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Andrew Danso

The Use of Technology in Music-based Interventions for Health and Education

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF HUMANITIES AND SOCIAL SCIENCES

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MUSIIKIN, MIELEN, KEHON JA AIVOJEN TUTKIMUKSEN HUIPPUYKSIKKÖ
CENTRE OF EXCELLENCE IN MUSIC, MIND, BODY AND BRAIN

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ABSTRACT

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In recent years, there has been an increase in cross-disciplinary collaboration between healthcare, music therapy, and music education, with digital music technology playing a significant role. This collaboration has created ample opportunities to enhance collaboration among these fields, particularly in the development of technology aimed at addressing specific problem areas. However, recent literature presents ambiguous evidence regarding the effectiveness of these technologies in improving outcomes in assessments commonly found within these domains, as well as their contributions to professional practice. Consequently, this dissertation aims to investigate the application of digital music technologies in diverse health-related and educational settings.

It does this by addressing three broad and fundamental research questions:

> *What types of affordances are present in technologies utilized in music therapy and educational settings?*
>
> *How can feedback be used across music therapy and educational settings?*
>
> *What practical ways can digital and music technology be used by music therapists and educators?*

This dissertation is based on four studies (a cross-sectional survey, a narrative review, development of a computational musical system and perceptual assessment, and a mixed-methods study), which results in four articles. Article I provides an understanding of how technology enabled the delivery of music therapy during a global pandemic. Article II finds promising evidence for symptom reduction during neglect rehabilitation through the use of Virtual Reality (VR) and Musical Neglect Training (MNT) interventions and explores intersections of VR and music therapy interventions for the purposes of neglect rehabilitation. Article III outlines the development of a musical system that uses sonification with the purposes of stimulating physical activity. A perceptual assessment of the musical system shows that the sonification accurately represent high- and low- activity subjects. Article IV tests an experimental intervention, the KAiKU Music Glove, compared to an established technology, the iPad, in a music classroom, with two groups of students being tested across academic assessments. The students also responded to user experience surveys and were qualitatively observed while using their technologies. Results show significant differences in test scores, favouring the iPad technology. Important ease of use ratings and qualitative observations are discussed.

The dissertation proposes the following set of affordances which are active across the four interventions, (1) Adherence and Motivation, (2) Physical Activity, (3) Perceptual Entrainment and Motor Coordination, (4) Engagement and Concentration, as well as advantageous types of feedback for therapeutic and educational practice present within the interventions. Additionally, the dissertation outlines areas where these interventions intersect in their stimulation of bodily movement, as well as multisensory behaviour. Cumulatively, the findings of this project provide an innovative resource in accounting for how digital music technology supports professional music therapy practice, rehabilitative practice, the stimulation of physical activity, and music learning in the classroom.

Keywords: music therapy, music technology, health care, well-being, education, interdisciplinarity

TIIVISTELMÄ (ABSTRACT IN FINNISH)

Danso, Andrew
Teknologian käyttö musiikkiin perustuvissa interventioissa terveydenhuollon ja koulutuksen alalla
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Tämän tutkimuksen tarkoituksena oli selvittää, miten digitaalisia musiikkiteknologioita voidaan soveltaa erilaisissa terveyteen liittyvissä ja koulutuksellisissa ympäristöissä. Tutkimus koostui neljästä osatutkimuksesta (poikittaistutkimus, narratiivinen katsaus, laskennallisen musiikkijärjestelmän ja havaitsemiseen perustuvan arvioinnin kehittäminen sekä monimenetelmällinen tutkimus), jotka johtivat neljään artikkeliin. Artikkelissa I tarjotaan ymmärrystä siitä, miten teknologia mahdollisti musiikkiterapian tarjoamisen maailmanlaajuisen pandemian aikana. Artikkelissa II löydettiin lupaavia näyttöjä oireiden vähentymisestä neglect-potilaiden kuntoutuksessa virtuaalitodellisuuden (VR) ja musiikillisen neglect-koulutuksen (MNT) interventioiden avulla ja tutkitiin VR:n ja musiikkiterapian interventioiden risteämispisteitä neglect-oireiden kuntoutuksessa. Artikkelissa III osoitetaan musiikillisen sonifikaation käytön toimintaperiaatteita fyysisen aktiivisuuden stimuloinnissa. Musiikkijärjestelmän havaitsemiseen perustuva arviointi osoittaa, että sonifikaatio edustaa tarkasti korkean ja matalan aktiivisuuden koehenkilöitä. Artikkelissa IV testataan kokeellista interventiota, KAiKU Music Glovea, ja verrataan sen käyttöä vakiintuneempaan teknologian, iPadin käyttöön musiikintunnilla, jossa kahta opiskelijaryhmää testattiin akateemisissa arvioinneissa. Tulokset osoittavat merkittäviä eroja testituloksissa, joissa iPad-teknologia oli suotuisampi.

Väitöskirjassa esitellään neljä eri affordanssikokoelmaa, jotka ovat läsnä kaikissa neljässä interventiossa: (1) sitoutuminen ja motivaatio, (2) fyysinen aktiivisuus, (3) havaitsemiseen perustuva synkronointi ja motorinen koordinaatio, ja (4) osallistuminen ja keskittyminen, sekä terapeuttisissa ja koulutuksellisissa käytänteissä hyödylliset palautejärjestelmät. Tämän väitöstutkimuksen tulokset tarjoavat uudenlaisen näkökulman digitaalisen musiikkiteknologian käyttömahdollisuuksista ammattimaisissa musiikkiterapiakäytännöissä, kuntoutuskäytännöissä, fyysisen aktiivisuuden stimuloinnissa ja musiikin oppimisessa luokkahuoneessa.

Avainsanat: musiikkiterapia, musiikkiteknologia, terveydenhuolto, hyvinvointi, koulutus, monitieteisyys

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LIST OF ARTICLES

List of articles included in this dissertation:

I. Leandertz, M., Danso, A., Carlson, E. (2021). Adapting to Change: How the COVID-19 Pandemic has Impacted the Music Therapy Profession. *Journal of Music, Health, and Wellbeing*, 1–19.

II. Danso, A., Leandertz, M., Ala-Ruona, E., Rousi, R. (2022). Neglect, virtual reality and music therapy: A narrative review. *Music and Medicine*, *14*(3), 174–186. https://doi.org/10.47513/mmd.v14i3.865

III. Mendoza, J. I., Danso, A., Luck, G., Rantalainen, T., Palmberg, L., Chastin, S. (2022). Musification of Accelerometry Data Towards Raising Awareness of Physical Activity. In *Conference on the Sonification of Health and Environmental Data,* 28–35. KTH Royal Institute of Technology. https://doi.org/10.5281/zenodo.7243875

IV. Danso, A., Rousi, R., Thompson, M. (2021). Novel and experimental music technology use in the music classroom: Learning performance, experience, and concentrated behavior. *Human Technology*, *17*(1), 81–112. https://doi.org/10.17011/ht/urn.202106223979

Author's contribution to the articles:

I. The author was partially responsible for designing the study, the data collection instrument, data analysis, and contributed to writing the manuscript.

II. The author designed the study, reviewed, and analysed the literature, prepared and wrote the manuscript with assistance from the co-authors.

III. The author designed the data collection procedure, and the data were also collected by this author. The author contributed to writing the manuscript.

IV. The author designed the study, collected, and analysed the data, prepared and submitted the manuscript with assistance from the co-authors.

FIGURES

TABLE

CONTENTS

1 INTRODUCTION

Digital technology refers to various applications and tools that use different types of hardware and software (Tulinayo, et al., 2018; Rice, 2003), facilitating electronic services or activities to create, process, transmit and display information. Digital technologies may include mobile phones, tablets, personal computers, and software applications. When integrated with music, digital music technology may include electronic music software, digital instruments, digital audio equipment, and digital music controllers. Digital music technology is a continuation of the tradition and properties of instrument-assisted music-making through information layering - referring to the sensory properties of devices (i.e., sound, and haptic feedback) that can be fully controlled by information manipulation. Consequently, use of these technologies can be seen as providing increased opportunities for action and agency. This will be elaborated on throughout the dissertation, with particular reference to affordances and embodied cognition. Such opportunities offer an additional informational layer for therapists, patients, teachers, and students to interact with, which can be augmented onto traditional instruments as well as established practices.

In recent years, the utilization of digital music technology has seen extensive intersection across the fields of health and education. Collaboration across health and educational sciences affords valuable contributions to music therapy and music education research. This holds particularly in cases were understanding the precise and approximate effects of interventions on specific populations and assessments are concerned. Across the four articles present in this dissertation, the technologies discussed integrate the tactile, haptic, visual, and auditory experience of musical interaction with digital technologies. Often such integration aims to strengthen connections between therapists', patients', teachers', and students' physiology (physical movement, control, and sensations) and cognition (mind) along with digitally generated music creation embedded in other activities. Specifically, the technologies examined in this dissertation incorporate affordances related to motivation, physical activity, motor coordination as well as engagement and concentration that provide distinct modes of feedback. These affordances are critical to therapeutic and educational processes. For instance, using music technology to induce physical activity may assist a patient living with mobility problems caused by a stroke, to move an affected limb in a coordinated manner, as well as adhere to a repetitive treatment task. Or, using music technology in an educational setting may assist the educational process by providing students additional learning tasks in the form of apps, and teachers support by giving them a tool that fosters increased interactivity with their students. Therefore, the articles present an unprecedented contribution across the music therapy and music education disciplines. The articles combine additional sub-discipline interventions, such as occupational therapy assessments or technology acceptance modelling, with the interaction of music. In this dissertation, processes such as feedback, physical activity, patient adherence, and therapist-patient communication, as well as the outcomes of activities completed in virtual environments on health and rehabilitation-related assessments are found within the four articles. Such findings provide pragmatic indications suggesting how therapists, patients, teachers, and students mediate between digital music technologies in support of the clinic or learner's goals. This dissertation examines the application of technology across the domains of music therapy and music education. It does this by addressing three broad and fundamental research questions:

> *What types of affordances are present in technologies utilized in music therapy and educational settings?*
>
> *How can feedback be used across music therapy and educational settings?*
>
> *What practical ways can digital and music technology be used by music therapists and educators?*

This dissertation consists of four original articles, based on four studies which will be discussed in the following chapters. Chapter 2 will introduce prior research, explaining how the fields of music therapy and music education interact with each other, as well as discussing affordance theory as it relates to these interventions. Chapter 3 describes the digital and music technologies used in the four original articles as interventions. Chapter 4 provides an overview of the methods and results used in each article and summarizes the backgrounds, aims, methods and results of all four articles. Chapter 5 presents a summary of the main findings from the four articles, discussing technological affordances and types of feedback that can be harnessed by music therapists and teachers from the examined technologies. In addition, embodied cognition and multisensory behaviour are discussed. Following this, practical applications of the technologies are outlined. Details of the challenges and implications from the technologies to music therapy and educational practice are also presented. Chapter 6 features the conclusion, outlining areas where digital music technology supports professional music therapy practice, as well as how it assists with music learning in the classroom.

Music is a multimodal stimulus, used and applied in many different settings, with digital technology assisting in its delivery. The following section - Digital Music Technology in Health and Education - introduces the core disciplines of music therapy and music education with digital technology in its foreground. Additionally, it provides knowledge regarding the publications of this dissertation that include theory and insight from the areas of information technology (IT), healthcare and neuroscience. This dissertation provides a first of its kind account on how digital and music technology may be applied across these disciplines, examining individuals interacting with music and innovative digital technology throughout the human lifespan.

2 DIGITAL MUSIC TECHNOLOGY IN HEALTH AND EDUCATION

Digital and music technology are distinct tools for driving behavioural change. This is often due to the significant features which the technology affords to its user. As such, digital and music technology have become capable mechanisms in delivering and supporting healthcare protocols, and music therapists' professional practice. They are also used as an intervention for healthcare, wellbeing, education, and as a tool to assist academic teaching and music learning.

2.1 An Introduction to the Discipline of Music Therapy

There has been an increase in the use of music technology in the music therapy process across all music-therapeutic methods in facilitating patient-therapist interaction, supporting data collection and analysis of these interactions (Agres, et al., 2021a; Magee, 2018; Creech, 2019; Krout 2014). There are extensive findings supporting the efficacy of music therapy over a range of medical, psychiatric, and subclinical populations (Agres, et al., 2021a; Bradt, et al., 2021; Magee, et al., 2017). Music therapists assist people throughout the lifespan, and function typically as part of a multidisciplinary team. The populations under care include "developmental, medical, behavioural, health, palliative, forensic, and other at-risk populations" (Agres, et al., 2021a, p. 3).

Music therapy has developed as a profession and is used to support individuals living with mental health issues and physiological problems. Bruscia (2014) states that, "music therapy is a systematic process of intervention wherein the therapist helps the client to promote health, using music experiences and the relationships that develop through them as dynamic forces of change" (p. 19). According to the American Music Therapy Association (2021) music therapists assist the following client populations: developmental and learning disabilities; Alzheimer's and other ageing related conditions; substance abuse problems;

brain injuries; physical disabilities; acute and chronic pain. Subsequently, interventions have been developed involving the patient and therapist through the use of personalized music experiences, applying methods such as music composition and song writing. Music-therapeutic interventions are commonly subdivided into two broad classifications, such as active and receptive interventions (Magee, et al., 2017; Wheeler, 2015). Active interventions include the patient being involved in the music-making process, while receptive interventions entail that the patient listens to live or recorded music, responding by different means (Bruscia, 2014; Wheeler, 2015).

2.1.1 Healthcare

The term 'healthcare' is broadly used to include personal medical services, preventive medical, and public health measures. This also includes health and safety regulation, and certain social support services for the chronically ill or disabled populations (Daniels, 1985). More recently, there has been an acceptance that health involves more than providing healthcare (Gentry & Badrinath, 2017). As such, The World Health Organization (WHO) defines health as, "a state of complete physical, mental, and social wellbeing, and not merely the absence of disease of infirmity" (Constitution of the World Health Organization, 2022). Accordingly, there are different types of teams involved in healthcare practices. Common but not exclusive to the music therapy profession are cross-disciplinary practices. Cross-disciplinary practices often refer to, "work increasingly accomplished through collaboration among interdependent groups of disciplinary specialists" (Nicolini, et al., 2012, p. 612). Cross-disciplinary practice lends itself to multidisciplinary practice. Multidisciplinary practice refers to activities involving the work by a group of professionals from scientific and professional fields. In healthcare practice, this denotes professionals working in different sectors. These fields may intersect with clients or activities in medical areas. For example, a multidisciplinary team may contain professionals working in different medical fields such as (but not limited to) neurosurgery, oncology, rehabilitation medicine, psychiatry, physicians, and music therapy (Norrefalk, 2003).

