

Full-Length Article

Uncommon music making: The functional roles of music in design for healthcareElif Özcan¹, Lois Frankel², Jesse Stewart³¹Critical Alarms Lab, Delft University of Technology, Erasmus Medical Center, Rotterdam, Netherlands.²School of Industrial Design, Carleton University, Canada.³School for Studies in Art and Culture: Music, Carleton University, Canada.**Abstract**

In this paper, we discuss uncommon settings and roles for music in order to demonstrate how music can aid in the design and implementation of socially responsible healthcare products that are encouraging, inclusive, and sensitive to critical contexts. We review three music-inspired design cases (CareTunes: Musical Alarms for Critical Care, Music and Senior Exercise, and We Are All Musicians and the Adaptive Use Musical Instrument) in which the authors took part. The literature review and the analysis of the case studies provide the following insights: music enhances sensory experiences, facilitates physical engagement with the world, music can guide medical professionals in critical contexts, and music creates social cohesion. All of these projects demonstrate the importance of involving participants (users or performers) in the process to address their life experiences. The use of music in design applications is experienced as a positive influence that can facilitate wellbeing for community members, persons with disabilities, medical patients, and healthcare professionals in the workplace.

Keywords: : *design interventions, music-inspired, community music, medical device, healthcare, wellbeing*

multilingual abstract | mmd.iamonline.com**Introduction**

Music is embedded in many aspects of our daily lives. In this paper, we will discuss some uncommon settings and roles for music, demonstrating how music can aid in the design and implementation of socially responsible healthcare products that are encouraging, inclusive, and sensitive to critical contexts. After an introduction to the benefits of music and its functional role in societies, we present three design cases

within the healthcare domain that incorporate music to empower clinicians, elderly patients, and people with physical disabilities. Finally, we reflect on music's potential as a tool for social intervention that can change and enhance familiar experiences.

Music and wellbeing

For most people, listening to music is a pleasurable activity. Likewise, singing or playing a musical instrument, whether on one's own or in a group context, can be highly gratifying, evoking a sense of achievement. However, the extent to which music influences our sense of wellbeing can go beyond pleasure and achievement due to its pervasiveness [1]. Being involved in musical activities shapes the way we perceive and process sensory information, influencing language acquisition, literacy and numeracy skills, and overall intellectual development [2, 3, 4, 5]. Active engagement in music boosts creativity and facilitates academic and general performance levels [1]. Playing music with others can reduce stress and increase proximal relationships among individuals, therefore helping with the personal and social development of young adults [6]. Moreover, playing instruments is a physical and rhythmic activity that not only improves spatial coordination and temporal reasoning, but also sharpens fine-motor skills. Overall, music has profound effects on sensory and intellectual development and therefore positively influence health and wellbeing.

Functional roles of music in society

In addition to promoting health and wellbeing, music performs a variety of functional roles in different contexts due

PRODUCTION NOTES: Address correspondence to:

Elif Özcan PhD. E-mail: e.ozcan@tudelft.nl | COI statement: The authors declared that the following financial support was given for the writing of this article:

Elif Özcan received funding from DesignUnited (a 4TU federation for Dutch design schools) in 2017 for prototyping CareTunes to be exhibited at Dutch Design Week.

Lois Frankel received funding for the initial ethnographic study from the Social Sciences and Humanities Research Council (Doctoral Fellowship). Subsequent funding for the Sensory Design Learning Resource Project was provided through the Scholarship of Teaching and Learning award from Carleton University's Educational Development Centre (EDC).

Jesse Stewart has received funding for the We Are All Musicians project through Social Sciences and Humanities Research Council (for the International Institute for Critical Studies in Improvisation); the Natural Sciences and Engineering Research Council

(for the Research and Education in Accessibility Design and Innovation); the Musagetes/Artseverywhere Foundation; and the Community Foundation of Ottawa.

The authors have no conflict of interest to declare.

to its positive effects on our physiological, psychological, and social health [7, 8]. For example, music is often used to induce and enhance emotions, playing as a backdrop to emotional scenes in films, in advertising, and in therapy contexts, among other fields [9]. In film soundtracks, music not only facilitates the narrative, but also conveys the emotions the characters are experiencing, shaping, in turn, the emotional response and mood of the audience [10, 11].

Music also can be used to alter our time perception. By providing listeners with a continuous perceptual experience that develops and changes over time, music allows listeners to discover new patterns and make new connections, reducing boredom. This is why music is used in elevators and by call centres while we are on hold—music changes our perception of the passage of time, making it less tedious [12]. Some scholars have speculated that music may have developed originally as a safe way for early humans to pass time in a manner that is analogous to the sleeping habits of other predators [4].

Clearly, music can be used to enhance or otherwise affect a wide spectrum of the human experience. In recent years, a growing number of stakeholders within healthcare contexts have become interested in exploring the functional roles of music for patient treatment and clinical workflow.

Targeted musical interventions in healthcare

Previous research has shown that music can be a highly effective tool in healthcare settings. For example, a recent study showed that music created specifically for preterm babies helped their brain development in their last three months spent in neonatal intensive care units [13]. In addition, music has been shown to aid in the (self)-regulation of emotions in (critical) healthcare settings [14, 15]. Music has been used in tranquillity rooms in which people (including those who are under stress due to perceptually and cognitively demanding routines) restore their senses and regain control of their mental processes and positive emotions [16]. Tranquillity rooms help people cope by giving them a respite from noisy and hectic environments, eliminating potential stressors such as loud noises and beeping alarms as described by the appraisal theory of Lazarus and Folkman [17].

