on MiDAS ratings, as part of Hypothesis 2. Specifically, we wanted to evaluate the efficacy of the custom-made DMIs, as compared to off-the-shelf DMIs. Three different Bayesian models were fitted to assess the possible effect of DMI use. In each case, predictors for each DMI were added to the model in Table 4. For the three models these additional predictors were, respectively: 1) a binary code for whether each given DMI was played at least once per session per participant; 2) a count of the number of times each given DMI was played per session per participant; 3) same as (2) but also including a squared count term to allow for a nonlinear effect. All three models performed worse under cross-validation than the Table 4 model, which does not include DMI. This means that our data are not sufficiently informative for us to make useful inferences about whether the different DMIs have different effects on our participants' MiDAS scores.

MiDAS Item	Hypothesis	Est	Est. Error	CI. Lower	CI. Upper	Evid. Ratio	Post. Prob	
Staff Mean	Session No. > 0	0.21	0.47	-0.56	0.97	2.19	0.69	
	Songs Played > 0	0.09	0.56	-0.79	1.04	1.25	0.56	
	Requests all < 0	-0.09	1.31	-2.21	1.96	1.12	0.53	
	Changes all < 0	-0.12	1.35	-2.31	2.01	1.15	0.54	
	MiDAS Pre mean > 0	0.16	1.19	-1.65	2.11	1.22	0.55	
	Complexity > 0	0.04	0.60	-1.11	1.31	1.08	0.52	
Facilitator Mean	Session No. > 0	0.18	0.04	0.10	0.25	>3999	1.00	*
	Songs Played > 0	0.14	0.04	0.08	0.20	>3999	1.00	*
	Requests all > 0	0.04	0.06	-0.05	0.14	3.62	0.78	
	Changes all > 0	0.13	0.04	0.07	0.19	>3999	1.00	*
	MiDAS Pre mean > 0	2.10	0.67	1.01	3.20	499.00	1.00	*
	Complexity < 0	-0.08	0.12	-0.31	0.16	3.21	0.76	

Table 4. Results of Bayesian regression with the formula *Post-session rating* ~ 1 + *Session number* + *Songs played* + *Complexity [monotonic]* + *Pre-session rating* + *Requests all* + *Changes all* + (1 | *Participant*). Bayesian regression model of mean staff and facilitator post-session MiDAS ratings and hardware, software, and content changes and requests. Note that here we have included all effects with evidence ratios greater than 10; Est. = Estimate; CI = 90% Confidence Intervals; Evid. Ratio = Evidence Ratio, Post. Prob. = Posterior Probability. '*': The posterior probability of the hypothesis exceeds 95%.

The model summarised in Table 4 shows strong evidence that changes made to the DMIs, either in the form of software, hardware or musical content had a positive effect on facilitator in-session MiDAS ratings. There is no evidence to suggest that participants had an improvement in their MiDAS rating as a consequence of providing feedback.

5. Discussion

This paper has demonstrated that, in general, participants experienced an increase in engagement cumulatively over the course our 20-session intervention, as perceived and judged by staff and facilitators. We also obtain strong evidence from the facilitator's ratings that engagement increased for individual sessions. This is consistent with findings from previous music studies with older adults.

We hypothesised that participants would experience an increase in engagement, as perceived by staff or facilitators, over individual sessions and over the course of all sessions. For the individual sessions, the slight increase in the staff post-session mean MiDAS ratings as compared with the pre-session MiDAS ratings, suggest a slight increase in participant engagement as a result of the attending the session, although we are unable to confirm our hypotheses owing to limited staff ratings data (as described in section 3.4.1) and because their pre-session ratings were so close to the ceiling. Nevertheless, we found strong evidence in the facilitator's in-session MiDAS ratings as compared with their pre-session mean MiDAS ratings, which suggests a positive increase in participant engagement as a result of attending an individual session. Specifically, our Table 3 shows that the sessions significantly increased participant, interest, response, and involvement.