Multidisciplinary teams have been found to practically improve collaboration between healthcare professionals (Bitter, et al., 2013) while the clinical fields, more generally, have been described as diverse and multidisciplinary (Erdemir, et al., 2020). Agres et al. (2021a) further expand on this multidisciplinary perspective, stating that music technology for health is within a multidisciplinary space, intersecting with topics including music therapy, music psychology and neuroscience, and music information retrieval. Wilson (1997) describes tensions between these disciplines due to different analysis techniques, methods, and approaches in knowledge creation. A distinction in the music therapy discipline, is that it employs a holistic approach whereby the therapeutic utilization of music is central to the goal of stimulating social, linguistic, physical, and affective dimensions. From this broad health perspective, music therapy examines functional outcomes such as measurable behaviours and physiological indicators of health and wellbeing. It further relies on subjective, first-person accounts by patients, as well as subjective second-person accounts by a guardian or therapist, which require self-reporting (e.g., pain, mood, and psychological distress) (Agres, et al., 2021a).

Music research has provided biomedical results leading to the advancement of evidence-based music interventions (Thaut, 2014). Researchers and clinicians have collaborated across disciplines in music therapy and neurology organizing these groups of results into a system of therapeutic techniques and practice known as neurologic music therapy (NMT). This system has allowed for the development of standardized clinical techniques supported by scientific evidence. NMT consists of 20 fundamental techniques defined by, "(1) a diagnostic treatment goal and (2) the role of the music - or mechanisms in the processes of music perception and music production - in achieving the treatment goal" (Thaut, 2014, p. 2). NMT's focus is on implementing music throughout the therapeutic process as a stimulus, influencing domains such as cognition and sensorimotor functions, as well as neurophysiological and neurological domains observed via scientific data (Thaut, 2014).

NMT's application is a clear example of applying findings of music-based interventions across different disciplines for health-related outcomes. Agres et al. (2021a) define this as a cross-disciplinary approach, stating that such an approach is appropriately suited for broad healthcare and practical therapeutic settings.

2.1.2 Multimodality

A multimodal approach to rehabilitation encompasses various approaches conducive to the therapeutic process. Therefore, rehabilitation and treatment selection become cooperative between assigned rehabilitation teams. As such, NMT is deployed across many neurological rehabilitation domains, with developed protocols for patients living with stroke, post-stroke neglect, aphasia, and Alzheimer's. In the case of stroke and post-stroke neglect, NMT involves musical activities. These are sometimes used adjunctly with other technologies applied as treatment tools to deliver an intervention including keyboards, electronic triggers (Silveira, et al., 2021), iPods, tablets (Silveira, et al., 2018), software, and Virtual Reality (VR). It follows that music activities and music based NMT interventions are based on activating neural plasticity in many brain regions (Sihvonen, et al., 2017). Indeed, multimodal activity is analogous to the neurochemistry of how the brain responds to music, potentially affecting a wide range of behaviours, including physical activity.

2.1.3 Physical Activity

Music elicits physical responses (Thayer, 1996). It can facilitate stimulation for physical activity, foster physical coordination and enable shared motivation to encourage physical movement (Weinstein, et al., 2016). In a study by Chastin and Granat (2010), there was preliminary evidence that sections of sedentary activity are 'power law' distributed, meaning that there is a practical relationship between periods of physically active and sedentary activity. A power law is a mathematical relationship between two quantities, where one quantity is proportional to the power of the other (Clauset, et al., 2009). It is commonly used to describe phenomena in which there are a few extreme values that dominate the distribution, while the majority of values are relatively small. A similar power law relationship is also observed in musical rhythms as Levitin et al. (2012), highlight the distribution of musical rhythm to fluctuate between repetition (consistent beats) and surprise (irregular beats).

Stimulating physical activity is congruent across the domains of music education, healthcare, and music therapy. For example, within education, Bakker et al. (2010) observed that children were able to engage easily in play, as well as concentrate on learning through interaction with objects. A similar relationship can be seen in children interacting with and playing a musical instrument (Hallam & Himonides, 2022). Sometimes, this is referred to as multisensory learning. The use of IT often requires physical interactivity (Laarni, et al., 2004) or the sensory interaction of computer interfaces. In healthcare, specifically in stroke rehabilitation, there is often the desired manipulation of a patient's physical activity in cases where limbs or portions of a patient's body have been rendered inactive due to cortical damage (i.e., by the stroke). Part of that manipulative stimulus may come by means of musical stimulus used to increase the physical activity of the patient and is understood to be how the brain processes musical stimulus.

2.1.4 Neuroscience and Brain Plasticity

Researchers examining the effect of music have significantly contributed to neuroscience research, and often associate the effects of music with neuroplasticity (Pantev & Herholz, 2011). Indeed, multiple brain functions are activated in music-making. These functions include perception, action, cognition, emotion, learning, and memory. According to Hallam and Himonides (2022), music is an ideal tool in showing how the human brain works, as well as how different brain functions interact with each other. Findings from Dalla Bella (2016), Strait and Kraus (2014), Herholz and Zatorre (2012) to name a few, have led to a richer understanding of cortical plasticity.

Fundamentally, how music influences plasticity changes in the brain can be observed in its neurochemistry. It is understood that the brain is a dynamic structure, with the potential to re-organize and re-wire itself, responding to intrinsic and extrinsic factors (Chatterjee, et al., 2021). This theoretical stance has been supported by rigorous scientific research and state-of-the-art scanning methods. According to Chatterjee et al. (2021) and Ripollés et al. (2016), the organization, quantity, and strength of neural connections in the central nervous system (CNS) develop with learning and experience, or during the recovery process from injuries and degenerative conditions. The ability of the CNS to create adaptive changes in its morphological and functional aspects, is referred to as neuroplasticity (Sasmita, Kuruvilla, & Ling, 2018; Chatterjee, et al., 2021). Generally, neuroplasticity is defined as "the ability of the nervous system to respond to intrinsic and extrinsic stimuli by reorganizing its structure, function and connections" (Cramer, et al., 2011, p. 1592).

Individuals engaging in various musical activities over long periods of time can elicit permanent changes in the brain (Hallam, 2016). Extensive engagement with music activates cortical reorganization, producing functional adaptations in how the brain processes information (Hallam & Himonides, 2022). Overall, the evidence of active engagement with music has a significant impact on brain structure and function (Merrett, et al., 2013; Norton, et al., 2005). Across cultures and the life span, musicians, and non-musicians alike experience music on a daily basis passively (e.g., by listening to music) or via active participation (e.g., playing an instrument, singing, and dancing) (Hallam & Himonides, 2022). The findings from music and neuroscience show the relevance of both innate (e.g., genetic) and environmental factors in shaping the brain (Zatorre, 2013). The domains of interest within this area include, perception, emotion as well as reward stimulated by music listening and music-specific disorders (e.g., acquired, and congenital amusia, Stewart, 2011). The multisensory experience of music engages our sensory, motor, and cognitive systems, involving a wide range of brain structures. Music stimulates plasticity in neuronal networks, which adhere to more general functions. These are relevant when implementing and developing music-based health interventions for the purpose of rehabilitation in various neurological diseases, such as stroke, dementia, neglect, and Parkinson's disease (Särkämö, 2018; Sihvonen, et al., 2017).

In summary, the neuroscientific study of music has been validated using standardized procedures and measurements (Särkämö, 2018), applying highly controlled protocols to identify a musical intervention's neural effects (Sihvonen, et al., 2017; Dalla Bella, 2016). Music interventions have been evaluated by controlled studies focusing on the neuronal networks beneficial effects (e.g., reward, plasticity of sensorimotor systems, arousal, affect regulation, Sihvonen, et al., 2017). This has provided foundational evidence that music may enhance well-being throughout the lifespan, activating numerous brain networks, demonstrating high potential for supporting and aiding in the recovery of brain function (Särkämö, et al., 2008), providing reward value (Salimpoor, et al., 2015), and engaging multiple cognitive processes (Hurwitz, et al., 1975; Flohr, 1981).

2.2 An Introduction to the Discipline of Music Education

There are broad meanings and variations in the term 'music education'. Often focused on learning to play an instrument, a 'complete' music education is applicable to many areas of learning. The benefits of a music education can be viewed across different cognitive domains. Several studies point to evidence that music education has on specific cognitive skills (Bugaj & Brenner, 2011; Costa-Giomi, 2004; Pitts, 2014, 2017; Schellenberg, 2012; Standley, 2008; Tierney & Kraus, 2013). A study by Hallam and Rogers (2016) found that playing an instrument lead to better academic outcomes. This finding is known as a transfer effect. A transfer effect is commonly divided into two domains: (1) near transfer, and (2) far transfer (Postman, 1971; Barnett & Ceci, 2002). These effects have been further described in terms of low and high road transfer (Salomon & Perkins, 1989). Near, or low road transfer, refers to the domain of learning associated with musicianship, and the cognitive processes involved when students learn to sing or play an instrument. Far, or high road transfer, refers to the effects of music education on academic achievement in different fields, such as mathematics (Barnett & Ceci, 2002). Accordingly, researchers argue that playing music or singing has the capacity to enhance cognitive functions such as memory (Chan, et al., 1998; Ho, et al., 2003), reading (Standley, 2008; Corrigall & Trainor, 2011), writing (Anvari, et al., 2002), mathematical skills (Vaughn, 2000; Hodges & O'Connell, 2010), spatial reasoning (Bilhartz, et al., 1999; Hetland & Winner, 2004), and intelligence (Degé & Kubciek, 2011a). Yet, research on far or high road transfer is inconclusive, as the studies are inconsistent in their applied methodologies. In addition, it is disputed as to whether these effects can be proved or disproved, as they are highly complex phenomena to measure.

Hallam and Himonides (2022) state that some musical skills are more likely to transfer than others. For example, transfer effects relate to the perceptual grouping of information, fine motor skills, conceptions of associations with written materials and sound, reading music and text, and the memorization of extended information (Norton et al., 2005; Schellenberg, 2003). Furthermore, when learning to play a musical instrument, a student is able to recognize personal strengths and weaknesses and become aware of a range of possible strategies (both task-related and personal) associated with motivation, concentration and monitoring progress and evaluating their outcomes.

2.2.1 Information Technology in Music Education

In recent years, computer use has been deemed to be an inevitable part of school pedagogy. According to Jeong and Kim (2017), teachers should be encouraged to use IT within and during classes. Notably, Chauhan's (2017) meta-analysis indicates that IT is an effective tool in specific learning domains. Breakthroughs in IT and their applications have served to improve conceptual and theoretical understandings for students using them (Chauhan, 2017; Koong & Wu, 2011). IT has also had a general impact on teaching and learning methods affecting key competencies. Additionally, it has been shown that IT helps foster better connections between learning and a student's life (Voogt & Roblin, 2012), as students consider its use analogous to their own lived experience. Thus, research that has involved learning by means of IT has demonstrated effective learning by students (Taşkm & Kandemir, 2010). Despite these findings, there are reports of technology integration in the classroom remaining challenging - specifically in terms of purpose, support, and barriers for use (Blackwell, et al., 2014; Wood, et al., 2008).

Himonides (2018) argues that technology - which extends to learning or playing music - can be seen as any other tool that supports teaching and learning. The author outlines that these tools: (1) equip learners for life in a broader sense;

(2) engage valued forms of knowledge; (3) recognize the importance of prior learning and experience; (4) teachers utilize a scaffold learning strategy; (5) assessment is congruent with learning; (6) enable active engagement of the learner; (7) cultivate both individual and social processes as well as outcomes; (8) acknowledge the significance of informal learning; (9) help with teacher learning; and (10) require support for consistent policy frameworks with teaching and learning as its primary focus.

IT in the music classroom functions on generally dependent ubiquitous device principles, including functionality and ease-of-use. Specifically, the Article IV study uniquely discussed Human Computer Interaction (HCI) concepts such as the functionality (Hillier, et al., 2015) of music technologies in the classroom, using the theoretical perspective of perceived ease-of-use, adapted from the theoretical framework of the Technology Acceptance Model (TAM) (Davis, 1985). TAM provides general reasons for technology acceptance in a given context, helping us explain user behaviour when students use technology in the classroom. Essentially, TAM helped us understand why a particular device in the classroom was either acceptable or unacceptable to a music student. A crucial factor related to computer acceptance behaviour, perceived ease-of-use, is stated to be the amount of effort the user expects to place into interaction while using the technology (Davis, et al., 1989), and was measured as part of Article IV study. This is further discussed in detail in the subsequent sections of the dissertation.

2.3 Intersections Between the Disciplines of Music Therapy and Music Education

In order to examine how music and digital technology are distinct tools for driving behavioural change, there is the necessity to combine knowledge from the disciplines in which they operate to bridge several gaps. The disciplines within which digital technologies operate regarding this dissertation are music therapy and music education. Indeed, multi-, and cross-disciplinary approaches are well suited for these purposes. The approaches can be considered highly effective (Agres, et al., 2021a) in terms of addressing complex problem areas. Obstacles to the approaches between the disciplines reside in a) their encompassing aims with specific research and development goals; and b) differences in research approaches, methodology, and outcomes. Therefore, in the following sections my aims are to present how the different studies in this dissertation bind together, how their research initiatives satisfy the respective disciplines, and to acknowledge their differences.

Gaps can be identified between both disciplines' approaches and different research areas. To illustrate, tensions exist in the use of differing practical approaches and methodologies where research is conducted. For example, music therapy uses broad holistic approaches, whereby the therapeutic use of music is central to the goal of stimulating physical and affective areas (Thaut & Volker, 2014; Agres, et al., 2021a). Music education uses a range of pedagogical approaches, encompassing the multifaceted goal of broad developmental transfer associated with literacy, mathematical, self-regulation, aural perception, and instrument learning development in students (Hallam & Himonides, 2022).

2.3.1 Similarities Between Music Therapy and Music Education

Music therapy applies a range of methodological techniques often regarded as holistic approaches to research areas (McFerran, 2010). Generally, these holistic approaches can be found in the phenomena of outcomes music therapy examin es, such as functional outcomes. Functional outcomes are measurable behaviour s and physiological indicators of health and wellbeing. These indicators rely on subjective first-person accounts by patients and subjective second-person accounts by a significant other or therapist, requiring self-reporting (e.g., pain, mood, and psychological distress).