In addition, music has been applied in various clinical settings as a stress reliever during pre-operative and/or post-operative stages. There is consensus amongst the studies that conducted systematic reviews and meta-analysis that music can act as medical treatment pre- and post-operatively in such a way that it significantly reduces pain amongst adults and children [18 – 20]. This pain-reduction effect is stronger for conscious patients and self-selected music in comparison to sedated patients and no music. The reviewed studies show similar effects for the indicators of anxiety and stress (e.g., systolic

blood pressure, heart rate and neuroendocrine stress response). The effects can be explained as the following: Music modulates attention in a way that distracts the patient from anxiety and pain-inducing stimuli during medical procedures [21, 22]. Peaceful sounding music, characterized by low arousal and positive valence, was found to be more effective at improving patient recovery than music with high arousal or white noise [23]. Furthermore, patient exposure to relaxing music (such as Pachelbel's Canon in D major) prevented increases in anxiety, heart rate, and blood pressure when patients were triggered by an oral presentation task [24].

In addition to reducing stress, music has been shown to have positive therapeutic effects on some psychological disorders [21, 25, 26]. In music therapy, music modulates attention and is used in various attentive disorders. It further regulates emotions as it modulates all major limbic and paralimbic structures involved in the maintenance, initiation, and modulation of emotions. Therefore music can be an effective treatment for affective disorders such as post-traumatic stress disorder (PTSD), which involves a dysfunction of the limbic system. It also modulates cognitive functions, such as memory processes (encoding, storage, decoding of musical information) and, as such, aids memory function among Alzheimer's patients. Music can also enable communication, serving as an effective treatment for selective mutism and other communication disorders [21].

We are inspired by the positive effects that music has had in various healthcare settings, and by the possibilities that such settings open for designers and musicians alike. The three design cases below present uncommon approaches to music-inspired products, services, and systems.

Music-inspired design cases

1. CareTunes - Musical alarms for critical care

Audible alarms are fundamentally designed to be a crucial work tool for clinicians, but clearly have negative consequences for patients' mental and physical health as well as clinicians' well-being and work efficiency [27 – 31]. The *raison d'être* of designing audible alarms is to inform clinicians about critical changes in a patient's physiological data, including the incoming vital signs as well as the status of patient's overall recovery. Currently, there is an excessive amount of non-actionable audible alarms in intensive care units [32 – 34]. Clinicians, especially nurses, often ignore the sound of alarms and do not (immediately) attend to the functions the alarms individually represent [35, 36]. This situation, as indication for alarm fatigue, limits the efficacy of audible alarms, which often communicate critical information.

The multiplicity of alarms in most hospital settings also causes anxiety among patients and visitors. Because alarms are often associated with a patient's vital signs and are used to indicate the necessity of medical action, patients and visitors often find these sounds distressing. In addition, medical alarms may have profound psychological effects such as contributing to patient delirium and Post Intensive Care Syndrome (PICS, which is similar to PTSD) in the long term after hospitalization. Music can be an effective intervention in the cacophony observed in many hospital settings, contributing to healing and a work environment that reflects the purpose of critical care, which is patient recovery through rest and, if possible, deep sleep. Eliminating redundant alarms and the cacophony of sounds would adhere to the original purpose of critical care.

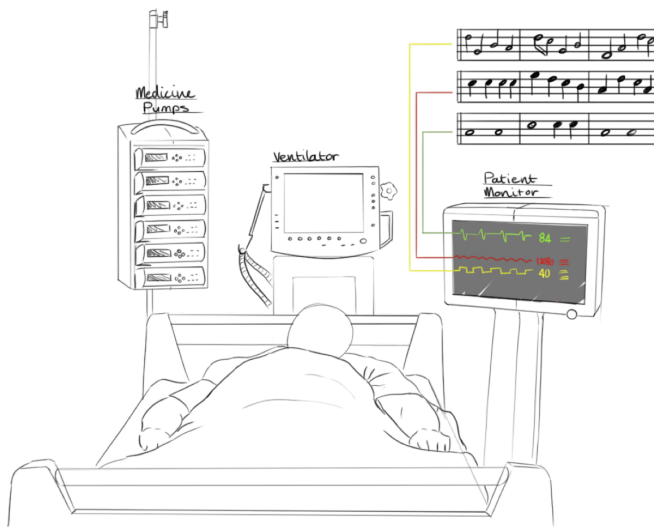


Figure 1. The concept of CareTunes [37] is shown.

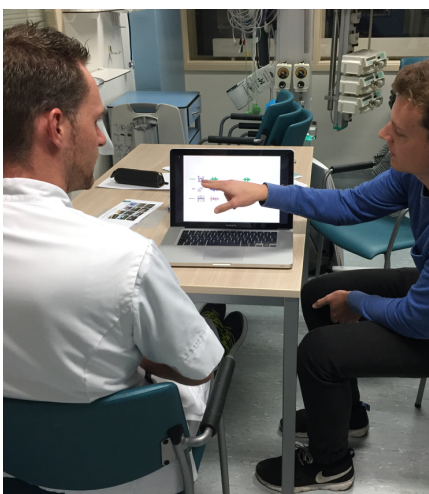


Figure 1b. The image depicts the interactions with nurses.

CareTunes (see Figure 1) is a concept that challenges the clinical utilization of audible alarms or the beeps of patient monitoring devices found in Intensive Care Units [37]. CareTunes is a continuous musical stream that summarizes patient vital signs and presents them in a coherent, logical, and pleasant way to clinicians, the ICU nurse in particular. With CareTunes nurses can have a clear understanding of the overall criticality of the patient status, their trend toward recovery or deterioration, impulsive changes in the vital signs of the patient, and the history of the changes of vital signs. The nurses' task at the nurse stations is to listen to the musical piece that represents a particular patient, recognize the onset of a critical event, and diagnose the source of the problem (e.g., heart, respiration)—all by listening to the music associated with a particular patient. The musical piece created by patient vitals will sound more pleasing than erratic audible alarms due to the harmonic and structured musical features of the data-driven composition. In addition, CareTunes music could be used in patient rooms as a positive indicator of patient status as well as a relaxing ambient sound similar to the music used in sensory rooms.