In Table 4, we assessed the MiDAS ratings over the course of all sessions, and looked at the effect size of each predictor on the various individual MiDAS items. Again, we found the lack of completed staff MiDAS ratings problematic for supporting our hypothesis. In contrast, the mean facilitator MiDAS ratings were strongly influenced by *Session no.*, suggesting that participants were generally more engaged in the sessions, and enjoyed them more, as they participated more. While it is difficult to pinpoint exactly why this is the case, there are a number of potential possible causes. Firstly, participants will have become more familiar with the controllers as they attended more sessions, thus the sessions evolved to become more "restorative activities" as the sessions went on (Creech, 2019). Secondly, the sessions may have had some cumulative effects: improved social interaction with other participants (Garrido et al., 2018), which may have resulted in decreased loneliness and depression (Joseph & Southcott, 2015; Zhang et al., 2017) improved self-esteem and reduced depressive symptoms (Cooke, Moyle & Shum, 2010b). Furthermore, as *Session No.* increased the facilitators in-session MiDAS response ratings decreased, although we can only speculate as to why this is the case: even though residents enjoyed the sessions as they participated more, there may have been other confounding reasons why they appeared less responsive to the facilitator, including concentrating on playing the DMI using increased complexity levels. We found strong evidence suggesting that *Complexity* levels had a negative effect on enjoyment.

We also hypothesised that aspects of participation (songs played, controllers played) affected the ratings of engagement but the data was not sufficiently informative for us to assess this. However, we did find very strong evidence from the facilitator's ratings that *Songs Played* had a positive effect on overall engagement. In Tables 3 and 4, we found that the facilitators' pre-session MiDAS interest and involvement ratings were strong predictors of the facilitators in-session MiDAS interest ratings, and to a lesser extent interest was a predictor of initiation ratings. Pre-session enjoyment was a strong predictor of in-session enjoyment as rated by facilitators, suggesting that if participants enjoyed the session at the beginning, the effect was likely to last throughout the session. Similarly, we found strong evidence to suggest that participant pre-session enjoyment, responsiveness, and involvement was positively associated with increased responsiveness, although pre-session initiation was found to have a negative effect on responsiveness.

We also hypothesised that aspects of the UCD process (e.g. requests made, or changes implemented) affected the ratings of engagement. Firstly, our UCD approach meant that we added new songs to the DMI regularly over the sessions, and so musical variety increased as the sessions went on. Secondly, these new songs were specifically requested by participants, yet we found no significant evidence to suggest that residents' overall engagement increased when change requests were made: rather, development changes were greater predictors of overall engagement. This suggests that participants preferred seeing changes come to fruition rather than the space to simply give feedback, and is consistent with previous studies that have found merit in personalisation and user-acceptance (Ancient and Good, 2014).

In fact, as part of this final hypothesis, we thought that by introducing more complex musical mappings (a requested change from participants), we would improve MiDAS ratings, as compared to basic musical parameter mappings (e.g. transitioning from one-to-many mappings to one-to-one mappings). However, Table 4 suggests that that complexity is not significant at all in predicting overall engagement despite the fact that complexity has a negative effect on enjoyment in Table 3. It is useful to note that the facilitator was aware of when the changes to complexity occurred so this may have biased their responses; hence, we should exercise some caution with this inference.

Overall, our implementation of complexity did not provide us with the positive results we had hoped for, but there were a lot of underlying assumptions about how we operationalised complexity for our DMI. From the requests, participants wanted more complex musical parts and more complex interactions, but it appears that when changes were implemented to address these requests, participants did not enjoy them. This may be due to a number of factors such as the increased concentration required, that the complexity was implemented in such a way that it was not helpful, or that our implementation of complexity did not operate on the right musical/motor/cognitive DMI elements that enhanced older adults' enjoyment. Thus, further work should investigate the nature of complexity, either in terms of musicality, motor or cognitive ability, for older adults with varying abilities. This should include a comprehensive investigation into the DMI design elements that should be made more complex, and those elements that should remain easily playable, with a view to ultimately being able to automate changes in complexity where possible.

6. Conclusion

This study focussed on the benefits of a music-making session with residents in an aged-care home, specifically with regards to health and wellbeing, interaction with music technology, and our user-centred design (UCD) approach. Our analysis focussed on two key areas: the immediate effect of each session, and the medium-term effect of the entire intervention, on the residents' engagement.