Welch et al. (2004) write that the methodologies in music education are wide ranging and can encompass naturalistic observations as well as experimental research. The research focus may include topics such as curriculum evaluation, musical motivation, and music therapy to name a few. Similarly, Young (2016) writes that there is variation in the methodological approach used in childhood music education, and this has been impacted by historical-cultural traditions, reflecting academic environments in various countries. For instance, researchers in North America lean towards quantitative approaches inside a reasonably positivist paradigm. Researchers in Europe (specifically, Northern Europe) apply qualitative approaches within a phenomenological paradigm. Similarly, applied research in music therapy areas contain methodological variation, and depending on the intervention goals, can include holistic or experimental protocols.

Accordingly, applied research in the areas of music therapy and education focus on the effectiveness and generalizability of their findings (Sihvonen, et al., 2017). This is similar to the broader definition of applied research, stated as, "striving to improve our understanding of a problem, with the intent of contributing to the solution of that problem" (Bickman & Rog, 2008, p. 9). Applied research in music therapy and music education aims to bridge the professional divide in research and practice. Thus, a goal found in many applied research projects is to problematize music practices in music therapy and education, with the aim of changing and improving them (Young, 2016; Smith, 2008). Such an approach has the advantage of being theory-driven as well as based on empirical validation from clinical populations. For example, in music therapy contexts, Randomized Controlled Trials (RCTs) are designed and used to collect quantitative data from specific clinical populations. This is done, in part, via testing large samples of patients in RCTs, using standardized outcome measures spanning from behavioural tests to neurological measurements (e.g., Functional Magnetic Resonance Imaging, fMRI, Electroencephalogram, EEG). RCTs often include an active control non-music condition, enabling the targeting of benefits specific to musical perception and musical activities (Särkämö, et al., 2008, 2013). Similarly, in music education contexts studies which correlate music participation with academic performance, as well as comparative study groups and control condition groups, are often operationalized.

2.3.2 Differences Between Music Therapy and Music Education

There is tension found in the literature describing the philosophical and methodological approaches across these two disciplines. In the music therapy discipline, NMT's philosophical approach is viewed with criticism by several music therapy scholars. Brodsky and Briggs (2016) argue that NMT too conveniently places music therapy into a neuroscientific context. Essentially, while NMT's methods and techniques are aligned with standardized research protocols (with the goal of methodological replication), it only uses music adjunctly to treatments. This is uncharacteristic of traditional music therapy, as music has previously been at the centre of the discipline. However, Thaut and Volker (2016) argue that NMT is a clinical translation of a neuroscientific research area, which prior to their establishment of the NMT field, did not exist for music therapy.

The music education literature reflects differences in understanding generalizability from music learning interventions. For instance, Standley's (2008) meta-analysis states that a strength and weakness of music education interventions rests in the diverse methodological designs of studies, which renders it difficult to produce generalizations. Both music therapy and education disciplines apply holistic (e.g., interpretivist epistemology, as measured by qualitative data) and experimental (e.g., objectivist epistemology, as measured by quantitative data) approaches within their methodologies. Occasionally this highlights an inherent tension inside the scholarship of each discipline. Where a holistic approach may be seen by experimental researchers as lacking in methodological rigor, there are also concerns for the ability to practice evidence deemed acceptable that would be in line with medical or educational intervention standards. Experimental protocols may be found in the neurology-based literature within music therapy (e.g., NMT), and intervention-related literature within music education (e.g., transferability of music education to cognitive skills). Holistic approaches (as measured by qualitative data) are found in both disciplines when measuring emotional, social, or psychosocial dimensions of music-related affect.

Further, technological developments in health-related research allows for an increased ability to adequately facilitate the bridging of these challenges by combining holistic and experimental protocols. For example, in the Danso et al. (2022) review, it is reported that VR interventions can impact both the experimental (e.g., quantitative measures of muscle recovery) and holistic dimensions (e.g., qualitative quality of life reports) of a subject. According to Carlson and Cross (2021), such technological developments will allow music therapy to emerge as an early leader towards individualized medicine. Moreover, some music education experimental protocols have shown positive results for the teaching of social values to children through the lyrical content of songs (Erhan & Aylin, 2020). This presents a significant holistic impact.

2.3.3 Technology Mediates Interactivity Between the Disciplines of Music Therapy and Music Education

In this dissertation's studies, technology plays a crucial role in mediating interactivity between the music therapy and music education disciplines, fostering an understanding of human subjects and their interactions with technology. Such understanding is highly significant in both music therapy and music education settings and practices due to their integral functions. For instance, in music therapy practices, the pursuit of patient-centred care necessitates the design and implementation of technological systems that align with patients' needs, preferences, and capabilities (Agres, et al., 2021a). The explicit reference to affordance theory in the following section (see section, 2.4 Affordances) assists in describing principles during the design and development stages of technological applications used in these settings. Often, by using affordance theory, the goal is outlining a more efficient utilization of technology across these domains. Specifically, this theory focuses on identifying action-perception couplings to discern how users perceive and interpret feedback provided by technology (Norman, 1999). Consequently, applying affordance theory can optimize feedback and error handling when employing specific technologies across music therapy, and music education disciplines. Furthermore, understanding human activity via technology use within these disciplines contributes to music related neuroscientific research through data acquisition and biomarker measurements (such as fMRI and EEG sensors), leading to more robust research outcomes.

In light of these considerations, the methodologies employed in the thesis aimed to enhance the understanding of human subjects and their interactions with technology across music therapy and music education disciplines. For example, the utilization of a cross-sectional survey (Article I) and a perceptual survey (Article III) provided a snapshot of human behaviour and experiences at specific points in time, generating valuable data for benchmarking and future comparisons. In addition, the narrative review (Article II) identified research methodologies and protocols used when combining VR technologies with music therapeutic practices. Lastly, the application of a mixed-method approach (Article IV) facilitated a comprehensive data collection and analysis procedure to better comprehend the complex dynamics among the sample's interactivity with experimental music technology.

2.4 Affordances

In this dissertation I refer to the concept of affordances from an ecological position. An ecological position refers to the relationship between an organism and its environment (Windsor & De Bézenac, 2012), and in the way that the environment provides opportunities and constraints for the possibilities of action (Heft, 1997). Gibson (1979) originally defined affordances as features of the environment that define what action possibilities are available to a user. For example, a guitar affords playing musical notes and chords by the plucking or strumming of its strings. Salomon (1997) extended the concept of affordances in relation to IT, stating, "it is the perceived and actual properties of a thing, primarily those functional properties that determine just how the thing could be used," (Salomon, 1997, p. 51).

Norman (1999) expanded on concepts associated with affordances as they relate to aspects of design. Crucially, objects contain multiple design features, such as affordances, feedback, and perceived affordances. These features can be engaged independently or simultaneously by the user. A perceived affordance is information that is perceivable by the user. It refers to the user's interpretation of an affordance based on their prior knowledge, experience, and expectations. Norman (1999) argues this is useful in relation to interacting with technology, as it helps users understand how they can interact with it, which can provide designers and researchers relevant information regarding its usability and overall user experience. Consequently, this can increase the likelihood of a successful interaction.

Most importantly, here I will make a distinction between use of the term 'affordance' and 'perceived affordance' and the reason why I refer to the latter throughout *Chapter 5's Discussion*. Gibson's (1979) definition is independent of the information which the user provides (e.g., their personal experience) or is provided (e.g., the information that the technology provides the user), and is only referring to the capabilities of the use or action of a specific object or user. Norman (1999) refers to the term perceived affordances as: (1) "a sign for what [the technology] is for, what is happening and what the alternative actions are;" (Norman, 1999, p. 18) (2) making relationships between how the use of a tool or technology can be dependent on prior knowledge or experience of the user; and (3), if using the technology is difficult or easy to interact with. In line with the studies in this dissertation, which are primarily concerned with music-related human activity in music therapeutic and educational contexts, Norman's (1999) definition of perceived affordances will be acknowledged throughout *Chapter 5's Discussion* and subsequent sections. This definition of perceived affordances also corresponds with Himonides' (2018) previous argument, regarding how technologies are appropriately optimized as tools to support learning (see previous section, e.g., *Information Technology in Music Education)*.

Music contains specific affordances which indicate its functionality as a tool to be used in therapeutic and educational settings. For example, music affords adherence and motivation in health contexts (Devlin, Alshaikh & Pantelyat, 2019), the stimulation of physical activity (Terry, et al., 2020), entrainment and motor coordination (Clayton, et al., 2020) and concentration (Bugos & Wang, 2022). Technology provides affordances that allow its users to complete a variety of tasks to achieve specific goals (e.g., accessing the internet), and when combined with music, grants users to create, interact and manipulate audio in novel ways (e.g., music production software). Applying music-related technology in health and education settings provides affordances to users by making new information perceivable to its users, enabling, and enhancing actions that would otherwise be limited should the technology not be available. For instance, the perceived affordances in VR (which include the ability to grasp and manipulate virtual objects) are crucial in influencing the user's experience and subsequent effectiveness of interaction. Using this technology alongside sound and music, helps with the achievement of goals that are conducive to motor rehabilitation, such as patient adherence (e.g., creating immersive tasks that involve repetitive movement), or education, such as maintaining concentration on a classroom task.

Given the above, affordance theory focuses on how users perceive and interact with objects or technologies based on their perceived functionalities or potential actions. By applying this theory to technological tools used in music therapy, and music education, one can enhance their design and functionality to achieve specific outcomes. For instance, in music therapy, NMT sessions which incorporate specific technologies such as buttons and music-based user-interfaces to theoretically target patient adherence and motivation, can be made more efficient in achieving this goal by incorporating affordance theory during their planning stages. Thus, when considering the affordances of these technologies during a session's planning stages, therapists can make the sessions more efficient.

3 TECHNOLOGY APPLICATIONS USED IN THE DISSERTATION

In the following subsection I describe the background and types of digital and music technologies, devices and interfaces used in the four articles of this dissertation. Additionally, I explain their specific aims when applied as interventions within their respective studies.

Musical interventions are known to activate various neural pathways in the brain. Accordingly, neurobiological mechanisms that activate neural systems in reward, arousal, affect regulation, learning, and activity-driven plasticity are induced. Musical activities such as music listening and playing musical instruments improve neuronal connectivity in the brain regions of healthy participants. These activities also activate grey and white matter changes in multiple brain regions (Sihvonen, et al., 2018; Zatorre, et al., 2007; Koelsch, 2014; Särkämö, et al., 2013a; Alluri, et al., 2012). With regards to neurological rehabilitation, Sihvonen et al. (2017) state that music-based interventions can affect various neurological functions including motor performance, speech, and cognition. Regarding the major neurological disorders, according to Sihvonen et al. (2017), the strongest evidence for the efficacy of music therapy interventions has been found in stroke rehabilitation. These have been identified in sixteen RCT studies. Gregory (2002) found that music therapy practice supported neurological rehabilitation, reporting that a sustained listening intervention maintained selective attention in elderly people with debilitating diagnoses affecting cognitive processes. In addition, Särkämö et al. (2008) found enhanced recovery of verbal memory and focused attention in patients undergoing recovery after a middle cerebral artery (MCA) stroke. This was observed when they were treated with self-directed music listening.

Practically speaking, music therapy has evolved its neurological rehabilitation interventions by borrowing and combining techniques applied in physio- and occupational therapy (Järvinen-Lepistö, Burger & Ala-Ruona, 2015). For instance, Schneider et al. (2010) found that music-supported training was more effective in the recovery of fine motor functions when compared to CIMT and standardized physiotherapy (Wolf, et al., 2008). Patients within the

Schneider et al. (2010) study reported the music-supported training as motivating, which is identified as clinically important (e.g., positively impacting patient adherence to treatment) in a stroke patient's successful recovery process (Järvinen-Lepistö, Burger & Ala-Ruona, 2015; Holden, 2005). In addition, prior evidence exists for the use of music as an effective training modality regarding the rehabilitation of neglect. Frassinetti et al. (2002a; 2002b) provide evidence that auditory stimuli can enhance visual perception during the rehabilitation of neglect.

Music education interventions (sometimes referred to as pedagogical solutions) often measure transfer effects. The literature discussing near transfer in music education holds consensus regarding what type of content is transferred. For instance, skills such as fine motor control, the perception of pitch, timbre, melody, sound differentiation, and creativity, are known to be associated closely with musical learning activities (Jaschke, et al., 2013). In contrast, the far transfer effect of music education to other subject areas such as mathematics, languages etc., remains dubious. For example, in a study that used piano instruction as an intervention, a positive transfer effect on children's self-esteem and musical academic achievement were found (as measured by standard assessments and school report cards, see Costa-Giomi, 2004). Yet, no far transfer effects from the intervention in other subjects, such as languages and mathematics, were reported (Costa-Giomi, 2004). However, transfer effects of music education to general intelligence have been reported. Schellenberg (2004) presents findings in music lessons enhancing intelligence quotient (IQ) test scores, with a relatively small effect size. The effect of the music lesson intervention is shown across IQ subsets, index scores, as well as a standardized measure of academic achievement. The length of time of the transfer effect has also been widely discussed. In a longitudinal study (one year in length) Ho et al. (2004) found that transfer effects from musical interventions remained for a length of time. In their study they tested a musical training intervention with children. Their results showed that children who participated while using the intervention demonstrated better verbal memory than a control group, who did not receive musical training. As these children were followed up a year later, those who had begun, or continued music training reflected significant verbal memory improvement. However, the investigation of far transfer remains an area of debate for researchers. Accordingly, interventions have been deployed to further investigate these areas.

Moreover, what specifically is transferred when we discuss transfer effects? Barnett and Ceci (2002) state that the content learned can be broken down across three dimensions: a) the specificity-generality of the learned skill; b) the nature of the performance change assessed; and c) the memory demands of the transfer task. The second dimension of transfer content, performance change, which refers to the "measure against which improvement is expected" (Barnett & Ceci, 2002, p. 622), is an aspect that we measured using the novel KAiKU Music Glove, applied to learning outcomes in a childhood music classroom in Article IV.