The main functionality of CareTunes [37] is collecting data from monitoring devices and transforming it into musical motives, i.e. continuously sonifying incoming data. That is, a range of data is selected and increase and decrease in the data is indexed to sonic notation such as increase or decrease in pitch, tempo and meaningful use of silence and intervals (see [38] for more info on data sonification). The following questions are essential when considering CareTunes as a musical monitoring system for medical patients: Which vital signs can we use for data sonification? How can we create harmonicity when sonifying data? What timbres (e.g., instruments or other harmonic devices) can be used together? How can we communicate the trend in patient recovery / deterioration and the changing criticality of information? Should there be a difference between the musical composition for nurses' workflow and for patients' need for comfort? How about the effects on the user? How pleasant is the musical motive when perceived by nurses? Do nurses feel calmer? Are they better informed about the onset of the critical events? Can untrained people (e.g., visitors) relate to the musical stream and ascribe meaning to the heard sound? Will the musical monitoring of patients fit within nurses' busy schedules?

For prototyping, 48 hours of patient data that are critical to patient monitoring was used (including heart rate, oxygen saturation, and blood pressure). Distinct musical roles (similar to the roles of the instruments) were assigned to patient vitals (see Figure 2): heart rate was represented by a percussive sound (e.g. beat on a drum), oxygen saturation by chords (e.g. guitar), and blood pressure by melody (e.g. piano-like sound). For status changes, a low-pass or high-pass filter was used for decreasing or increasing values respectively.

Following interviews and discussions with clinical care nurses, we revisited CareTunes adding a “musical updates” feature in which a continuous stream of musically-expressed data is reduced to particular musical motifs to inform the nurses about trends in patient monitoring. Critical care nurses at Erasmus Medical Centre Rotterdam found this version more fitting for their workflow than the previous version in which they had to search for trends in continuous patient-made music. A special screen is also designed to depict the changes in the musical updates for critical care nurses to refer to at their station (see Figure 2).



Figure 2. CareTunes as musical updates with the function of each musical motif is shown on the left. The right image depicts the visual display of CareTunes to be used by critical care nurses [37]. An interactive demos can be found on <http://koenbogers.nl/>.

CareTunes brings together the knowledge and skills of designers, researchers, artists, engineers, and clinicians in a unique and creative way. This project allowed us to demonstrate our vision and poses critical questions regarding sound design in health care. We developed an effective alternative to the alarm-dominated cacophony of intensive care units, one that consisted of pleasant-sounding music that communicated vital information in a way that nurses could understand. CareTunes makes it clear that pleasant sounds can be informative and represent criticality in intensive care units.

The design of CareTunes is meant to trigger public discussions on the auditory quality of critical care environments, including the effects of noise on clinicians and patients, as well as the limited design space imposed by

healthcare policies and international standards. Since its materialization by Koen Bogers (2018) [37] and especially its debut at the Dutch Design Week 2018 (The Silent ICU display by Critical Alarms Lab [39] at the Embassy of Health Exhibition), CareTunes served its purpose to debate the validity of auditory warning systems and how we can shape the future of information system design and auditory design for critical care environments.

Four different stakeholders worked together in the conceptualization and creation phase of CareTunes [40]. An electronic music artist ensured the musical quality of the project; a clinician with a musical background reflected on the clinical utilization; a data-driven medical device company contributed to the viability of the product; and designers and design researchers worked with critical care nurses to determine the intervention point and type. These stakeholders (see the Acknowledgments) were instrumental in conceptualizing and developing CareTunes, and each one gained new integrated knowledge and skills about designing with music.

2. Music and Senior Exercise

There is extensive research demonstrating the positive relationship between music and motivation during exercise [41 – 44]. According to Wongkee (ibid) [44], “musical melodies and rhythms make exercise more enjoyable and divert exercisers’ attention from their physical discomforts”. Indeed, a recent pilot study investigating ways to generate music while exercising, using a variety of user-friendly, adaptive music technologies, suggested that seniors are motivated to exercise and engage more with one another while making music [44].

We conducted two ethnographic studies with participants at Seniors’ Recreation Centres in Ottawa, Canada. During the first study, we focused on the sensory experiences of seniors in post-rehabilitation exercise classes in order to design wearable devices to support their exercise. Their classes were different than music-driven fitness classes in which the instructor leads a group of participants through a range of quick-paced exercises with a rhythmic musical soundtrack [45]. In these classes, due to the extent of rehabilitation the participants need simply to be able to walk down the street, many of the exercises were slow and targeted to specific users’ needs, with no musical soundtrack. One of the important findings of the first ethnographic study was that “one-kind-fits-all” wearable exercise monitoring support devices were unacceptable to the seniors. Moreover, we recognized that the participants were not only at the centre to exercise; they were also keenly interested in social interaction. We wondered if their social interaction could be enhanced by a shared music-making experience during exercise, making it more fun and socially cohesive.

This led to our second ethnographic study, in which we focused on the link between music and exercise, especially the motivational qualities of music. Building on the work of other researchers, we theorized that incorporating music into seniors’ exercise classes would reduce perceived effort and increase the positive effects of exercise [43, 46]. Since this was a design-driven inquiry, the main question we asked was “How can design contribute to developing responsive music making objects that create positive exercise experiences for seniors [36]? We engaged the seniors in making music with adaptive musical instruments such as the Adaptive Use

Table 1. *Adaptive Musical Instruments*

Musical Instrument (AUMI) software (see Table 1: Figures 3a and 3b) on iPads and the SensAble Adaptive Music Interface (SAMI) developed by Dr. Adrian Chan and his research team at Carleton University in dialogue with composer and percussionist Dr. Jesse Stewart. (see Table 1: Figures 4a and 4b).