We sought to understand whether custom DMIs enhanced residents' engagement but were unable to quantitatively verify this due to insufficient data. Qualitative data captured during the process is currently being analysed and might enhance our understanding of the impact of the DMIs on resident wellbeing. Similarly, across the whole process we captured the button press data for each DMI, which is also currently under analysis, with a view to assessing whether our process saw improvements to resident's musical ability and motor control, using different complexity mappings, and different instruments.

In terms of assessing our UCD approach to developing the DMIs, we found that development changes had a positive effect on the mean MiDAS ratings. While we were expecting a more modest effect size, we found limitations in our data that were in part a result of our UCD approach, which involved rapid prototyping. Because a UCD approach relies upon feedback from end-users, it is difficult to structure development changes so as to avoid correlation and conflation between changes made and the response measures. Similarly, our request mechanisms were unstructured, so as to facilitate ad-hoc and confident discussion among residents, so that we could develop a sustainable music-making tool. Consequently, further studies seeking to evaluate UCD and rapid prototyping approaches might consider a more structured approach to the feedback and development process. Despite this, we hope that our qualitative data will enhance our understanding of the efficacy of our approach.

Our approach has implications for rehabilitation of older adults, particularly those with motor and cognitive impairment. Firstly, we have found that older adults will positively engage with novel music technology. By overcoming this significant barrier to adoption, we can enhance the longer-term rehabilitative effect of group music making. Secondly, we have demonstrated the potential for residents with different abilities to all make music together, although to maximise the sustainability of the devices, sessions and the subsequent rehabilitative benefit, residents must be given the right adaptation for individual interfaces that balances ambition and ability. Finally, we found that rapid DMI prototyping positively enhanced engagement, suggesting that in the case of a custom DMI, an upgrade schedule should be aligned with key rehabilitative milestones. Similarly, in the case of pre-developed digital music system, resident exposure to new features or functionality of the device might also be strategically introduced, so as to maximise engagement for key phases of resident rehabilitation.

Following our process, we received feedback from managers and carers of the aged care facility saying that our music making sessions with DMIs was a success, and we achieved our primary objective: to make a sustainable hardware and software based DMI prototype, which is still being used in the aged care facility. At the end of our process, we trained care staff on the operation of the DMIs, and the group music-making sessions are now a hotly anticipated, permanent, two-weekly event.

7. References

Ableton, (2019). What's new in Live 10. Retrieved from <https://www.ableton.com/en/live/>. Accessed 12 December 2019.

Akai. (2019). APC Mini. Retrieved from <https://www.akaipro.com/apc-mini>. Accessed 30 November 2019

Aldridge, D. (2000). Music therapy in dementia care : More new voices. London: Jessica Kingsley.

Ancient C, & Good A. (2014). Considering people living with dementia when designing interfaces. Design, user experience, and usability. User experience design practice. p. 113–123.

Apple. (2019). Logic Pro X overview. Retrieved from <https://www.apple.com/au/logic-pro/>. Accessed 12 December 2019.

Apple. (2019b). GarageBand for Mac. Retrieved from <https://www.apple.com/au/mac/garageband/>. Accessed 12 December 2019.

Biasutti, M., & Mangiacotti, A. (2017). Assessing a cognitive music training for older participants: a randomised controlled trial. *International Journal of Geriatric Psychiatry*, *33*(2), 271–278. http://doi.org/10.1002/gps.4721

Buitenweg, J., Murre, J., & Ridderinkhof, K. (2012). Brain training in progress: A review of trainability in healthy seniors. Frontiers in Human Neuroscience, 6(2012), 183.

Bürkner P. C. (2018). Advanced Bayesian Multilevel Modeling with the R Package brms. *The R Journal*. 10(1), 395-411. doi.org/10.32614/RJ-2018-017

Cady, E., Harris, R., & Knappenberger, J. (2007). Using music to cue autobiographical memories of different lifetime periods. *Psychology of Music*, *36*(2), 157–177. http://doi.org/10.1177/0305735607085010

Cappelen, B., & Anderson, A. (2014). "Designing four generations of Musicking Tangibles," in *Music, Health, Technology and Design*, K. Stansaeth (Ed.). Oslo: NMH-publications, 1–19.