Given the above, what is the additional content transfer from technology, as it is applied across various contexts? And where is the music directly used (e.g., the music classroom), or peripherally used (e.g., using music as part of multidisciplinary rehabilitation practice)? What happens as a product of these dynamics? We pursued a similar line of inquiry across our four studies. This inquiry entailed the underpinning questions of: (1) what is the role of teleh ealth technologies in professional healthcare practice for music therapists?; (2) what rehabilitative effects can VR and MNT interventions provide on a post-stroke neglect population?; (3) what role could musical sonification have on stimulating physical activity in elderly subjects?; and (4), would an experimental technology affect music learning when compared to an established technology? Hence, we examined state-of-the-art and experimental interventions across these multidisciplinary contexts, ranging from professional practices, physical activity stimulation, rehabilitation, and education.

3.1.1 Telehealth technology (Article I)

Throughout the height of the COVID-19 pandemic, the use of telehealth technology was crucial for the delivery of healthcare. Specifically, telehealth technology has been defined as, "the use of medical information that is exchanged from one site to another through electronic communication to improve a patient's health" (Tuckson, et al., 2017, p. 1585). According to music therapy activities, telehealth technology is often utilized to provide care without face-to-face or physical contact with a patient, facilitating video consultations and giving its clients a sense of normalcy (Leandertz, et al., 2021).

3.1.2 Virtual Reality (Article II)

VR systems rely on computer hardware and software to create and facilitate interaction between the user and virtual environment (Shu, et al., 2018). In rehabilitation contexts, the user of VR typically involves a patient being presented with visual-audio stimuli provided through a head-mounted display (HMD) to create real-time feedback. Additional feedback can be provided by involving the patient's senses (such as physical movement, sound, or touch) utilizing different interaction devices. A patient can interact with virtual environments using various inputs, for example, sensors, haptic devices, joysticks, or cameras (see e.g., Article II for a detailed description).

VR has undergone testing and analysis as a medical tool to aid in patient recovery, particularly motor rehabilitation. Due to its capacity to promote realistic movement in task-based settings for enhancing motor function, the technology has gained recognition as a useful tool for use in motor rehabilitation. Various studies have identified the benefits of using VR applications in motor rehabilitation settings. The results of recent studies report improving balance, endurance, dexterity, speed, and active range of motion (AROM), particularly in the participant's upper limbs (Holden, 2005; Viau, Feldman, McFadyen, & Levin, 2004). VR applications are often games (or in rehabilitation contexts, 'exergames'), encouraging participant interaction in the form of exercises, which focus on improving motor control (De Bruin, et al., 2010). Given that these VR applications stimulate movement that does not require real-world interaction, they may be viewed as a secure way to practise movements linked to motor function. Simply put, as a participant engages with VR during rehabilitation, they avoid the potentially disastrous effects of dysfunctional movement in a real-world environment.

3.1.3 Musification of Daily Activity (Article III)

Musification of Daily Activity is a system developed by Mendoza et al. (2022) to produce musical sonification of daily activity data recorded by wearable devices. In order to do this, data was used from two participants who wore two accelerometers attached to their chest and thigh. The accelerometer recordings corresponded to a low-activity sedentary subject, while the other corresponded to a high-activity non-sedentary subject.

In Article III's study, sonification is presented as a tool for raising awareness and influencing behaviour change by presenting daily activity information to users in a clear and engaging way. Sonification is the process of converting data into sound. In Article III, we propose that sonification can be used to provide immediate feedback to patients with mobility problems about the quality and amount of movement throughout the day, allowing them to make potential adjustments to their overall physical activity the following day.

Challenges to physical activity interventions have included engagement and long-term adherence. In line with our promising findings, we argue that musical sonification is one potential strategy to counteract these challenges. We aimed for this intervention to be used as a tool to drive behavioural change and raise awareness of physical activity in populations that may be hard to reach. These populations include older adults, or those with visual and/or learning difficulties.

3.1.4 KAiKU Music Glove (Article IV)

The KAiKU Music Glove is a touch-triggered musical MIDI controller. The glove is worn on one hand, and the other/opposite hand presses the sensors that are built into the glove's fingers. The sensors have been arranged by the manufacturer in a practical manner and are positioned primarily for educational uses in the instruction of music theory. Two rows of touch sensors are positioned on the controller, which is presented as a potentially efficient way to teach the musical scale. For instance, as both the teacher and students wear the glove, the device may support the teaching of interval and chord structures. This approach is an attempt to optimize the process of music teaching and learning (Paule-Ruiz, et al., 2016) based on the Kodály method (Harrison, 2021).

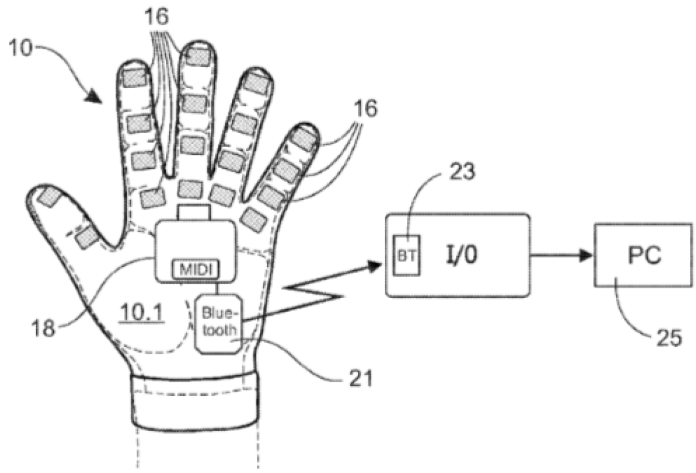

FIGURE 1. A diagram showing the KAiKU Music Glove connected to a computer through a musical instrument digital interface (MIDI) and Bluetooth (BT) (PC), (for more information see e.g., Article IV).

3.2 Future Directions

When observed together, these various devices and digital technologies support music therapy and education sessions, using multiple input signals (both technologically and sensory) from specific interfaces, e.g., telehealth technology, to entirely custom-made interfaces, e.g., KAiKU Music Glove. These allow professionals, patients, and students to engage in unique musical activity. Considerations that influence the adoption of these technologies reside in e.g.: their costs; VR, continuous development (technological maturity levels); Musification of Daily Activity; their ease-of-use, e.g., KAiKU Music Glove; the training needed to use the technology, e.g., telehealth technology; and crucially, if the technologies transfer to clinical and educational outcomes significantly. These considerations need to be taken into account in the future development of technology intended to be used in therapy and training environments.

4 AN OVERVIEW OF RESEARCH AIMS AND METHODOLOGIES

Central to the aims of the dissertation, the methodologies captured evidence in examining how music and digital technologies are distinct tools for driving behavioural change across the music therapy and music education disciplines. Article I reported qualitative findings related to how technology, namely telehealth technology, functioned as a crucial intermediary device between client and therapist. Similarly, Article II applied a qualitative methodology to establish unique intersections in music therapy and VR interventions. Article III combined a quantitative and qualitative methodology to understand the development and assessment of an algorithm to stimulate physical activity. The mixed-method research approach found in Article IV combined quantitative data, e.g., learning performance results, both qualitative and quantitative data, e.g., user experience surveys, and qualitative data, e.g., observed behaviour, situating the study at an intersection of device combined human interaction analysis. These methodologies combined provided a unique analysis encompassing experimental and holistic-related findings.

The dissertation contains four articles, each presenting different methodological approaches. Conversely, there is considerable convergence between them, as they analyse music and digital technology as a purposeful intervention toward diverse identified populations. The aforementioned articles demonstrate significant overlap and interconnections concerning the influence of technology on various aspects of music therapy and music education. Several key areas of convergence can be identified:

1. **Technological integration in music therapy practice:** Both Article I and Article II investigates the incorporation of technology within music therapy practice. Article I specifically focuses on the integration of telehealth technology during the COVID-19 pandemic and emphasizes the advantages and challenges associated with its implementation. Article II explores the combined utilization of virtual reality (VR) technology and

auditory cues in music therapy interventions tailored to stroke and neglect populations.

2. **Adaptation of music therapy practice:** Both Article I and Article II examine how music therapists adapt their practices in response to technological advancements. Article I investigates the adaptations made by music therapists to their therapeutic approach when utilising telehealth platforms. On the other hand, Article II explores the integration of VR technology with music therapy techniques to address neglect bias.

3. **Assessment and outcomes across music therapy and music education:** Article II and Article IV examine the evaluation of outcomes in music therapy and music education. Article II provides a comprehensive review of interventions and assessments used in VR and music therapy research for stroke and neglect populations. Meanwhile, Article IV examines learning performance and concentration-related behavioural patterns within music education, exploring the impact of various technologies.

4. **Wearable technology and behavioural change:** Article III and Article IV discuss the application of wearable technology and its potential in facilitating behavioural change. Article III focuses on the development of a system that employs musical sonification of daily activity recorded by accelerometers to raise awareness and promote physical activity. Similarly, Article IV investigates the effects of the KAiKU Music Glove, a wearable device, on learning outcomes and concentration-related behaviour in music education.

5. **Technology acceptance and user experience:** Both Article IV and Article III examine the perceived ease of use and user experience of different technologies. Article IV incorporates the Technology Acceptance Model (TAM) to examine students' expectations and experiences with assigned technologies such as the iPad and KAiKU Music Glove. Conversely, Article III examines participants' perceptions and identification of musical sonifications based on the recordings of daily physical activity levels.

These articles converge in their exploration of technology's role in music therapy practice, the adaptation of music therapy approaches, the assessment of outcomes across music therapy and music education, the utilization of wearable technology for behavioural change, and the investigation of technology acceptance and user experience within music education. Cumulatively, the results from these articles will provide answers to following research questions in Chapter 5:

What types of affordances are present in technologies utilized in music therapy and educational settings?

How can feedback be used across music therapy and educational settings?

What practical ways can digital and music technology be used by music therapists and educators?

4.1 Summaries of Articles

4.1.1 Article I

Background and Aims: After COVID-19 was declared a global pandemic on 11th March 2020, music therapists around the world adapted their practices accordingly. Music therapy clinical practice is known for its adaptiveness, enabling flexibility to accommodate for and target specific client needs during sessions (Leandertz, et al., 2021; Bruscia, 2014). As social distancing measures were part of a global response to decrease the transmission of COVID-19, it was acknowledged that telehealth technology would play a distinct role in the delivery of healthcare services. It therefore saw rapid adoption across international organizations. Telehealth specifically refers to activities used in delivering care without face-to-face or physical interaction with patients (Wosik, et al., 2020). Such an adaptation may pose challenges and risks toward music therapy practice. A lack of technical knowledge as part of therapeutic practice, as well as establishing best practice methods and the requirement for training in relation to clinical activity were identified as necessary to carry out music therapy practice. Furthermore, the integration of telehealth software in a clinical music therapy setting is a relatively unknown phenomenon, since there is little standardized information available, as to how to establish this with common protocols and ethical codes (Rowland, et al., 2020). Therefore, the aims of this study were to investigate the COVID-19 pandemic's effects on the professional practice of music therapists.

The research questions in this study were the following:

How has the COVID-19 pandemic impacted music therapists' practices?

Does a global pandemic change music therapists' self-perception of their professional identity?

How has music therapists' use of technology in their practice changed during the COVID-19 pandemic?

Objectives: The objective of this study was to examine the disruption of professional music therapy practice caused by the COVID-19 pandemic. Furthermore, we investigated the integration of telehealth technology as part of music therapy practice.
Methods: In this article we used a cross-sectional survey design, applying a qualitative analysis to the survey responses. This provided us with rich descriptive data. The methodology was highly apt for its purpose, considering the design of the survey and small yet specific sample size (*N* = 77).

Results: Our results provided an unprecedented understanding of how technology enabled the delivery of music therapy during a global pandemic. Specifically, using the telehealth platform allowed music therapists to conduct sessions remotely. Music therapists reported altering their approach to sessions due to the telehealth platform itself. For instance, due to audio delay, music therapists opted for the use of call-and-responses music therapy techniques or turn-taking techniques, pre-recording musical aspects of their sessions, or transitioning entirely to receptive therapy. Consequently, we found both benefits and challenges for the use of telehealth technology in the support of music therapy practice. For example, telehealth technology provided increased client accessibility, as well as enabled the delivery of music therapy during the COVID-19 pandemic. Additional benefits were found in the music therapists' operational outcomes (e.g., a positive business impact and continuation of therapeutic practice) and benefits to the professionals' workflow (e.g., simplicity of using telehealth software in some sessions). The challenges identified were mainly caused by situational changes, as well as the strain of adaptation to telehealth technology. For example, music therapists reported:

- The need to adapt cross-functionally within their professional role (e.g., switching from music therapist to counsellor);
- The need for additional technological competence;
- The lack of acoustic instruments that could be used effectively while using telehealth technology;
- Therapist fatigue while using telehealth technology;
- The lack of connection with their clients.

While our findings emerged as unique at the time of publication due to the nature of remote music therapy during a global pandemic, they were in fact in line with existing literature discussing telehealth technology's strengths and limitations (Agres, et al., 2021b; Smith, et al., 2020; Wosik, et al., 2020; Nagler, 2014; Hahna, et al., 2012).

4.1.2 Article II

Background and Aims: The focus of this article was to investigate the combined use of VR technology and auditory cues to neutralize neglect bias. This was by identifying and describing interventions and assessments in VR and music therapy research applied to stroke and neglect populations. This aimed at providing an understanding of whether or not such an intervention is applicable for treating neglect.

Objectives: This review summarizes evidence of existing interventions and assessments used for post-stroke and neglect populations in VR and music therapy research. In addition, an exploration of VR's purpose to be used adjunctly as an intervention in music therapy practice is provided within the article's commentary.

Methods: In conducting this review, we completed non-systematic searches of the PubMed and PsycINFO databases. We applied a qualitative methodology to provide a line of deep inquiry in combining VR with music therapy (specifically, combining VR with the Neurologic Music Therapy, NMT technique of Musical Neglect Training, MNT), taking the form of a narrative review. A narrative review aims to summarize the authors' findings in a condensed format, typically encapsulating the content of each article (Green, et al., 2006). The review reported on both typical qualitative measurements (such as, measurements of activities of daily living survey results) and quantitative measurements (such as, neuroimaging evaluation results).

TABLE 1. Reports on the objectives/goals, interventions, study designs, and findings of the studies examined in Article II (for more information see, e.g., Article II).