Adaptive Use Musical Instrument (AUMI) [44]

The AUMI software is accessed on an iPad mounted in a position that enables the iPad camera to track users’ movements. The screen is divided into a customizable number of zones that can be resized and arranged horizontally, vertically, radially, or in a grid. Each zone is assigned a different pitch or sound (see Figure 3a). A circular cursor on the screen follows the movements of the user. As the cursor moves into different zones, the corresponding sounds are triggered (see Figure 3b), creating music. The tuning, instrumentation, and scale are all customizable so that musical output can be set to group preferences.

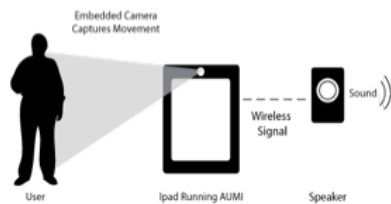


Figure 3a: *Diagram of AUMI*

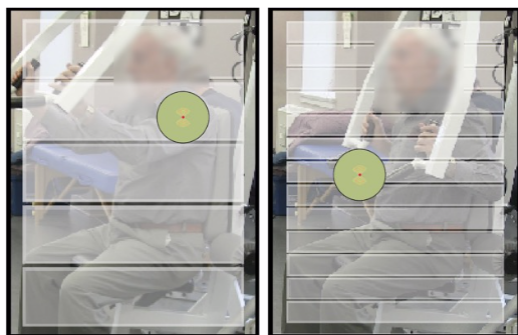


Figure 3b: Screenshots of AUMI interface using 5 and 13 notes

Through both ethnographic inquiries and design studies, we observed that participants could exercise on their own, moving the ball around in space or together by tossing it to one another. This led to insights about using responsive music making devices for exercise:

SensAble Adaptive Music Interface (SAMI) [44]

The SAMI system includes a foam ball with an embedded gyroscope and an accelerometer that trigger audio responses from a computer running a synthesizer program known as DIN (see Figures 4a and 4b). Depending on the speed and direction of the ball, the sensors will trigger different keystrokes, and in turn, output different musical pitches, the tuning and timbre of which are customizable within the DIN software. SAMI was chosen as a technology probe because, unlike the AUMI, it requires the user to interact with a physical object to create music.

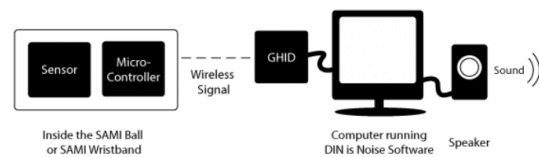


Figure 4a: SAMI system overview



Figure 4b: SAMI system with foam ball

- Music making during a seniors’ exercise class may provide **engagement** and **motivation** for those exercises and having **sensory feedback** (audio and visual) about the exercise contributes to participants’ **positive motivation**,

- The **music should be pleasant** for the user and **not distract them** from completing their exercises properly,
- It should allow the **users to feel in control of the music making**, and
- Give the instructors and users a **tool to monitor** their exercises and **fitness progress** [44].

Based on these recommendations we then wondered, “What could responsive musical instruments for exercise be like? Sound like? Work like”? In our next project, four industrial design students tackled this new question. They were participant observers in Seniors’ Gold Club Fitness Classes at a different local community centre. There, they participated in classes, talked to instructors and the senior exercisers and held co-design sessions with them to enlist their help in designing exercise equipment that they would want to use [47].

This study supported the cultural value of the music in the classes – mostly related to the exercisers’ teen years. It found that social interaction was minimized due to the volume of the music during the class and listening to the instructor over the music increased the challenge for some. In fact, some exercisers were challenged to keep up with the music; some people had difficulty adjusting to rhythm and others had difficulty isolating ambient noise from immediate noise (person talking in front of them). As noted, people tended to

prefer music with which they are familiar since it is easier to find and follow the beat. The type of music, or specifically its tempo, melody, lyrics and rhythm can have an effect on its motivational qualities [48]. The student designers realised that there could be potential for a stronger connection between the music and the exercise class participants. According to the literature, “performing and creating music in groups can provide additional benefits for individuals, giving participants an increased sense of pride and accomplishment, increased social satisfaction and affirmation, which includes positive social relationships” [49].

After conducting a co-design session in which exercisers and designers developed ideas for exercise equipment together, the students became aware of specific issues of importance to those individuals. The student designers then spent months refining the design concepts by making working models and prototypes and conducting usability tests to ensure users would find them comfortable and functional. Each of the students focused on a set of exercises for different areas of the body which led to different outcomes for responsive music making. 3 of these are shown in Table 2 and Figures 5, 6, and 7.

Table 2. *Concepts for Responsive Musical Instruments for Exercising*

Pulse: Musical Dexterity Exercise Instrument [50]

This student focused on an instrument that strengthens dexterity. The concept emerged from a co-design session with older exercisers who wished they could have more exercises for their hands. After iterative concept development and usability testing a hand held instrument for grip strength, finger flex and wrist flexion was designed. Each exerciser would work with 2 instruments, 1 in each hand, by flexing, twisting, or squeezing to produce different musical responses (see Figure 5). These movements control the musical reverb, echo, filter as well as other effects selected on a mobile application.



Figure 5: *Musical Dexterity Exercise Instrument.*

Harmony: Balancing Exercise Instrument [51]

This student developed a Balancing Exercise Instrument that places emphasis on music, synchronicity, creativity and social interaction for older adults (see Figure 6). While a person is balancing on the device it responds to how balanced the exerciser is. If the exerciser is not balanced the music emitted by the device becomes muffled and the board vibrates. A team of balancing exercisers can gently compete with another team by modulating the musical output on their boards in response to active balancing movements.