Carpenter B., Gelman A., Hoffman M. D., Lee D., Goodrich B., Betancourt M., Brubaker M., Guo J., Li P., and Riddell A. (2017). Stan: A probabilistic programming language. *Journal of Statistical Software*. 76(1). 10.18637/jss.v076.i01

Challis, B. (2013). Assistive Synchronised Music Improvisation. In: De Michelis G., Tisato F., Bene A., Bernini D. (eds) Arts and Technology. ArtsIT 2013. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 116. Springer, Berlin, Heidelberg.

Cooke M., Moyle W, & Shum D. (2010b). A randomized controlled trial exploring the effect of music on quality of life and depression in older people with dementia. Journal of Health Psychology 15: 765–776.

Creech, A. (2019). Using Music Technology Creatively to Enrich Later-Life: A Literature Review. *Frontiers in Psychology*, *10*, 218–14.

Creech, A., Hallam, S., McQueen, H., & Varvarigou, M. (2014). *Active ageing with music: Supporting well being in the Third and Fourth Ages.* London: IOE Press.

Crowe, B., & Rio, R. (2004). Implications of technology in music therapy practice and research for music therapy education: A review of literature. *Journal of Music Therapy*, *41*(4), 282–320. doi:10.1093/jmt/41.4.282

Cycling'74. (2019). What is Max?. Retrieved from <https://cycling74.com/>. Accessed 12 December 2019.

Decorps, J., Saumet, J., Sommer, P., Sigaudo-Roussel, D., & Fromy, B. (2014). Effect of ageing on tactile transduction processes. *Ageing Research Reviews*, *13*, 90–99. http://doi.org/10.1016/j.arr.2013.12.003

De Jong Gierveld, J. (1998). A review of loneliness: Concept and definitions, determinants and consequences. *Reviews in Clinical Gerontology*, *8*(1), 73–80. http://doi.org/10.1017/S0959259898008090

Dinh, D. (2019). *Increasing Social Participation in Senior Center Through Program Development*. Student Capstone Projects. 4.

Dopp, A., Parisi, K., Munson, S., & Lyon, A. (2019). Integrating implementation and user-centred design strategies to enhance the impact of health services: protocol from a concept mapping study. Health Research Policy and Systems, 17(1), 1. http://doi.org/10.1186/s12961-018-0403-0

Dunphy, K., Baker, F., Dumaresq, E., Carroll-Haskins, K., Eickholt, J., Ercole, M., et al. (2019). Creative Arts Interventions to Address Depression in Older Adults: A Systematic Review of Outcomes, Processes, and Mechanisms. *Frontiers in Psychology*, *9*, 47–24. http://doi.org/10.3389/fpsyg.2018.02655

Favilla, S., & Pedell, S. (2014). Touch Screen Collaborative Music - Designing NIME for Older People with Dementia. *Proceedings of New Interfaces for Musical Expression (NIME)*.

Fragaszy, D., & Crast, J. (2016). Functions of the hand in primates. In T. Kivell, P. Lemelin, B. Richmond, & D. Schmitt (Eds.), *The Evolution of the Primate Hand*. New York, NY: Springer. http://doi.org/10.1007/978-1-4939-3646-5_14

Franz, R., & Neves, B., (2019). Usability is ageless: conducting usability tests with older adults. In B. Neves & F. Vetere (Eds.). Aging and digital technology. Singapore: Springer Nature, pp. 99-114.

Frid, E. (2018). Accessible Digital Musical Instruments - a Survey of Inclusive Instruments *Presented at the NIME, SMC and ICMC Conferences*. *International Computer Music Conference, 2018,* 5-10 August, Daegu, Korea.

Garrido, S., Dunne, L., Chang, E., Perz, J., Stevens, C., & Haertsch, M. (2017). The Use of Music Playlists for People with Dementia: A Critical Synthesis. Journal of Alzheimer's Disease: JAD, 60(3), 1129-1142.