Study Title	Author(s) and Reference	Study Objective/Goals	Intervention	Study Design	Number of Participants	Outcomes
Musical Neglect Training for Chronic Persistent Unilateral Visual Neglect Post-stroke	Kang and Thaut (2019)	Spatial Neglect Symptoms	Musical Neglect Training *6-weeks follow up	Pre- and Post- Test Design	2	Albert's Test, Line Bisection Task *1-week follow-up
Rehabilitation in Chronic Spatial Neglect Strengthens Resting-state Connectivity	Wåhlin, Fordell, Ekman, and Lenfeldt (2018)	Stroke severity, Awareness of physical sensation, Unilateral Neglect severity, Neglect severity, DAN Analysis, Brain Functional Anatomy	RehAtt®	Between Group Design	13	fMRI *1-week before intervention *1-week after intervention Star Cancelation Test, Line Bisection Task, Behavioural Inattention Test, Visual Extinction Test, VR-DISTRO battery *1-2 weeks between assessments *1-week follow-up
Increase of Frontal Neuronal Activity in Chronic Neglect Training in Virtual Reality	Ekman, Fordell, Eriksson, Lenfeldt, Wåhlin, and Eklund (2018)	Stroke severity, Unilateral Neglect severity, Neglect severity, Awareness of physical sensation, Attention Behaviour	RehAtt®	Between Group Design	12	Catherine Bergego Scale, Star Cancelation Task, Line Bisection Task, Visual Extinction Test, Baking Tray Task, *Posner Cueing Task 1-2 weeks between sessions * fMRI scan 1-week before intervention and 1-week after intervention
Differing Effects of an Immersive Virtual Reality Programme on Unilateral Spatial Neglect on Activities of Daily Living	Yasuda, Muroi, Hirano, Saichi, and Iwata (2018)	Visual Neglect severity, Unilateral Neglect severity, Stroke severity	Immersive VR programme	Case Study	1	Line Cancellation Test, Line Bisection, Catherine Bergego Scale.

Increasing Upper Limb Training Intensity in Chronic Stroke Using Embodied Virtual: A Pilot Study	Perez-Marcos, Chevalley, Schmidlin, Garipelli, Serino, Vuadens, Tadi, Blanke, Millán (2017)	Motor Impairment, Awareness of physical Sensation, Safety of intervention, Patient Motivation	Mind-Motion ™ PRO	Between Group Design	10	Fugl Meyer Assessment of Upper Extremity, Active Range of Motion, Muscle Strength, Functional Independence, Pain ratings, Safety and Acceptance of Technology, Tolerance to VR Intervention, Adverse Event Monitoring, Self-evaluation, Acceptance of technology, Motivation
Use of Virtual Reality In Improving Poststroke neglect: Promising Neuropsychological and Neurophysiological Findings From a Case Study	De Luca, Lo Buono, Leo, Russo, Aragona, Leonardi, Buda, Naro, and Calabrò (2019)	Cognitive Impairment, Motor Impairment, Attention Behaviour	Bts-Nirvana System	Case Study	1	Mini Mental State Examination, Repeatable Battery for Neuropsychological Status, Behavioural Inattention Test, Trunk Control Test.
Virtual Reality Application for the Remapping of Space In Neglect Patients	Ansuini, Pierno, Lusher, and Castiello (2006)	Unilateral Neglect severity, Stroke severity	Hollow Box, Computer Monitor, DataGlove.	Between Group Design, Within Subjects Design	9	Albert's Test, Star Cancelation Test.
Virtual Reality Games as an Adjunct in Improving Upper Limb Function and General Health among Stroke Survivors	Ahmad, Singh, Nordin, Nee, and Ibrahim (2019)	Motor Impairment, Patient Motivation, Patient functional independence, Stroke severity	Virtual Reality Games	Quasi-Experimental Design: Non-equivalent Control Group Design	36	Fugl Meyer Assessment of Upper Extremity, Wolf Motor Function Test, Intrinsic Motivation Inventory, ADL, Stroke Impact Scale.
Feasibility, Safety and Efficacy of a Virtual Reality Exergame System to Supplement Upper Extremity Rehabilitation Post-Stroke: A Pilot Randomized Clinical Trial and Proof of Principle	Norouzi-Gheidari Hernandez, Archambault, Higgins, Poissant, Kairy (2020)	Motor Impairment, Stroke severity	Jintronix System	Two-arm pilot randomized clinical trial, pre-post follow-up design.	18	Fugl Meyer Assessment of Upper Extremity, Stroke Impact Scale, Motor Activity Log. *Baseline *Post-intervention *4-weeks follow up

Results: After establishing the state-of-the-art, we explored VR's compatibility with the NMT technique of MNT, which may integrate adjunctly with music therapy practices and/or multidisciplinary rehabilitative practices. We argued that due to the multisensory defects that neglect causes, a combination of both VR and MNT interventions may aid in counteracting the rightward bias in neglect patients. We contend that this is due to:

- Adjunct use of VR rehabilitation providing a music therapist with relevant tasks (relevant to MNT) to include during neglect rehabilitation.

- VR's multimodal capabilities including, immersion in a virtual environment via audio and visual stimuli, access to motor tasks within applications, activities and games simulating realistic bodily movements associated with ADL, a safe environment to practice rehabilitation, and VR's kinematic tracking capabilities using motion capture technology, may be applied to patient assessment.

Summary: The review extracted various outcomes, finding under-reported results in neurological regions that co-activate in a neglect patient's brain during their use of a VR intervention. This translated to an overall increase in focus of attention in a study's neglect-affected population. The review contributes to the understanding of the application of VR and music therapy as interventions for intersectional purposes. Specifically, these intersecting purposes exist in multimodality, assessment, task-based activity, patient adherence, and patient motivation. These are in large part aligned with NMT's rules for learning-oriented motor therapy practices, as outlined by Thaut and Volker (2014) (e.g., repetition, feedback, cueing, task orientation, ecological validity, and patient motivation).

4.1.3 Article III

Background and Aims: In recent years, wearable technology has enabled a wide range of opportunities to monitor the daily activities of populations, enabling behavioural change techniques (Mendoza, et al., 2022; Michie, et al., 2013), as well as encouraging increases in physically active and less sedentary lifestyles. Despite this promising evidence, long-term engagement remains a major challenge. A review by Wang et al. (2022) indicates that more engaging methods are needed to achieve significant behavioural change. Therefore, this paper focuses on developing a system to produce a musical sonification of daily activity recorded by accelerometers. The sonification method described in Article III is specifically designed to provide patients with rapid feedback (the following day) regarding the type and quantity of physical activity. Using this feedback, patients may potentially alter their regimens the next day or even produce sonification's based on the type and volume of physical activity that is monitored by the accelerometer and produced by the algorithm. Consequently, we argue that sonification can be used as a tool to raise awareness and encourage behavioural change by displaying information about daily activities to users in an engaging way. It can also be used within interventions to increase physical activity.

Objectives: We devised a two-part study. The parts were: (1) a proof-of-concept system which creates musical sonification's to influence behavioural change; and (2) a perceptual assessment to understand if a person could correctly identify each musical sonification.

Methods: In order to do this, the study used data from two participants who wore two accelerometers attached to their chest and thigh. The accelerometer recordings corresponded to a low-activity sedentary subject, while the other corresponded to a high-activity non-sedentary subject. The accelerometer data were pre-processed across two measures, Mean Absolute Deviation (MAD) and the activity identified from the positioning of the accelerometers. The segmentation is based on an algorithm created by Foote (2000), as well as a similar procedure developed from previous accelerometer recordings (Mendoza & Thompson, 2017; Rodrigues, et al., 2021). The sonification components are composed of three polyphonic additive synthesizers, which produce bell-like sounds tuned to temporal pitches. In addition, a drum-machine with 16 steps and five voices was included in the sonification. Similar to Article I and Article II, this study employed a qualitative section, using a survey instrument launched via social media channels (e.g., Twitter and Facebook). This was in order to assess the accuracy in identifying musical sonification's, as representing a low or high activity subject.

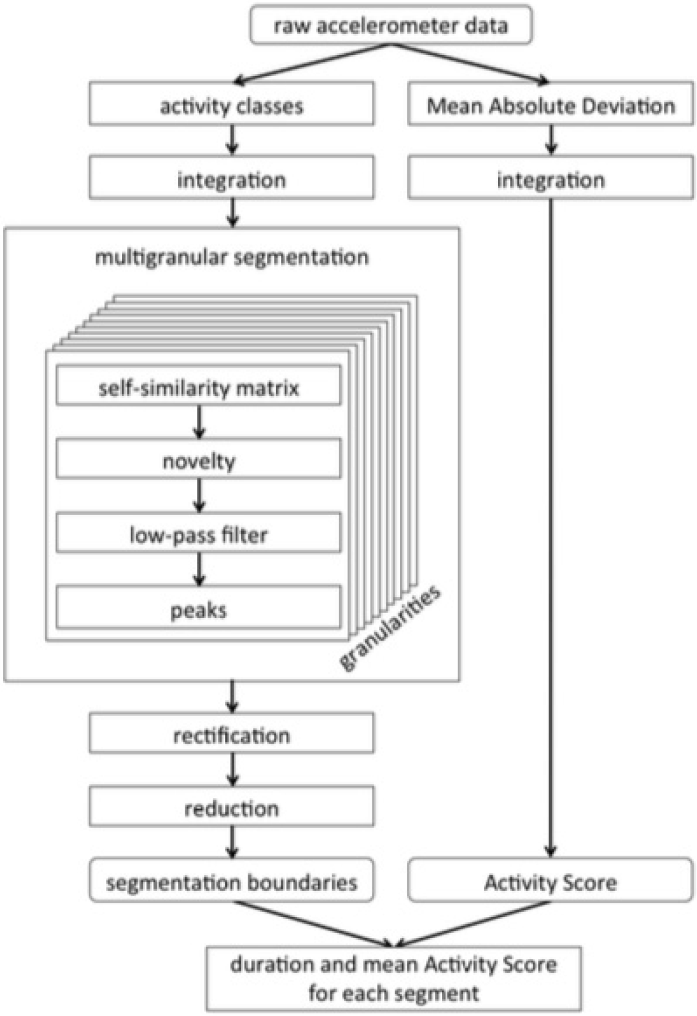

FIGURE 2. A diagram showing the process of the creation of the multigranular segmentation of daily activity (for more information, see e.g., Article III).

Results: A total of 1847 responses were collected by the survey, of which 1225 (66.3%) correctly identified the sonification corresponding to high activity. The null hypothesis for this test is the random proportion of correct responses, with our results being considered sufficient to reject the null hypothesis (p-value = 1 x 10^{-5}). This suggests that the proportion of correct responses is significant. This provides an indication that this method may be used to raise awareness of activity levels corresponding to a behavioural change intervention.

4.1.4 Article IV

Background and Aims: Opportunities are continuously being discovered regarding the benefits and strengths of combining novel embodied music technology in music lessons (Kang & Jackson, 2021; Ng, Ng & Chu, 2021; Xambó, 2017; Nolan, 2009; Kokotsaki & Newton, 2015). From a teacher's perspective, IT can support music education instruction through the advanced technological capabilities of the technology as well as help the teacher to manage and influence student learning outcomes. This was carried out by examining the students' learning performance, their experience of using their assigned technologies in the context of music learning, as well as their behaviour while using the iPad with the Keyboard Touch Instrument app or the KAiKU Music Glove (a tactile wearable device which activates musical notes via touch). This study produced results from an innovative wearable device, the KAiKU Music Glove, as well as an existing device, the iPad. One group of students were assigned the KAiKU Music Glove (*N* = 21) and another assigned the iPad (*N* = 21). These technologies were used throughout both groups' music lessons for six weeks.

In addition, we chose the perceived ease of use of the original Technology Acceptance Model (TAM) (Davis, 1989) as a theoretical concept to investigate how much the students expected to exert effort within technological interaction in the music classroom. This helped to delineate the relationship between participants' behaviour, learning outcomes, and experiences with their assigned technologies.

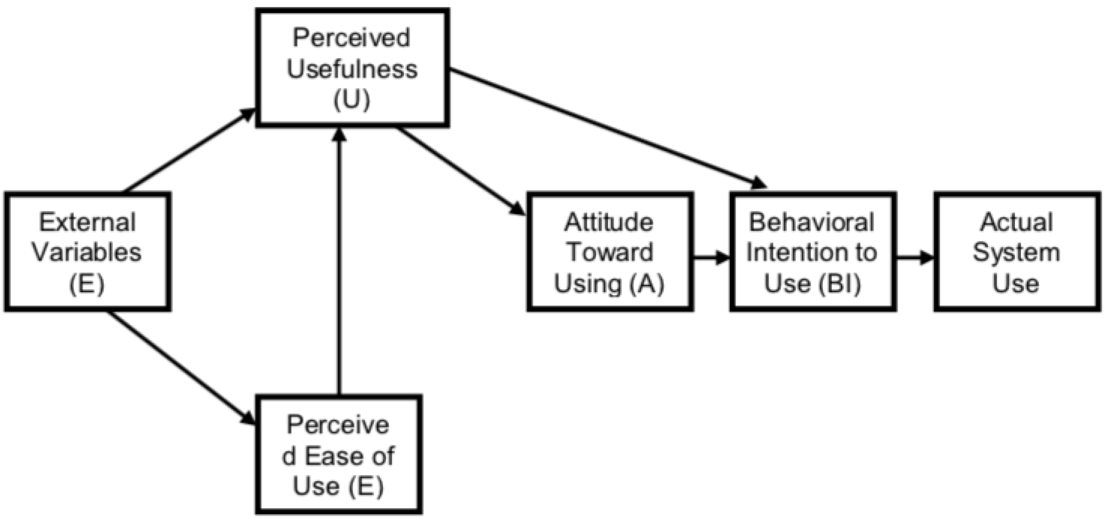

FIGURE 3. The technology acceptance model (TAM; Davis, 1985) is shown in this diagram (for more information, see e.g., Article IV).

The three research questions informing this study included:

> *What is the difference in musical knowledge before and after using the iPad with the Keyboard Touch Instrument app and the KAiKU Music Glove connected to the iPad in the children's music classes?*
>
> *What are the students' ratings of perceived ease of use before and after using the iPad only or the KAiKU Music Glove in the music classroom?*
>
> *What is the difference in concentration-related behaviour patterns of the student's while interacting and playing the iPad or KAiKU Music Glove in children's music classes?*

Methods: In this article we applied a mixed-methods research approach, employing both qualitative and quantitative research methods to study the participants' musical activity in their music classroom. Mixed-methods research uses quantitative and qualitative methods in a single or multi-phased study (Tashakkori & Teddlie, 1998) at all or across many research stages (Creswell, 1994). This includes sampling strategies, data collection and analysis, synthesizing findings, and reporting. The study was comparative in focus, observing the learning outcomes in two groups of students, one group using the KAiKU Music Glove, and another group using Apple's iPad. The quantitative data included learning performance tests and the qualitative data contained subjective experience surveys and behavioural observations.