Figure 6: *Balancing Exercise Instrument.*

Maestro: Collaborative Music for Older Adults' Exercise [52]

This student generated a system of hand-held devices that enables a group of participants to collaboratively adjust the music they emit and hear in real time, while working on their upper body range of motion (see Figure 7). It not only connects with a hub to display exercisers' individual results, it also provides new opportunities for novel exercise activities in which the music-making exercisers vary their range of motion movements so that they can collaborate in altering the volume and/or tempo of the music.



Figure 7: *Maestro devices are organized on a hub, and used individually.*

These studies provided insights into the motivational contribution that music already makes to exercise for the senior population, and suggested additional possibilities for the incorporation of musical features into the design of exercise devices. They confirmed the need for flexibility in incorporating music into design interventions since exercising seniors have different musical preferences, most of which are familiar pieces from their younger years. Musical exercise devices could allow individual exercisers to have more agency in selecting the musical output and in using musical feedback for measuring their progress. In addition to motivating individual exercise, musical interventions were also shown to enhance social interaction. Indeed, responsive musical instruments can do so through different formats, either for individual exercise challenges or for group exercise activities. For example, teams of exercisers could modify the qualities of the music through their exercise movements in friendly competition. The projects provide initial examples of ways that small teams of exercisers can manipulate musical structure in response to their behaviours and influence their social interaction during exercise. These exploratory prototypes illustrate how musical feedback could enhance exercise, engagement, social interaction, and fun in a variety of uncommon ways that bring music and exercise together. We look forward to bringing these devices to market after further development; indeed, several of our participants were disappointed that they are not yet available to purchase!

1. We Are All Musicians (WAAM) and the Adaptive Use Musical Instrument (AUMI)

We Are All Musicians (WAAM) is an interdisciplinary research-creation project aimed at fostering accessible and inclusive group music making. In order to realize this vision, the WAAM project uses a variety of adaptive use technologies in conjunction with more traditional musical instruments in order to facilitate inclusive group music sessions.

The Adaptive Use Musical Instrument (AUMI), as illustrated in Figures 3a and 3b above, has become an important tool within WAAM activities, particularly those involving persons with disabilities. The software's zoom function allows a user to focus on a person's entire body or on a specific body part. If, for example, an AUMI user with a spinal cord injury can only move a few fingers, the instrument can be configured to track the movement of those fingers and turn that motion into music.

The development of the Adaptive Use Musical Instrument has been an interesting example of co-design that involves composers, musicians, scholars, software developers, occupational therapists, and community members around the world [53]. The idea for an instrument that could adapt to anyone's range of motion came from American composer, improviser, and humanitarian, Pauline Oliveros (1932-2016). She enlisted the help of researchers in the United States and Canada, a loose collective that came to be known as the AUMI-Consortium. The Consortium has met regularly via video conference calls for more than ten years. There are now three versions of the AUMI—one for Mac, one for PC, and one for iOS devices—all of which are available as free downloads through www.aumiapp.com.

The We Are All Musicians project has used the AUMI in a variety of settings, including several hospitals. For example, in 2016 WAAM partnered with Artswell (a non-profit organization dedicated to using the arts to improve the quality of life and well-being of individuals living with the effects of age, illness or injury), the Alzheimer's Society of Ottawa and Renfrew County, the Bruyere Continuing Care Centre in Ottawa, and the National Arts Centre to co-facilitate a program called "Music Matters."

Through the Music Matters program, we made music twice a week for eight weeks with a group of eight seniors living with Alzheimer's and other forms of dementia, as well as their caregivers who, in most cases, were their spouses. One thing that many members of the group had in common was a deep love for music. Several participants had extensive experience singing in choirs. Other participants had little or

no prior experience performing music, but nonetheless shared a passion for music.

Part of the intention behind this project was to provide an opportunity for all of the participants to have a new musical experience that would be shared by both caregivers and those receiving care. Through an eight-week long process of musical exploration and dialogue, we co-created an original piece that combined music, poetry, and dance, performing the results of our collaboration at Canada's National Arts Centre on May 1st, 2016.

At first, most of the participants showed little interest in the Adaptive Use Musical Instrument, preferring to sing songs from their youth. However, the AUMI played an important role in enabling one member of the group to participate. After one of our singing sessions, a participant named Felix said "I like to sing with my feet." He went on to explain that he much preferred dancing to singing. So we included a dance number in which the Adaptive Use Musical Instrument translated Felix's dance movements into sound. Using the AUMI in this way inverted the traditional relationship between music and dance: instead of the dancer responding to the music, the music was generated by the movements of the dancer. For Felix, the AUMI provided a gateway into the music, enabling him to participate in a manner that was fun and enjoyable for him.

When interviewed about their experience in the Music Matters program, other participants indicated that it was a positive experience for them too: "It makes me happy. It makes me very happy" said one participant. Another said "It means a fair bit, because we enjoy music and we enjoy the people here. We're all probably more or less in the same boat." Several participants even indicated that the experience had a positive impact on their cognitive health. One participant said "It keeps my brain moving. It makes me think." Another stated "Singing is a very healing thing at any time. And it's also fun."

The Music Matters project as a whole highlighted the power of music to bring people together, to promote health and wellbeing, and to foster a sense of community across differences in age and cognitive health. Angela Parić, a graduate student in the Health Sciences Department at Carleton University, studied the health impacts of the Music Matters program, finding that care recipients' levels of enjoyment and willingness to initiate music making both significantly increased throughout the program. In general, care recipients were "more relaxed, content, and cognitively engaged" during and after Music Matters sessions than they were at the outset. Likewise, caregivers reported fewer negative emotions following the Music Matters program. However, caregivers also reported a decrease in their own sense of well-being. This unexpected result may be due to "caregiver burnout" and increased levels of awareness of the challenges of being full-time caregivers [54].