Garrido, S., Dunne, L., Perz, J., Chang, E., & Stevens, C. (2018). The use of music in aged care facilities: A mixed-methods study. Journal of Health Psychology, https://doi.org/10.1177/1359105318758861.

Garrido, S., Stevens, C., Chang, E., Dunne, L., & Perz, J. (2018). Music and Dementia: Individual Differences in Response to Personalized Playlists. *Journal of Alzheimer's Disease*, *64*(3), 933–941. http://doi.org/10.3233/JAD-180084

Garrido, S., Stevens, C., Chang, E., Dunne, L., & Perz, J. (2019). Musical Features and Affective Responses to Personalized Playlists in People with Probable Dementia. American Journal of Alzheimer's Disease & Other Dementias, 34(4), 247-253.

Gelman, A. & Hill, J. (2007). Data Analysis Using Regression and Multi-level/Hierarchical Models. Analytical Methods for Social Research. Cambridge University Press.

Gokturk, M., & Sibert, J. (1999). An analysis of the index finger as a pointing device. (pp. 286–287). Presented at the CHI '99 Extended Abstracts on Human Factors in Computing Systems, Pittsburgh, Pennsylvania.

Hahna, N., Hadley, S., Miller, V., & Bonaventura, M. (2012). Music technology usage in music therapy: a survey of practice. *Arts Psychother*. 39, 456–464. doi: 10.1016/j.aip.2012.08.001
Heinz, M., Martin, P., Margrett, J., Yearns, M., Franke, W., Yang, H., et al. (2013). Perceptions of technology among older adults. *J. Gerontol. Nurs*. 39, 42–51. doi: 10.3928/00989134-20121204-04
Hendriks, N., Truyen, F., & Duval, E. (2013). Designing with Dementia: Guidelines for Participatory Design together with Persons with Dementia (pp. 649–666). Presented at the 14th International Conference on Human-Computer Interaction, Cape Town, South Africa. http://doi.org/10.1007/978-3-642-40483
International Organisation for Standardization. (2019). Ergonomics of human-system interaction - Part 210: Human-centred design for interactive systems (Standard No. 9241-210:2019). Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:9241:-210:ed-2:v1:en.
Holmes, C., Knights, A., Dean, C., Hodkinson, S., & Hopkins, V. (2006). Keep music live: music and the alleviation of apathy in dementia subjects. *International psychogeriatrics*, *18*(4), 623–630. https://doi.org/10.1017/S1041610206003887
Istvandity, L. (2017). Combining music and reminiscence therapy interventions for wellbeing in elderly populations: A systematic review. *Complementary Therapies in Clinical Practice*, *28*, 18–25. http://doi.org/10.1016/j.ctcp.2017.03.003
Jack, R., Mehrabi, A., Stockman, T., & McPherson, A. (2018). Action-sound Latency and the Perceived Quality of Digital Musical Instruments. *Music Perception*, *36*(1), 109–128. http://doi.org/10.1525/mp.2018.36.1.109
Jokela, T., 2002. (2002). Making user-centred design common sense: striving for an unambiguous and communicative UCD process model. In Proceedings of the second Nordic conference on Human-computer interaction NordHCI, October 19 - 23, 2002, Aarhus, Denmark.
Jones, L., & Lederman, S. (2006). Human hand function. Oxford: Oxford University Press.
Joseph, D., & Southcott, J. (2015). Singing and companionship in the Hawthorn University of the Third-Age Choir, Australia, International Journal of Lifelong Education, 34:3, 334-347, DOI: 10.1080/02601370.2014.991951
Jiancaro, T., Jaglal, S., & Mihailidis, A. (2017). Technology, design and dementia: An exploratory survey of developers. Disability and Rehabilitation: Assistive Technology, 12(6), 573-584.
Kessels, R., Boekhorst, S., & Postma, A. (2005). The contribution of implicit and explicit memory to the effects of errorless learning: a comparison between young and older adults. *Journal of the Int'l Neuropsychological Society: JINS*, *11*(2), 144–151.
Koger, S., Chapin, K., & Brotons, M. (1999). Is Music Therapy an Effective Intervention for Dementia? A Meta-Analytic Review of Literature. Journal of Music Therapy, 36(1), 2-15.
Kim, S., & Yoo, G. (2019). Instrument Playing as a Cognitive Intervention Task for Older Adults: A Systematic Review and Meta-Analysis. *Frontiers in Psychology*, *10*, 477–13. http://doi.org/10.3389/fpsyg.2019.00151
Kopec, W., Nielek, R., & Wierzbicki, A. 2018. (2018). Guidelines Towards Better Participation of Older Adults in Software Development Processes Using a New SPIRAL Method and Participatory Approach. Presented at the 11th International Workshop on Cooperative and Human Aspects of Software Engineering (CHASE 2018), Gothenburg, Sweden. http://doi.org/https://doi.org/ 10.1145 / 3195836.3195840