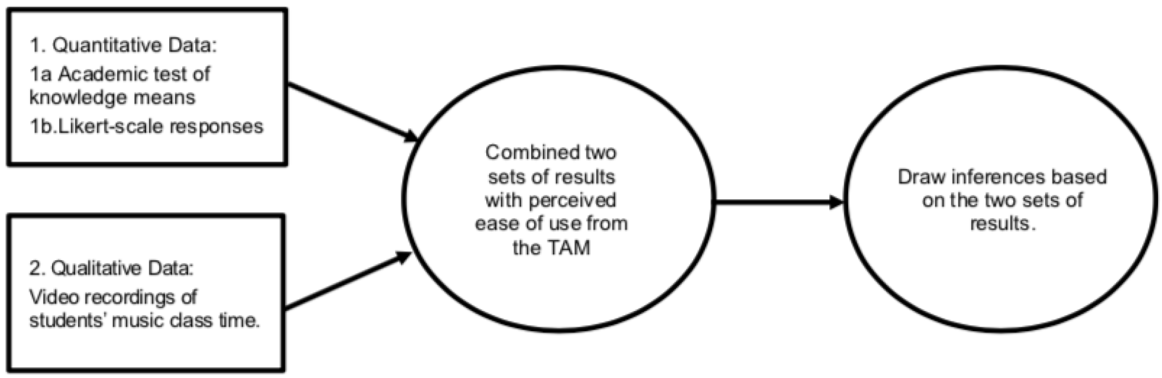

FIGURE 4. Design of Article IV mixed-method study using both qualitative and quantitative data (for more details see e.g., Article IV).

Results: The results of the study show a significant difference in test score changes ($p = <.01$) and a medium effect size ($d = .75$), indicating that using the iPad and Keyboard Touch Instrument app increased learning compared to the KAiKU Music Glove. Students rated both technologies higher for perceived ease-of-use before using their devices and rated them lower after use. When applying

Davis et al.'s (1989) concept of perceived ease-of-use to the behavioural data, we find that students may have anticipated less effort to use their assigned technologies before using them at the beginning of the study. This changed towards the end of the study when students realized that more effort was required to use them. The teacher interacted more frequently with students who used the KAiKU Music Glove. Thus, there was an association between the use of the KAiKU Music Glove and students remaining on-task (displaying higher concentration-related behaviour) as they requested support from the teacher. In addition, differences in the observed concentration-related behaviour of the two students in each group may have been due to the fact that the observed students were more familiar with the iPad and less familiar with the KAiKU Music Glove.

Summary: When the data on perceived ease-of-use is combined with its observational data, results suggest that students' expectations of the technology may have influenced their concentration-related behaviour, leading to the actual use of the system. It follows that the higher performing class (the class that used only the iPad and the Keyboard Touch Instrument app) may have perceived their technology as easier to use, resulting in less effort spent on interactions when using the technology[1]. The data reflects this, showing that students who only used the iPad behaved more off-task than students who used the KAiKU Music Glove, suggesting that students who used the iPad were less focused than students who used the KAiKU Music Glove. The combination of quantitative academic achievement data and qualitative concentration data yielded practical findings on the impact of music technology on children's educational outcomes.

[1] Tractinsky, N., Katz, A., Ikar, D. (2000). What is beautiful is usable. *Interacting with Computers*, *13*(2), 127–145. https://doi.org/10.1016/s0953-5438(00)00031-x

5 DISCUSSION

The digital and music technologies presented in this dissertation contain distinct features characterizing their interaction as a tool for use in music therapy and music education. In the following subsections of the discussion, I describe how the perceived affordances listed below are present within our study's technological interventions and commensurate with music therapeutic and educational practices. Furthermore, the interventions are often described in relation to their objectives and assessments for which they are utilized. In addition, the role of feedback is discussed. The discussion also includes observations regarding the practical ways in which technology in general can support music therapy and education. This is related in all four articles. The following subsections *Perceived Affordances* (5.1.1 through to 5.1.4) will address the dissertation's first research question:

Research Question 1. What types of affordances are present in technologies utilized in music therapy and educational settings?

5.1.1 Perceived Affordance I: Adherence and Motivation

Patient engagement in treatment practices is a well-known problem in the wider rehabilitation literature. A lack of patient engagement during rehabilitation can be a major factor in undesirable patient outcomes. In the field of music, motivational rewards can be enhanced through the use and selection of personally preferred music. In general, the experience of music is known to activate neurobiological reward systems and regulate aspects of memory, attention, executive function, mood, and motivation (Sihvonen, et al., 2017; Salimpoor, 2011). In Article II, we examined patient engagement as an intersecting goal of VR and music therapy. This is because often both interventions involve activities with the intention of engaging the patient via a motivating stimulus. Also, VR plays an additional motivational role in rehabilitation by providing realistic experiences that can be gamified. These gamification experiences regularly take the form of serious games (e.g., a video game designed to rehabilitate a specific deficiency in a patient group) that can be used adjunctly with music-based technologies, which incorporate music-based feedback features to stimulate rehabilitation (see section in the Discussion, e.g., *Perceptual Entrainment and Motor Coordination*). As argued in Article II, we present intersections of VR using music therapy techniques (MNT, see section in this chapter, e.g., *VR and Music Therapy*) with the technology providing feedback stimuli, potentially enhancing the motivational aspects of treatment. In addition, serious games can be applied between sessions for use in the patient's home (Agres, et al., 2021a).

The aforementioned interventions, music, VR, and serious games can have a significant impact on reducing patient drop-out rates as well as increasing patient motivation to continue treatment. For instance, music-based interventions report reduced dropout rates as they are applied to various populations. A study by Schutzer and Graves (2004) found that incorporating music into physical activity interventions supports older adults' participation and engagement. This was due to music enhancing the experience of physical activity and reducing the perceived difficulty, monotony, and discomfort associated with physical activity.

5.1.2 Perceived Affordance II: Physical Activity

Music acts as a catalyst to motivate people to participate in physical activities such as exercise. Current evidence details the improvements in psychological states that music provides to enhance the enjoyment of physical exercise or training activities (Kuan, 2014; Leyes, 2006). Taken together, this suggests that music use during physical activity is a versatile and motivating stimulus to promote physical activity, health, and well-being across the human lifespan. However, as recommended in these reports (Terry & Karageorghis, 2011; Karageorghis, 2008), there are significant gaps in the current state-of-the-art, particularly in applied research. Accordingly, one of Article III's central purposes was to address a lack of evidence on whether music can be used to track someone's physical activity as part of a behavioural intervention. As outlined in the development of the Musification of Daily Activity intervention, which uses music to indicate the total amount of physical activity over a given period of time, and importantly, the time of day, physical activity produced a musical sonification. This can, for example, allow a person to identify by listening to an audio file of their day, to learn about which times of the day they were more or less active, spending more or less time being physically active. Article III's significant result highlights the potential of using musical sonification as an innovative technique to afford and therefore stimulate physical activity.

5.1.3 Perceived Affordance III: Perceptual Entrainment and Motor Coordination

Temporal or rhythmic structure is an essential element of music that leads to the perception of a beat or pulse. When sensory-motor processes (e.g., human movement) are combined with the pulse of the temporal structure of music, this is called perceptual entrainment (Large & Jones, 1999). Accordingly, Dalla Bella (2016) state that perceptual entrainment and auditory-motor coupling are mechanisms necessary to human musical responses in the rehabilitation of motor disorders. Agres et al. (2021a) and Magee et al. (2017) find that these mechanisms of perceptual entrainment and auditory-motor coupling have influenced some musical serious games developed for rehabilitation, as well as the technology used in rhythmic gait training. Similarly, Article III refers to the work of Chastin and Granat (2010) and Levitin et al. (2012), who find that the temporal dynamics of human movement have similarities with music.

5.1.4 Perceived Affordance IV: Engagement and Concentration

Integrating digital technology into the music classroom may encourage the students to produce music in new ways. For instance, in Article IV we discuss the crucial role digital technology has with regards to play in the music classroom, as prior research has attributed play to increased motivation, challenge and positive affect (Woszczynski, Roth & Segars, 2002). In addition, play has been shown to have a biological and evolutionarily valuable function associated with learning (Prensky, 2001). Therefore, through play with digital technologies, involvement in the process of learning music encourages concentration (Koo, 2009). This relates to the concept of *musicking*, conceived by Small (2011). Essentially, Small (1998) argues that engagement with music is an active process. According to Ansdell (2016), both music education and music therapy have embraced these concepts. A distinct reason for this is that these disciplines consider music a *process*. For instance, Jensenius (2022) argues that collaborative musicking denotes the interactivity between therapist and patient, with the larger goal to improve communication as well as the overall wellbeing of the patient. Such examples are illustrated concretely in Article I, where therapists collaboratively *musicked* with their clients using telehealth technologies as a way to maintain levels of care. It was also observed in Article IV, where students actively used existing and experimental technologies to learn and create music. In Article IV, we reported high levels of concentration while the students used their assigned technology. The findings were broadly supportive that play with the devices fostered concentrated behaviour. This was due to the fact that the children were engaged with the interaction of objects (i.e., the iPad or KAiKU Music Glove).

In order to learn, student concentration is regarded as a vital aspect of *student effort* spent in the classroom. In Article IV we refer to the findings of Bester and Brand (2013), who state that the amount of time and effort spent in a classroom is worthless unless the students are learning - a distinct process that happens within the concentration span of learners. Client concentration was also a finding we refer to in Article I. Notably, clients who participated in telehealth-related sessions report being in a more comfortable, less distracted state, as they were in their own space during sessions.

Engagement with technologies for the purposes of education may encourage novel literacies, which stimulate concentration. In Article IV we measured how easy a technology is perceived to use for a given educational task. We found that students' expectations of the studied technologies impacted their concentrated behaviour, which in turn, may have affected their academic performance results. For instance, students who used the iPad in our study reported high scores in the perceived ease-of-use of that technology. This resulted in less interactive effort to use the technology, which consequently improved their academic performance scores. This was more so compared to the novel technology device (e.g., KAiKU Music Glove) that required greater interactive effort that was recorded in the study as concentrated-related behaviour.

5.2 Feedback: Therapist, Teacher and Music

This subsection, *Feedback: Therapist, Teacher and Music* will address the dissertati on's second research question:

Research Question 2. How can feedback be used across music therapy and educational settings?

Digital technology can also be advantageous for the purposes of therapists' and teachers' feedback. A goal in the therapeutic process is often to assess the patient's behavioural responses to particular stimuli and adjust their strategy accordingly. This can be addressed by real-time digital feedback, or new measuring techniques offered by the technologies. Often within applied settings, which involve people with clinical needs, music technologies can be grouped into devices which: 1) create music, (e.g., MIDI/electronic instruments, sonified wearable instruments/devices); 2) record and listen to music, as well as analyse music usually combined with assistive devices (e.g., GarageBand, Ableton Live, MIDI Toolbox); and 3) devices which target specific cognitive or motor functions (VR, Brain-Computer Interface). Optical motion capture delivers highly accurate measurements of body motion and movement for tracking music-induced movement (Agres, et al., 2021a; Burger, et al., 2013). Yet, this requires an extensive laboratory setup. Alternative, more affordable, motion capture devices, such as Leap Motion and Microsoft Kinect have been explored for their effectiveness as music-based solutions within health care (Agres et al., 2019; Beveridge et al., 2018). One drawback, however, is that these devices offer less accuracy during tracking.

Similarly, as teachers apply technologies within the classroom to their pedagogy, they may gain access to different modes of feedback, which may be advantageous in some learning environments. In Article IV's study, the teacher was involved in using IT as a method of sensory feedback, using two devices, the iPad and KAiKU Music Glove, to enable musical interaction with students. Correspondingly, the students engaged with their devices in the same manner, creating sound by tactile input while receiving visual, auditory, and haptic feedback through their device.

Musical feedback can also be applied as information in support of motor learning (Effenberg, et al., 2016; Sigrist, et al., 2015). Musical feedback may also comprise the translation of a signal which is not fundamentally auditory (e.g., an aspect of a movement, acceleration, etc.). As this activity is triggered, it can be signalled by creating a sound which directs attention. This specific state, referred to as sonification, may serve as information to aid in intensifying dimensions difficult to perceive. Sonification may provide additional indication about the quality of performance, or information about a particular practice during rehabilitation. An example of sonified feedback is provided in Article III's study where sonification's of physical activity were created using accelerometery recordings from older adults throughout a 24-hour time window. Such a system may be useful in developing a larger scale public health intervention, with its primary focus to increase healthy physical activity or reduce sedentary behaviour in individuals.

Finally, feedback from technologies can be of importance for general patient adherence and student concentration. For instance, many VR interventions aim to help reduce dropouts from clinical trials, as reported in Article II. In addition, engagement was monitored via student concentration in Article IV study, highlighting the critical impact technology has on a student's concentration in class.

5.2.1 Feedback: Sonification and Physical Activity

Kramer et al. (1999) define sonification as "the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation" (Walker & Nees, 2011, p. 1). Furthermore, sonification is a type of auditory display using non-speech audio to represent information. Its purpose is to convert data into sound which exploit the auditory perceptual ability of human beings in a comprehensive manner. Scholz et al. (2016) who used musical sonification training as a therapeutic intervention to treat motor impairments, reported promising results, specifically in motor joint smoothness and reduced perceived joint pain. Sonification requires human interaction for it to affect datasets, and as such, that interactivity may take the form of motion or physical activity.

Physical activity can be measured by various forms of feedback, including haptic or accelerometer tracking. This feedback can be converted into sonification data. For instance, the system developed in Article III is intended to provide feedback to a participant or clinician about the type of physical activity complete through musical sonification. For instance, the sonification system in Article III acquires 'movement' data via worn accelerometers. It then processes that data by using a novel method which quantifies the participants daily activity, and then produces a musical synthesis of the participants daily activity, through mapping the processed data to different musical parameters. The participants can listen to the playback of this musical synthesis through a device, such as a computer, as the output musical synthesis is converted to an audio file. We argue this may be advantageous towards driving behavioural change, (e.g., increasing physical activity), as the system may make a person aware of their physical activity in an engaging way. Within a therapeutic context, sonification can help a patient listen and interact with elements of music that are difficult to perceive. That is, sonification provides perceptual input amplifying musical dimensions difficult to perceive (Agres, et al., 2021a).