Since 2018, the WAAM project has been using the Adaptive Use Musical Instrument in another hospital setting—at Saint Vincent Hospital, a complex care facility in Ottawa, Canada. Each visit includes a group music making session and also one-on-one sessions with patients who are unable to leave their rooms. In the group sessions, the AUMI provides a way into the music for patients who are unable to hold or play other musical instruments. Likewise, in the one-on-one sessions with patients with limited mobility, the AUMI enables us to enter into musical dialogue with one another.

We have started to use the AUMI interface in a new way at Saint Vincent as well. In addition to translating movements into digital sound, we are using the AUMI to send MIDI (Musical Instrument Digital Interface) signals to solenoid strikers attached to an assortment of acoustic percussion instruments (bells, bowls, cymbals, tambourines, woodblocks, etc.). These items are propped up by mounts made of Lego building blocks (see Figure 9). The building blocks allow for rapid prototyping as we explore—with input from the participants—a wide variety of objects for their sonic potential. In a way, each session is an exercise in co-design as we work together to reconfigure the instrument (which we have been calling "moto-mechano-music") to meet the needs of those who attend these sessions.

The initial responses to the moto-mechano-music experiments have been very favourable. One participant, Scott Mayhew, who has been to every group session at Saint Vincent Hospital stated "I love this. It gives me joy and I am doing something. There is a community. We are doing something together" [55].



Figure 9. Jesse Stewart of the *We Are All Musicians* project sets up the *Moto-Mechano-Music* system at Saint Vincent Hospital (Photo credit: Artsfile).

Discussion of the design cases

The three design cases discussed above highlight the transformative potential that music can play in a variety of healthcare settings. The **CareTunes project** has turned clinical alarms into musical streams that convey critical information about hospital patients while improving the overall sound design of hospitals. Having musical alarms may improve clinician workflow as well as patient comfort during their stay. Consequently, patient outcomes are expected to improve contributing to more pleasant and shorter hospital stays and better recovery after hospitalization (e.g., less patients returning due to PICS). Clinicians may benefit from music that alleviates alarm fatigue and may even improve morale amongst them due to more efficient alarm responses.

The Senior Exercise concepts integrated music into new tools/instruments for exercise that could not only motivate elderly exercisers, but also give them feedback about their performance, while having fun. These uncommon music-making devices could provide senior exercisers with more agency in selecting and modifying their exercise music, individually and in groups. That could also contribute to a different kind of social engagement with fellow exercisers.

In the **We Are All Musicians project**, the Adaptive Use Musical Instrument has enabled people who might not otherwise have opportunities to make music to participate fully in group music making activities. AUMI and other adaptive and assistive music technologies are playing an important role in fostering inclusive music-making environments that allow people with diverse minds and bodies to collaborate with one another across differences of various kinds. In all the three cases, music-inspired design decisions have made a positive difference to a variety of users. However, we also demonstrated that for music to be an effective feature of a product, its relevance for user context and their concerns need to be first established. Thus, ethnographic studies are required to position music as positive intervention for the targeted audience.

Conclusion

In this paper, we examined the profound effects that music can have on health and wellbeing, and presented uncommon approaches to music and design in several healthcare settings. In our view, healthcare has much to gain from design with music in mind for the following reasons:

Music enhances sensory experiences. People with cognitive impairments (e.g. dementia), patients in hospital care, and children who are developing sensory skills (e.g. babies and toddlers) will benefit from interacting with music, which is a

structured sensory input that acts as an auditory puzzle for the person to solve.

Music facilitates physical engagement with the world. The rhythmic and continuous nature of music engages our motor skills and encourages physical interactions with other people and the environment. Some people with physical disabilities (e.g., patients recovering from a stroke, seniors recovering their mobility after an injury, etc.) will benefit from products that use music as feedback system.

Music can be a functional tool for medical professionals. Many healthcare workers are wary of redundant medical alarms. In contrast, music can be used to convey medical information in a less stressful but effective manner, facilitating the workflow of medical professionals.

Music creates social cohesion. Music is a fundamental human right. As such, everyone should have opportunities to make music including persons with disabilities. Inclusive music making fosters social cohesion by creating bonds between individuals and facilitating a sense of belonging to a community.

Clearly, music has much to offer when it comes to design for healthcare. We have focused on the potential of music-centred design and related activities in healthcare settings; however, we want to emphasize the importance of longitudinal studies and clinical trials that aim to demonstrate the potential of music-inspired interventions to foster physical, cognitive, and emotional health. These studies are relatively rare [13], but necessary [56] to position music as an integral part of design for healthcare.

Acknowledgments

CareTunes was the product of an international collaboration facilitated by Critical Alarms Lab in the form of MSc thesis of Koen Bogers (2018) under the supervisory team of Elif Özcan (TU Delft and Erasmus MC, NL), Aadjan van der Helm (TU Delft, NL), Astrid Gribnau (New Compliance, NL) Joseph Schlesinger (Vanderbilt University, USA), and Yoko Sen (Sen Sound, USA). Elif Özcan also acknowledges Lydia Stravraki's contribution for the literature survey on functional role of music.

The Music and Exercise projects received enthusiastic support from the Churchill Seniors Centre and the Dovercourt Recreation Centre in Ottawa Canada. Special thanks to the participants in all three projects, and to Dr. Jesse Stewart and Dr. Adrian Chan of Carleton University, who kindly shared their expertise and instruments with us.

The We Are All Musicians (WAAM) project has benefitted from the support of many individuals, organizations, and community groups. Special thanks to all the members of the AUMI-Consortium, to Tracy Luciani at

Saint Vincent Hospital, to Adrian Chan of Carleton University, to Angela Paric for her research on the health impacts of the Music Matters program, and to Hasi Elsib for documenting WAAM projects so thoroughly and creatively. And extra special thanks to all of the musicians who have participated in WAAM workshops and performances.