Krout, R. (2013). Music Technology Used in Therapeutic and Health Settings. In Magee (Ed.). *Music technology in therapeutic and health settings*. Retrieved from https://ebookcentral.proquest.com

Lindeck, J. (2014). Applications of music technology in a children's hospice setting. *Music technology in therapeutic and health settings*, 199-213.

Macritchie, J., Breaden, M., Milne, A., & Mcintyre, S. (2020). Cognitive, Motor and Social Factors of Music Instrument Training Programs for Older Adults ' Improved Wellbeing. *Frontiers in Psychology*, *10*(January), 1–15.

Magee, W. (Ed.). (2013). *Music technology in therapeutic and health settings*. Retrieved from https://ebookcentral.proquest.com

McDermott O, Orrell M, & Ridder, H., (2015). The development of Music in Dementia Assessment Scales (MiDAS). *Nordic Journal of Music Therapy* 24(3) 232-251.

McLaughlin, A., Rogers, W., & Fisk, A. (2009). Using direct and indirect input devices. *ACM Transactions on Computer-Human Interaction*, *16*(1), 1–15. http://doi.org/10.1145/1502800.1502802

Mihailidis, A., Blunsden, S., Boger, J., Richards, B., Zutis, K., Young, L., & Hoey, J. (2010). Towards the development of a technology for art therapy and dementia: Definition of needs and design constraints. The Arts in Psychotherapy, 37(4), 293-300.

Mimura, M., & Komatsu, S. (2007). Cognitive rehabilitation and cognitive training for mild dementia. *Psychogeriatrics*, *7*(3), 137–143.

Miranda, E., & Wanderley, M. (2006). New Digital Musical Instruments. A-R Editions, Inc.: Middleton, Wisconsin.

Muller, M., & Kuhn, S. (1993). Participatory design. Communications of the ACM, 36(6), 24–28. http://doi.org/10.1145/153571.255960

Nair, B., Browne, W., & Marley, J. (2013). Music and dementia. Degenerative Neurological and Neuromuscular Disease 3: 47–51.

Nath, A., & Young, S. (2015). Vesball - a ball-shaped instrument for music therapy. *Proceedings of New Interfaces for Musical Expression (NIME)*.

Nicolau, H. (2013). *Disabled "R" all: bridging the gap between health and situational induced impairments and disabilities*. Universidade Técnica De Lisboa Instituto Superior Técnico. Unpublished Doctoral Thesis.

Norman, D. (2013). The design of everyday things; Rev. and expanded ed. New York, NY: Basic Books.

Novation Music. (2019). LaunchPad. Retrieved from <https://novationmusic.com/launch/launchpad-mk2>. Accessed 30 November 2019

O'Connor D., Ames D., Gardner B., & King, M. (2009). Psychosocial treatments of behavior symptoms in dementia: A systematic review of reports meeting quality standards. International Psychogeriatrics 21: 225–240.

O'Modhrain, M., & Essl, G. (2004). PebbleBox and CrumbleBag - Tactile Interfaces for Granular Synthesis. In Proceedings of New Interfaces for Musical Expression (NIME'04), June 3-4, 2004, Hamamatsu, Japan.

O'Rourke, H., Collins, L., & Sidani, S. (2018). Interventions to address social connectedness and loneliness for older adults: a scoping review, 1–13.