5.3 Bodily Stimulation

This section outlines areas where the interventions used across the four studies intersect in their stimulation of bodily movement, referred to as embodied experience, and multisensory behaviour. In the following section, we outline how the concepts of embodied cognition and embodied experience associate to a therapeutic context, as well as how they link to the studies found in the dissertation. Particular attention is given to how embodied cognition is observed in concentrated behaviour and physical movement.

5.3.1 Embodied Cognition

A human's physical body, sensation and movement are critical mechanisms to perception, cognition, and ultimately behaviour. This is what is meant by embodied cognition. Embodied cognition suggests that our mental processes as well as experiences are influenced and bound to our bodies, and not only limited to our brains. In general, this means that the way humans interact with the world is mediated by their embodied experience. Within a therapeutic context, this links to a patient's subjective experience as they physically move or complete a physical activity which can influence their mood. Consequently, this concept of embodied cognition and embodied experience (the aesthetic dimension of the sense-making process, see e.g., Cox, 2017) suggests that human's mental processes are connected to physical experiences as well as their interactions within the world.

In Article V, we noted that the study's participants (students) were engaged in an embodied musical experience. What we specifically meant by this was that the students were simultaneously engaged in a human-device interaction using assigned technologies (e.g., KAiKU Music Glove or iPad technology), and multisensory musical engagement (touch, sight, and sound). Here we can observe Geeves and Sutton (2015) concept of embodiment - it being an integrated component of the ongoing engagement of bodily properties that are kinaesthetic-tactile-affective. The students reported high levels of concentrated-related behaviour when they engaged in this embodied musical experience by playing and creating music through IT devices. This resonates with Huzinga's (2004) findings, in which it was observed that play supports children to concentrate on learning as they are engaged with the interaction of objects. Furthermore, the students did not interact with each other using verbal communication, with only the slightest of utterances in speech. An association with Moran's (2011) analysis of embodied cognition and action strategies can be made, which musicians undertake as they perform with each other, signifying an awareness with one another, as well as their simultaneous coordination while playing music.

In Article's II and III we refer to embodied motor feedback, where the movements of participants from the real world are monitored and reproduced to allow for motor activation which may significantly impact the recovery process. For instance, in VR patients are often required to replicate real world movements to complete a task. In the case of the Musification of Daily Activity algorithm, we measured and sonified each participant's ADL to potentially function as a behavioural intervention. Such embodied feedback provides the user and therapist multisensory feedback with regards to the patient's physical performance and broader rehabilitation. Both Article II and III present the unique potential of how embodied visual (VR) and musical (sonified) feedback can be manipulated by the participants and research team in ways which activate as well as record multisensory behaviour.

5.3.2 Multisensory Behaviour

Multisensory behaviour is the utilization of multiple senses, such as sight, touch, taste, and sound to perceive and interact with one's environment. These behaviours can indeed be voluntary, such as when a patient hears a sound and turns a part of their body towards the source of the sound. Crucially, in rehabilitation settings, multisensory behaviour is vital during the development of sensory-motor skills, such as the ability to coordinate movement with vision.

Cumulatively, all the interventions discussed in this dissertation stimulate multisensory behaviour: MNT (sight, sound, tactile; Article II); VR (sight, tactile, haptic, sound); Musification of Daily Activity (sound and physical movement; Article III); and the KAiKU Music Glove (sight, sound, tactile, haptic; Article IV). As respective interventions, they achieve stimulation across multiple senses, engaging users, learners, and patients at the same time. Multisensory stimulation has been seen as generally efficacious across therapeutic and educational contexts, as it enables information to process across multiple areas of the brain (Chaterjee, et al., 2021). This makes subject matter easier to understand and remember. Furthermore, multisensory stimulation helps to engage more of the brain leading to a more immersive and interactive experience, which is highly useful for educational and therapeutic purposes (Bohil, et al., 2011). For example, in Article IV students using the KAiKU Music Glove and iPad technology along with the tutelage of the music teacher helped some students to reinforce their learning and improve on their academic performance across the study period. Furthermore, in Article II patients' exposure to the stimuli found in VR helped to engage a post-stroke neglect patient's neurological region in a manner that encouraged increased saccadic eye movements. Despite this, the body of evidence surrounding the support of multisensory intervention use during the rehabilitation of neurological disorders is relatively limited (Cheng, et al., 2019), and more research is needed to arrive at generalizations.

5.4 Practical Applications of Digital and Music Technology in Health and Educational Settings

Technologies that integrate music can be placed into many different settings where therapists or educators do not essentially have specialized music training (e.g., sessions led by occupational therapists or classrooms led by music teachers), or at least, it is not available. Crucially, for these technologies to be used across multidisciplinary settings, they must be made accessible and not require high levels of musical competence to use. The following subsections (5.4.1 through to 5.4.5) will address the dissertation's third research question:

Research Question 3. What practical ways can digital and music technology be used by music therapists and educators?

5.4.1 Virtual Reality Use in Music Therapy

In music therapy practice, post-stroke and neglect rehabilitation often involves musical tasks and activities, having the patient move rhythmically to musical stimuli, or engaging in a musical task (see, e.g., Kang & Thaut, 2019). Similarly, VR also sees the patient engage with stimuli, moving the upper limbs as part of activities or games that involve repetitive movements. As the interventions use various modes of stimulation (musical, audio, visual) and possess the ability to target multiple areas simultaneously, these interventions are both multimodal. Essentially, there is the possibility that both interventions can address the neurological, physical, and perceptual needs of a patient within an individual session. As discussed in Article II, areas of intersection between music therapy and VR are in assessment and patient adherence. Specifically, the kinematic feedback captured via VR systems during their use, may support a music therapist in understanding the effects of audio stimulus on a patient's motor movement during, between, and after sessions. As musical interventions are known to be motivating due to the musical stimulus they provide patients, VR's interventions are also known to positively contribute to patient motivation, providing a rewarding task-based stimulus (in the form of games, e.g., exergames and serious games). For instance, a significant impact of music in the acquisition of motor skills is that it makes a learning environment to attain the skill more enjoyable, increasing players' intrinsic motivation to master the necessary skills.

Likewise, findings in using and applying VR as an intervention during the rehabilitation of motor skills point toward patient motivation as being its most significant beneficial feature (Laver, et al., 2017).

For VR to be effective, user *presence* is deemed crucial in the virtual environment. Presence can be defined as, "the perceptual illusion of non-mediation" (Lombard & Ditton, 2006, Presence Explicated section). Understanding, as well as enhancing presence of virtual environments is important, as Slater and Wilbur (1997) argue, "the greater the degree of presence, the greater the chance that participants will behave within a virtual environment in a manner similar to their behaviour in similar circumstances associated with everyday reality" (p. 8). The relation between immersion and presence is described by Cummings and Bailenson (2015) as, "the more immersive the system, the more likely an individual will feel present within the mediated environment and the more likely that the virtual setting will dominate over physical reality in determining user responses" (p. 3). Cumulatively, presence, immersion, and music help to meet fundamental principles of rehabilitation. Principles such as intensity, task-oriented training, biofeedback, and motivation as outlined by Dias et al. (2019) - who developed various mini-games for rehabilitation in poststroke recovery - are driving factors to encourage and stimulate motivation in rehabilitation contexts. Associated with presence is the role that audio plays, enhancing users to feel like *they are there*. Kern and Ellermeir (2020) assessed the role of audio-virtual environments, finding statistically significant effects of audio on perceived presence and realism within a targeted population. Similarly, musical activities such as singing have also been found to play an active role in the immersion of VR. Tamplin et al. (2019) found that a music therapy singing intervention, which uses VR, helped patients with spinal cord injury (SCI) to feel less inhibited to sing in front of others while immersed in a virtual environment. Singing is used to assist with respiratory muscle training after SCI. Coupled with the beneficial effects that singing has for respiratory muscle training after SCI and positive user experience scores after using VR, the VR intervention used in the study by Tamplin et al. (2019) was found to be feasible to include adjunctly with music therapy as an SCI intervention.

Within many rehabilitation applications and games, making movements in virtual environments similar to everyday movements is critical to the patient's rehabilitation training. These everyday movements are purposefully designed to simulate realistic movement. This resemblance to realistic movement is associated with the goal of improving patient performance in Activities of Daily Living (ADL), which requires significant coordination of motor skills. ADL are generally described as functional tasks that a patient will complete on an everyday basis (e.g., walking, opening a door, etc.) with the larger goal of increasing patient independence.

However, both music and VR interventions do not report significant effects on ADL. Furthermore, in post-stroke rehabilitation the wider evidence points to music therapy and VR being no less effective than conventional rehabilitation on the effects of ADL. Yet, there is some evidence that music therapy and VR can be used to improve patient outcomes in the absence of other interventions (Laver, et al., 2017). This holds also for different cognitive domains (e.g., enhancing memory and language abilities) (Lyu, et al., 2018).

The overall benefit to using music as an intervention for assisting with human rehabilitation is its flexibility and the range of activities that it can offer (Magee, et al., 2017), which is discussed in Article II. VR shares this feature. Consequently, we report considerable overlap of VR being used as a rehabilitation technology that can be used adjunctly with MNT practice, due to its flexibility and range of tasks made available in the form of gamification. These intersecting purposes across both interventions make them a viable intervention for use during rehabilitation in specific contexts. The specific context aimed for maximum benefit when using both interventions is in post-stroke and neglect rehabilitation. This is due to how stroke rehabilitation has been typically conducted in music therapy practice, as well as in VR rehabilitation.

5.4.2 Delivery of Healthcare

Ease of access for therapists and patients has been a key principle for the use of telehealth in large-scale healthcare programs (Predmore, et al., 2021). Crucially, throughout the COVID-19 pandemic, telehealth enabled interactivity for therapists and their patients. In the same way that telehealth involves a two-way real time interaction between the patient and therapist, receptive and improvisational music therapy incorporate similar interactivity. The accessibility of music technologies for music therapists to use as part of practice is an area of extensive investigation. Accessibility in this area may refer, generally to the ease of use of technologies, or access of technologies for therapists to use in their practice. The therapists' own beliefs and attitudes toward using these technologies is also considered influential toward their general adoption (Agres, et al., 2021b). Agres and colleagues' more recent survey of opinions of music therapists using technology during COVID-19 found implications in differing levels of use and attitudes toward music technology by region. For instance, music therapists based in North America and Asia/Oceania report high frequencies of technology use during therapeutic sessions, as well as an attitude to continue using technology after the COVID-19 pandemic. This was in comparison to music therapists based in Europe, who responded to using technology less frequently, as well as not responding definitively as North American or Asian/Oceanian based therapists to continue using technology for therapeutic practice. Agres et al. (2021b) suggest training in technology usage is less common in music therapists based in Europe compared with North American and Asian/Oceanian based music therapists, which might have significant bearing on how frequently technology is used by music therapists in different regions. Similarly, Article I report findings of high technology use from music therapists based in North America during COVID-19, however, our study noted that these therapists would prefer more training regarding music technology use as part of their professional practice.

While telehealth enabled the delivery of music therapy during the peak of the COVID-19 pandemic, music therapists adapted their practices. For instance, in Article I we found that most therapists who adopted telehealth technology to carry out their sessions stopped using collaborative music making altogether. Instead, they opted for call-and-response, turn-taking, pre-recording of music related session materials, or transitioning, to complete receptive music therapy interventions.

5.4.3 Data Analysis

As outlined in this dissertation, music therapists can utilize technology, such as interfaces or software programs to help with data collection and analysis. Interfaces and software can be used by a music therapist to track a client's progress over the duration of treatment sessions. For example, by using software to record sessions, a music therapist can analyse the client's responses to treatment as indicated by the data shown. Following this, patterns can be identified in the client's responses to music therapy, which may help the therapist specify their approach and carry out informed treatment decisions. As this dissertation explains, music therapists may use technology to improve treatment, such as using VR to provide their patients immersive musical experiences. Collaboration across the fields of music therapy and education may offer a viable area for data analysis and future practical development. As discussed in Article II, the use of biomarkers (e.g., fMRI scanning) provide insights into the neural mechanisms activated during the use of VR, providing an understanding of the behavioural responses in neglect patients during the use of VR.

5.4.4 Biomarkers

In order to improve our understanding as well as the quality of the therapeutic process, biological measures can be captured such as fMRI image scanning[2] . Consequently, music therapy uses biomarkers to understand the effects of therapeutic interventions on its patients or targeted populations. As discussed in the previous section, neurological measurements in the areas of music therapy and education aim to improve the understanding of a problem, bridging professional gaps in research and practice.

Article II reports on the post-rehabilitation session results from patients living with chronic neglect, utilizing fMRI scanning as a data collection method that shows the results from training in a multisensory VR intervention for rehabilitation. The results from the study (Ekman, et al., 2018), as reviewed in Article II, show an increase in the neglect participants' task-evoked brain activity after the VR intervention used for rehabilitation sessions - specifically, the regions activated include the prefrontal and temporal areas during attentional cueing (e.g., when a patient using the VR application is directed toward a specific

[2] In the wider literature there are additional measures referred to such as fNRIS, EEG, ECG, hormone measures, impedance cardiography, skin conductance response, respiratory measures, cortisol, adrenaline, see Agres, et al. (2021a).

target). This corresponded with brain and behavioural changes during use of their VR intervention - monitored via fMRI scanning. In particular, the scan showed Blood-oxygen-level-dependent (BOLD) signals increase as the patients used their VR intervention for rehabilitation. The behavioural improvements reported increased cue-induced focus of attention found in the prefrontal cortex, bilateral middle, and superior temporal gyrus after 15 hours of training. The same team (Wåhlin, et al., 2019) followed up with a study using fMRI scanning to understand the activity of neural mechanisms related to the recovery of neglect. The fMRI results from this study indicate that as patients completed training using a VR intervention, a region responsible for saccadic eye movements to the left became more integrated with the left posterior parietal cortex. Crucially, this fMRI data highlights a new mechanism that can be used during the rehabilitation of patients with visuospatial neglect. Coleman et al. (2017) state that such data is crucial for future study, due to a lack of understanding of the neurological mechanisms that can be taken advantage of during neglect rehabilitation.