References

- Hallam, S. 2010. "The Power of Music: Its Impact on the Intellectual, Social and Personal Development of Children and Young People." *International Journal of Music Education* 28: 269-289. doi:10.1177/0255761410370658.
- Bilartz, T. D., Bruhn, R.A., & Olson, J.E. (2000). The effect of early music training on child cognitive development. *Journal of Applied Developmental Psychology*, 20, 615–636.
- Geoghegan, N., & Mitchelmore, M. (1996). Possible effects of early childhood music on mathematical achievement. *Journal for Australian Research in Early Childhood Education*, 1, 57–64.
- Schäfer, T., Sedlmeier, P., Städtler, C., & Huron, D. (2013). The psychological functions of music listening. *Frontiers in Psychology*, 4, 511. <http://doi.org/10.3389/fpsyg.2013.00511>
- Wong, P. C. M., Skoe, E., Russo, N. M., Dees, T., & Kraus, N. (2007). Musical experience shapes human brainstem encoding of linguistic pitch patterns. *Nature Neuroscience*, 10, 420–422.
- Clift, S., Hancox, G., Staricoff, R., & Whitmore, C. (2008). Singing and health: A systematic mapping and review of non-clinical research. Sidney de Haan Research Centre for Arts and Health: Canterbury Christ Church University.
- Coffman, D. D. (2002). Music and quality of life in older adults. *Psychomusicology: A Journal of Research in Music Cognition*, 18(1-2), 76.
- Laukka, P. (2007). Uses of music and psychological well-being among the elderly. *Journal of happiness studies*, 8(2), 215.
- Juslin, P., & Västfjäll, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. *Behavioral and Brain Sciences*, 31(5), 559-575.
- Davies, S. (1980). The Expression of Emotion in Music. *Mind*, 89(353), 67-86.
- Cohen, A. J. (2001). Music as a source of emotion in film. *Music and emotion: Theory and research*, 249-272.
- Kellaris, J., & Kent, R. (1992). The influence of music on consumers' temporal perceptions: Does time fly when you're having fun? *Journal of Consumer Psychology*, 1(4), 365-376.
- Lordier, L., Meskaldji, D. E., Grouiller, F., Pittet, M. P., Vollenweider, A., Vasung, L., ... & Hüppi, P. S. (2019). Music in premature infants enhances high-level cognitive brain networks. *Proceedings of the National Academy of Sciences*, 201817536.
- DellaVolpe, J.D.; Huang, D.T. (2015). Is there a role for music in the ICU? *Journal of Critical Care*, 19, 17.
- Uhlir, S.; Jaschke, A.; Scherder, E. (2013). Effects of music on emotion regulation: A systematic literature review. In *Proceedings of the 3rd International Conference on Music & Emotion*, Jyväskylä, Finland.
- Love, T, The Simple Change That Can Save Patients Lives. BBC online. <http://www.bbc.com/future/story/20180810-the-simple-change-that-can-save-patients-lives> Augst 13th 2018. Accessed October 23rd 2019.
- Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. Springer.
- Hole, J., Hirsch, M., Ball, E., & Meads, C. (2015). Music as an aid for postoperative recovery in adults: a systematic review and meta-analysis. *The Lancet*, 386(10004), 1659-1671.
- Fu, V. X., Oomens, P., Sneiders, D., van den Berg, S. A., Feelders, R. A., Wijnhoven, B. P., & Jeekel, J. (2019). The Effect of Perioperative Music on the Stress Response to Surgery: A Meta-analysis. *Journal of Surgical Research*, 244, 444-455.
- Vetter, D., Barth, J., Uyulmaz, S., Uyulmaz, S., Vonlanthen, R., Belli, G., ... & Clavien, P. A. (2015). Effects of art on surgical patients: a systematic review and meta-analysis. *Annals of surgery*, 262(5), 704-713.
- Koelsch, & Siebel. (2005). Towards a neural basis of music perception. *Trends in Cognitive Sciences*, 9(12), 578-584.
- van der Heijden, M. J., Araghi, S. O., van Dijk, M., Jeekel, J., & Hunink, M. M. (2015). The effects of perioperative music interventions in pediatric surgery: a systematic review and meta-analysis of randomized controlled trials. *PLoS one*, 10(8), e0133608.
- Sandstrom, G. M., & Russo, F. A. (2010). Music Hath Charms: The Effects of Valence and Arousal on Recovery Following an Acute Stressor. *Music and Medicine*, 2(3), 137-143.
- Knight, W. E., & Rickard, N. S. (2001). Relaxing Music Prevents Stress-Induced Increases in Subjective Anxiety, Systolic Blood Pressure, and Heart Rate in Healthy Males and Females. *Journal of Music Therapy*, 38(4), 254-272.
- Bensimon, M., Amir, D., & Wolf, Y. (2008). Drumming through trauma: Music therapy with post-traumatic soldiers. *The Arts in Psychotherapy*, 35(1), 34-48.
- Carr, C., d'Ardenne, P., Sloboda, A., Scott, C., Wang, D., & Priebe, S. (2012). Group music therapy for patients with persistent post-traumatic stress disorder—an exploratory randomized controlled trial with mixed methods evaluation. *Psychology and Psychotherapy: Theory, Research and Practice*, 85(2), 179-202.
- Özcan, E., Birdja, D., Simonse, L., & Struijs, A. (2019). Alarm in the ICU! Envisioning patient monitoring and alarm management in future intensive care units. In *Service Design and Service Thinking in Healthcare and Hospital Management*(pp. 421-446). Springer, Cham.
- Kristensen, M. S., Edworthy, J., & Özcan, E. (2016). Alarm fatigue in the ward: An acoustical problem?. *SoundEffects-An Interdisciplinary Journal of Sound and Sound Experience*, 6(1), 88-104.
- Edmondson, D., Richardson, S., Falzon, L., Davidson, K. W., Mills, M. A., & Neria, Y. (2012). Posttraumatic stress disorder prevalence and risk of recurrence in acute coronary syndrome patients: A meta-analytic review. *PLoS One*, 7(6), e38915.
- Griffiths, J., Fortune, G., Barber, V., & Young, J. D. (2007). The prevalence of post-traumatic stress disorder in survivors of ICU treatment: A systematic review. *Intensive Care Medicine*, 33(9), 1506–1518.
- Tulloch, H., Greenman, P. S., & Tassé, V. (2014). Post-traumatic stress disorder among cardiac patients: Prevalence, risk factors, and considerations for assessment and treatment. *Behavioral Science (Basel)*, 5(1), 27–40.
- Cvach, M. (2012). Monitor alarm fatigue: An integrative review. *Biomedical Instrumentation and Technology*, 46(4), 268–277.
- Drew, B. J., Harris, P., Zègre-Hemsey, J. K., Mammone, T., Schindler, D., Salas-Boni, R., et al. (2014). Insights into the problem of alarm fatigue with physiologic monitor devices: A comprehensive observational study of consecutive intensive care unit patients. *PLoS One*, 9(10), e110274.
- Tsien, C. L., & Fackler, J. C. (1997). Poor prognosis for existing monitors in the intensive care unit. *Critical Care Medicine*, 25(4), 614–619.
- Borowski, M., Görges, M., Fried, R., Such, O., Wrede, C., & Imhoff, M. (2011). Medical device alarms. *Biomedizinische Technik*, 56, 73–83.
- Graham, K. C., & Cvach, M. (2010). Monitor alarm fatigue: Standardizing use of physiological monitors and decreasing nuisance alarms. *American Journal of Critical Care*, 19(1), 28–34. <https://doi.org/10.4037/ajcc2010651>