Orpwood, R. (2004). User Involvement in Dementia Product Development. *Dementia* 3, 3 (October 2004), 263–279.

Orpwood, R., Chadd, J., Howcroft, D., Sixsmith, A., Torrington, J., Gibson, G., & Chalfont, G. (2010). Designing technology to improve quality of life for people with dementia: user-led approaches. *Univers. Access Inf. Soc.* 9, 3 (August 2010), 249–259.

Pérez-Ros, P., Cubero-Plazas, L., Mejías-Serrano, T., Cunha, C., & Martínez-Arnau, F. (2019). Preferred Music Listening Intervention in Nursing Home Residents with

Cognitive Impairment: A Randomized Intervention Study. *Journal of Alzheimer's Disease*, *70*(2), 431–440. https://doi-org.ezproxy.uws.edu.au/10.3233/JAD-190361

Pfordresher, P. (2006). Coordination of perception and action in music performance. Advances in Cognitive Psychology, 2, 183–198.

Rodrigues, É., Carreira, M., & Gonçalves, D. (2016). Enhancing typing performance of older adults on tablets. *Universal Access in the Information Society*. http://doi.org/10.1007/s10209-014-0391-y

Roli. (2019). Blocks. Retrieved from <https://roli.com/products/blocks> accessed 30 November 2019

Sathian, K., Zangaladze, A., Green, J., Vitek, J., & DeLong, M. (1997). Tactile spatial acuity and roughness discrimination: impairments due to aging and Parkinson's disease. *Neurology*, *49*(1), 168–177. http://doi.org/10.1212/wnl.49.1.168

Schneider, C., Hunter, E., & Bardach, S. (2018). Potential Cognitive Benefits From Playing Music Among Cognitively Intact Older Adults: A Scoping Review. *Journal of Applied Gerontology*, 073346481775119. https://doi.org/10.1177/0733464817751198

Schneider, S., Schönle, P., Altenmüller, E., & Münte, T. (2007). Using musical instruments to improve motor skill recovery following a stroke. Journal of Neurology. 2007 Oct;254(10):1339-46. Epub 2007 Jan 27. DOI:10.1007/s00415-006-0523-2

Schuler, D., Namioka, A., & Suchman, L. (1993). Participatory design: principles and practices. Mahwah: CRC Press.

Seinfeld S., Figueroa H., Ortiz-Gil J., & Sanchez-Vives. M. (2013). Effects of music learning and piano practice on cognitive function, mood and quality of life in older adults. Frontiers in Psychology. DOI: 10.3389/ fpsyg.2013.00810.

Seymour, P., Matejka, J., & Foulds, G. (2017). The 19th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS), 2017. AMI: An Adaptable Music Interface to Support the Varying Needs of People with Dementia. 30 October-1 November 2017. Baltimore, Maryland. http://doi.org/10.1145/3132525

Skedung, L., El Rawadi, C., Arvidsson, M., Farcet, C., Luengo, G., Breton, L., & Rutland, M. (2018). Mechanisms of tactile sensory deterioration amongst the elderly. *Scientific Reports*, *8*(1), 5303. http://doi.org/10.1038/s41598-018-23688-6

Skoog. (2019). Skoog Music. Retrieved from <https://skoogmusic.com/specialeducation/>. Accessed 30 November 2019.

SoundBeam UK Ltd. (2019a). Homepage. Retrieved from: https://www.soundbeam.co.uk/. Accessed 30 November 2019.

SoundBeam UK Ltd. (2019b). Product Manual (Software 1.0.585 – Nov17). Retrieved from: https://static1.squarespace.com/static/56d802d962cd9424aa8b5eb7/t/5ca62d17b208fc56340504aa/1554394418566/Manual+SB6+MASTER+310818.pdf

Steinberg. (2019). Cubase, overview. Retrieved from <https://new.steinberg.net/cubase/>. Accessed 12 December 2019.