37. Bogers, K. (2018). *Care Tunes: Music as a Nurses' Monitoring Tool*. Master's Thesis, Industrial Design Engineering; Delft University of Technology; Delft, The Netherlands.
38. Hermann, T., Hunt, A. D., and Neuhoff, J. (2011). The sonification handbook (pp. 301–324). Berlin: Logos Publishing House.
39. Critical Alarms Lab: <https://delftdesignlabs.org/criticalalarmlab/>
40. Özcan, E., Birdja, D., & Edworthy, J. R. (2018). A Holistic and Collaborative Approach to Audible Alarm Design. *Biomedical instrumentation & technology*, 52(6), 422-432.
41. Kennedy, a. B., & Blair, S. N. (2014). Motivating People to Exercise. *American Journal of Lifestyle Medicine*, (c), 1559827614524135-. <http://doi.org/10.1177/1559827614524135>
42. Tenenbaum, G., Lidor, R., Lavyan, N., Morrow, K., Tonnel, S., Gershgoren, A., ... Johnson, M. (2004). The effect of music type on running perseverance and coping with effort sensations. *Psychology of Sport and Exercise*, 5(2), 89–109. [http://doi.org/10.1016/S1469-0292\(02\)00041-9](http://doi.org/10.1016/S1469-0292(02)00041-9)
43. Van Der Vlist, B., Bartneck, C., & Mäueler, S. (2011). moBeat: Using interactive music to guide and motivate users during aerobic exercising. *Applied Psychophysiology Biofeedback*, 36(2), 135–145. <http://doi.org/10.1007/s10484-011-9149-y>
44. Wongkee, A. (2016) Designing Responsive Music-making Devices: Creating Positive Exercise Experiences for Seniors (Master's thesis). Carleton University, Ottawa, Ontario, Canada.
45. Frankel, L. D. (2015) *Sensory Insights for Design: A Sensory Anthropology Approach to Industrial Design*. PhD thesis, Concordia University.
46. Seath, L., & Thow, M. (1995). The Effect of Music on the Perception of Effort and Mood During Aerobic Type Exercise. *Physiotherapy*, 81(10), 592–596.
47. Ferrier, A., Lewansadowski, B., Mackenzie-Haines, J., and Simla, L. (2017) Music for Motion Phase 1 Report, School of Industrial Design Carleton University, Canada.
48. Karageorghis, C. I., & Priest, D.-L. (2012). Music in the exercise domain: a review and synthesis (Part I). *International Review of Sport and Exercise Psychology*, 5(1), 44–66. <http://doi.org/10.1080/1750984X.2011.631026>
49. Bailey, B. (2005). Effects of group singing and performance for marginalized and middle-class singers. *Psychology of Music*, 33(3), 269–303. <http://doi.org/10.1177/0305735605053734>
50. Mackenzie-Haines, J. (2018). Music for Motion Phase 1 Phase 4 Report, School of Industrial Design Carleton University, Canada.
51. Lewandowski, B. (2018). Music for Motion Phase 1 Phase 4 Report, School of Industrial Design Carleton University, Canada.
52. Simla, L. (2018). Music for Motion Phase 1 Phase 4 Report, School of Industrial Design Carleton University, Canada.
53. Oliveros, Pauline, Leaf Miller, Jaclyn Heyen, Gillian Siddall, and Sergio Hazard. (2011) A musical improvisation interface for people with severe physical disabilities. *Music and Medicine*, 3(3): 172-181.
54. Parić, A. (2019). Biopsychological Effects Of Social Participation On Aging: The Role Of Identity-affirming Music And The Arts. PhD thesis, Carleton University.
55. Robb, Peter. (2019) Making music and building community in Saint-Vincent Hospital. *Artsfile*.
56. Devlin, A., & Arneill, A. (2003). Health Care Environments and Patient Outcomes: A Review of the Literature. *Environment and Behavior*, 35(5), 665-694.

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