Stensæth, K. (2013). "Musical co-creation?" Exploring health-promoting potentials on the use of musical and interactive tangibles for families with children with disabilities. *International Journal of Qualitative Studies on Health and Well-Being*, *8*, 20704. http://doi.org/10.3402/qhw.v8i0.20704

Sun, Y., Zatsiorsky, V., & Latash, M. (2011). Prehension of half-full and half-empty glasses: time and history effects on multi-digit coordination. *Experimental Brain Research*, *209*(4), 571–585. http://doi.org/10.1007/s00221-011-2590-6

Svansdottir, H., & Snaedal, J. (2006). Music therapy in moderate and severe dementia of Alzheimers type: A case control study. International Psychogeriatrics, 18(4), 613-621.

Takehara, N., Okuno, R., Ichinose, T., Matsumoto, K., Watabe, S., Sato, K., Masuko, T., & Akazawa, K. (2017). A Novel System for the Elderly to Learn Playing Electronig

[sic] Musical Instrument in Ensemble. *2017 International Conference on Culture and Computing (Culture and Computing), 2017*, 163-169.
Taylor J. (2016). An ARTISAN Perspective for Software Development, Commercialisation and Artistic Co-creation: A Case Study. In: Lugmayr A., Stojmenova E., Stanoevska K., Wellington R. (eds) Information Systems and Management in Media and Entertainment Industries. International Series on Computer Entertainment and Media Technology. Springer, Cham.
Topo, P. (2009). Technology Studies to Meet the Needs of People with Dementia and Their Caregivers: A Literature Review. Journal of Applied Gerontology, 28(1), 5–37.
Humberstone, J., & Taylor, J. (2015). Making music learning fun : designing an interactive iBook for informal learning. *Acmc2015-Make!: Proceedings of the Australasian Computer Music Association, University of Technology Sydney, 18th-21st November 2015*, 69-74.
Villeneuve, M., Penhune,V., & Lamontagne, A. (2014). A piano training program to improve manual dexterity and upper extremity function in chronic stroke survivors. Frontiers in Human Neuroscience, 8, 662.
Vahia, I., Kamat, R., Vang, C., Posada, C., Ross, L., Oreck, S, et al. (2017). Use of tablet devices in the management of agitation among inpatients with dementia: an open-label study. *Am. J. Geriatr. Psychiatry* 25, 860-864. doi: 10.1016/j.jagp.2016.07.011
Ward, A., Woodbury, L., & Davis, T. (2017). Design considerations for instruments for users with complex needs in SEN settings. *Proceedings of New Interfaces for Musical Expression (NIME),* May 2017*,* Aalborg, Denmark.
Ward, A., Davis, T., & Bevan, A. (2019). Music Technology and Alternate Controllers for Clients with Complex Needs. *Music Therapy Perspectives*, *37*(2), 151–168.
Waycott, J., Pedell, S., Vetere, F., Ozanne, E., Kulik, L., Gruner, A., & Downs, J. (2012). Actively engaging older adults in the development and evaluation of tablet technology (pp. 643–652). Presented at the 24th Australian Computer-Human Interaction Conference, New York, New York, USA: ACM Press.
Wickremaratchi, M. (2006). Effects of ageing on touch. *Postgraduate Medical Journal*, *82*(967), 301–304. http://doi.org/10.1136/pgmj.2005.039651
Young, G., & Murphy, D. (2015). HCI Models for Digital Musical Instruments: Methodologies for Rigorous Testing of Digital Musical Instruments. In Proceedings of the 11th International Symposium on Computer Music Multidisciplinary Research (CMMR 2015), Plymouth, UK, June 16-19, 2015.
Zhang Y, Cai J, An L, et al. (2017). Does music therapy enhance behavioral and cognitive function in elderly dementia patients? A systematic review and meta analysis. Ageing Research Reviews 35: 1–11.

8. Acknowledgements

The authors would like to acknowledge Matthew Breadon, Dave Anthony, Felix Dobrowohl, Alison Short, Ehab Ghobreyal, Khushali Surti and the lifestyle team at <anon>. This project was funded by the NSW government Families and Community Services (FACS) “Liveable Communities Grant” number LC-0096.

9. Declaration of Interest

The authors report no conflicts of interest.