5.4.5 Support for the Music Teacher

Practically speaking, a music teacher's instruction can be improved using technology. Video conferencing tools such as Zoom have been used during and after the COVID-19 pandemic to provide online music instruction. Websites and apps for music education can provide teachers with interactive tasks, games, and other activities for the purposes of aiding students in learning and practicing musical concepts. Teachers can use technology to promote students' self-efficacy. Teachers might, for instance, employ technology such as a Digital Audio Workstation (DAW) to enable students to record themselves, which they can then playback and assess their progress for themselves. The students then record themselves playing and subsequently analyse their recordings to identify areas where they can improve.

5.5 Limitations

There are various limitations found across the four articles of this dissertation. Due to their novelty, the interventions studied have received little exploration in wider scientific literature, meaning that the results to date stand in relative isolation, without much previous research to be supported by. The use of a range of research designs is intended to provide a comprehensive representation of the effects of digital music technologies across music therapy and education. However, combining both quantitative and qualitative data may lead to a too broad research scope, decreasing each intervention’s relevance to the individual’s underlying therapeutic and educational goals which require targeting.

The types of methodologies used throughout the different studies imply strong ecological relevance, highlighting results which are externally valid, but lack in precision when targeted toward clinical and educational assessments. An example of this is found in Article II, where VR provides little effect on a patients' ADL (a clinical assessment) but encourages patient adherence and motivation (often the measurement of a secondary treatment effect). Thus, the methodologies provide starting points for future development of the interventions, rather than showing definitive results regarding effects on patient symptoms or of a student's learning. This leads to difficulties in interpreting the four articles homogeneously, as the studies use different units of analysis to examine a range of interventions and effects in differing contexts.

Objectively evaluating each intervention's efficacy within each study setting is challenging and may benefit from increased standards of clinical control, or a controlled classroom environment. For example, to determine the precision of the algorithm developed in Article III, there is a need for a controlled trial, but such trials are resource-heavy and difficult to implement. Article IV's students used and interacted with their assigned technologies somewhat differently, and this was not controlled by the researchers. The populations analysed across Articles I and IV were small, and a larger sample size of students using their respective technologies would produce a truer analysis. With the exception of Article III, the studies did not provide specific architectural and engineering specifications, instead they focused on the outcomes of the technologies being used within specific contexts. While this provided outcomes in differing contexts, the risks of implementing some of these technologies in their current state need to be addressed architecturally (KAiKU Music Glove, Article IV).

5.6 Relevance and Implications

This dissertation provides significant contributions in exploring how these interventions can be applied to specific contexts that have never been explored before. It provides accounts of how these interventions can directly impact health and rehabilitative outcomes (Article II & Article III) in a beneficial manner, as well as how professionals can mediate (Article I) between the technologies and their practice. The specific implications of the studies span across their perceived affordance capabilities and feedback opportunities which the devices exhibit in different contexts. These perceived affordance and feedback capabilities support therapeutic and educational principles, for example, patient adherence and motivation, or engagement and concentration, which can be tailored toward therapists, patients, teachers and students goals.

Crucially, the evidence reported in this dissertation supports the implementation of digital music technology into differing clinical and educational settings where supervision is present. For instance, in Article IV the teacher had ongoing interactions with the students in the classroom while they used and interacted with the KAiKU Music Glove. Furthermore, in Article II researchers and professionals continuously supervised their clients while using VR technology during rehabilitation tasks.

The contributions found across the four articles imply feasibility of these interventions across patient-centred care and student-centred learning, in support of multidisciplinary collaboration. For example, Article II reported VR to be used for exploring symptom reduction possibilities in virtual task environments on individual post-stroke patients in multidisciplinary teams (e.g., VR being used by an occupational therapist and physiotherapist on an individual patient). Significantly, as the four studies technologies were implemented under supervision among these populations, there was an acceptance to use them. Practically speaking, this entails that these studies provide promising preliminary evidence for therapists, patients, teachers, and students to consider before implementing these interventions (e.g., VR, and telehealth technology) in supervised settings. Moreover, the findings of this dissertation may act as a valuable resource of information for therapists, patients, teachers, and students, especially should they wish to learn more about a specific technological intervention type, its duration of use, and what type of environment it was applied in.

6 CONCLUSION

This dissertation covers cross-disciplinary applications of digital music technologies. As a result, the research provides innovative evidence on how digital music technology can support professional music therapy practice, as well rehabilitative practice, and physical activity stimulation. In addition, it examines the use of novel and experimental digital music technology in the music classroom.

The results provide the following insights: (1) an understanding of how music therapists use telehealth technology to conduct remote sessions, finding that the technology improved accessibility to-and-for patients; (2) the establishment of a state-of-the-art in music therapy and VR research, and the subsequent exploration of VR's compatibility with the NMT technique of MNT, suggesting that VR may integrate adjunctly with music therapy practices as well as multidisciplinary rehabilitative practices; (3) indications that a novel sonification method may raise awareness of activity levels corresponding to behavioural change; and (4) a significant difference in children's music test score changes, indicating that the iPad is more effective when learning music compared to the KAiKU Music Glove.

This project highlights the perceived affordances across the technologies, providing evidence in these areas that may be of practical use for music therapists and educators. The role of real-time feedback in these technologies is also discussed, as it serves as an information aid to therapists and educators. In addition, this dissertation presents a general account of the challenges involved in cross-disciplinary practices, and importantly, the factor of ease-of-use within each study. The challenge lies in connecting these disciplines adequately together. Future work resides in the continual development of these technologies, and whether their use significantly transfers to clinical and educational outcomes.

YHTEENVETO (SUMMARY IN FINNISH)

Tässä väitöskirjassa tutkitaan digitaalisten musiikkiteknologioiden soveltamista musiikkiterapian ja musiikkikasvatuksen alueilla. Tämä tapahtuu tarkastelemalla kolmea laajaa ja perustavanlaatuista tutkimuskysymystä:

1. Mitä ominaisuuksia on teknologioissa, joita käytetään musiikkiterapiassa ja opetustilanteissa?

2. Miten palautetta voidaan käyttää musiikkiterapiassa ja opetustilanteissa?

3. Miten musiikkiteknologiaa voidaan käyttää käytännössä musiikkiterapeuttien ja opettajien toimesta?

Tämä väitöskirja koostuu neljästä alkuperäisartikkelista, jotka perustuvat neljään osatutkimukseen (poikittaistutkimus, narratiivinen katsaus, laskennallisen musiikkijärjestelmän ja havaintoperusteisen arvioinnin kehittäminen sekä monimenetelmätutkimus).

Artikkeli I lisää ymmärrystä siitä, kuinka teknologia mahdollisti musiikkiterapian tarjoamista globaalin pandemian aikana. Artikkelissa II esitellään lupaavia näyttöjä oireiden vähentymisestä neglect-potilaiden kuntoutuksessa virtuaalitodellisuuden (VR) ja musiikillisen neglect-koulutuksen (MNT) interventioiden avulla ja tutkitiin VR:n ja musiikkiterapian interventioiden risteämispisteitä neglect-oireiden kuntoutuksessa. Artikkelissa III kuvataan musiikkijärjestelmän kehittämistä, joka käyttää sonifikaatiota fyysisen aktiivisuuden stimuloimiseksi. Havaintoperusteinen arviointi musiikkijärjestelmästä osoittaa, että sonifikaatio edustaa tarkasti korkean ja matalan aktiivisuustason koehenkilöitä. Artikkelissa IV testattiin kokeellista interventiota, KAiKU Music Glovea, ja verrattiin sen käyttöä vakiintuneempaan teknologian, iPadin käyttöön musiikintunnilla, jossa kahta oppilasryhmää testattiin akateemisissa arvioinneissa. Tulokset osoittavat merkittäviä eroja testituloksissa, joissa iPad-teknologia oli suotuisampi. Oppilaat vastasivat myös käyttäjäkokemuskyselyihin ja heitä tarkkailtiin laadullisesti teknologioiden käytön aikana. Artikkeli IV osoittaa merkittäviä eroja testipisteissä, jotka suosivat iPad-teknologiaa.

Tulokset tarjoavat seuraavia oivalluksia: (1) ymmärryksen siitä, kuinka musiikkiterapeutit käyttävät etäterveysteknologiaa etäistuntojen toteuttamiseen, sekä havaintoja siitä, että teknologia paransi toimintamahdollisuuksia sekä potilaille että terapeuteille; (2) musiikkiterapian ja VR-tutkimuksen tämänhetkisen tilanteen kartoittaminen ja jatkuva tutkimus VR:n yhteensopivuudesta MNT-tekniikan kanssa vihjaavat, että VR voi toimia lisänä musiikkiterapian käytänteisiin sekä monialaiseen kuntoutukseen; (3) viitteitä siitä, että uudenlainen sonifikaatiomenetelmä voi lisätä tietoisuutta toimintatasosta ja siihen liittyvästä käyttäytymisen muutoksesta; ja (4) merkittävä ero lasten musiikkitestien tulosten muutoksissa osoittaa, että iPad on tehokkaampi musiikin oppimisessa verrattuna KAiKU Music Glove -tekniikkaan.

Erityisesti tässä väitöskirjassa tutkitut teknologiat sisältävät ominaisuuksia, jotka liittyvät motivaatioon, fyysiseen aktiivisuuteen, motoriseen koordinaatioon sekä sitoutumiseen ja keskittymiseen, tarjoten erilaisia palautteen muotoja.

Väitöskirjassa ehdotetaan seuraavaa joukkoa affordansseja, jotka ovat aktiivisia neljän interventiotutkimuksen aikana: (1) Sitoutuminen ja motivaatio, (2) Fyysinen aktiivisuus, (3) Havaintoperustainen synkronointi ja motorinen koordinaatio, (4) Sitoutuminen ja keskittyminen sekä hyödylliset palautetyypit, jotka tukevat terapeuttisia ja pedagogisia käytäntöjä interventioissa. Nämä ominaisuudet ovat kriittisiä terapeuttisille ja pedagogisille prosesseille. Esimerkiksi musiikkiteknologian käyttö fyysisen aktiivisuuden lisäämiseksi voi auttaa aivohalvauksen aiheuttamasta liikkuvuushäiriöstä kärsivää potilasta liikuttamaan toimimatonta raajaa koordinoidulla tavalla ja sitoutumaan toistuvaan hoitotehtävään. Toisaalta musiikkiteknologian käyttö opetustilanteessa voi tukea opetusprosessia tarjoamalla opiskelijoille lisäoppimistehtäviä sovellusten muodossa sekä auttaa opettajia tarjoamalla työkalun, joka edistää lisääntynyttä vuorovaikutusta opiskelijoiden kanssa. Nämä affordanssit tarjoavat käytännöllisiä viitteitä siitä, kuinka terapeutit, potilaat, opettajat ja opiskelijat voivat hyödyntää digitaalista musiikkiteknologiaa klinikalla tapahtuvan toiminnan tai oppijan tavoitteiden tukemisessa.

Tämän väitöstutkimuksen tulokset tarjoavat uudenlaisen näkökulman digitaalisen musiikkiteknologian käyttömahdollisuuksista ammattimaisissa musiikkiterapiakäytännöissä, kuntoutuskäytännöissä, fyysisen aktiivisuuden stimuloinnissa ja musiikin oppimisessa luokkahuoneessa. Haasteena on yhdistää nämä eri alojen käytännöt asianmukaisesti. Tulevaisuuden työn on syytä keskittyä näiden teknologioiden jatkuvaan kehittämiseen ja seuraamaan, vaikuttaako niiden käyttö merkittävästi kliinisiin ja pedagogisiin tuloksiin. Tämä väitöskirja tarjoaa ensisilmäyksen siihen, kuinka digitaalista teknologiaa ja musiikkiteknologiaa voidaan soveltaa eri aloilla, tutkien ihmisten vuorovaikutusta musiikin ja innovatiivisen digitaalisen teknologian kanssa eri elämänkaaren vaiheissa.

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ORIGINAL PAPERS

I

ADAPTING TO CHANGE: HOW THE COVID-19 PANDEMIC HAS IMPACTED THE MUSIC THERAPY PROFESSION

by

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Adapting to Change: How the COVID-19 Pandemic has Impacted the Music Therapy Profession

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Abstract

COVID-19 was declared a global pandemic on March 11, 2020. Since then, it has had an undeniable impact on many aspects of society, with far-reaching effects. The COVID-19 pandemic has likely affected music therapists in various ways, as they typically work in-person with their clients, often in healthcare related settings. This study aims to investigate the COVID-19 pandemic's impact on the professional practice of music therapists.

A questionnaire was shared online to certified music therapists around the world during the early stages of the COVID-19 pandemic. There were three broad areas of inquiry that the questionnaire covered, including the situational changes and/or practical adaptations that music therapists have seen in their clinical practice, music therapists' utilisation of technology in their practice in the transition to virtual therapeutic settings, and music therapists' current self-perception of their professional identity.

Results show that music therapists have adapted their professional practices in various ways, resulting in a diverse range of clinical settings. In some circumstances, music therapy has been deemed as an essential service, and music therapists have continued their practices in health care facilities. In others, music therapists have had to shift their practice to a telehealth model of care in order to resume seeing their clients in a virtual therapy setting. The divide between essential and non-essential music therapists is evident from the range of clinical settings reported, and stems further into music therapists' perceptions of their professional identity. Music therapists who have transitioned to a virtual practice reported some positive business-related outcomes, but also reported limitations to their approaches and use of specific interventions. Results also indicate that there is some hesitancy or uncertainty in regard to relevant data protection laws and their applications within a virtual music therapy practice.

1. Introduction and Background

COVID-19 was declared a global pandemic on March 11th, 2020. Music therapists around the world have been forced to adapt their professional practices in various ways, resulting in a diverse range of settings and situations for music therapists to practice in. Music therapy clinical practice is often characterized by its ability to adapt and change, because of the profession's inherent reflexivity, which allows the flexibility to meet clients' needs at a moment's notice during a session (Bruscia, 2014: 46-47). However, the COVID-19 pandemic saw the adaptive skills of music therapists tested on a much broader scale, potentially having a lasting impact on many aspects of clinical settings, professional practice and identity.

Bruscia provides this working definition of music therapy: 'Music therapy is a reflexive process wherein the therapist helps the client to optimize the client's health, using various facets of music experience and the relationships formed through them as the impetus for change. As defined here, music therapy is the professional practice component of the discipline, which informs and is informed by theory and research' (2014: 46). Thus far, the definition of the profession of music therapy has remained consistent through the diverse range of settings that music therapists may work in, while utilising various approaches and methodologies to guide their practice. Some music therapists work in facilities such as hospitals, rehabilitation centres, schools, or long-term care homes. Some music therapists own their own business and work from their own music therapy clinic, or secure contracts in clients' homes or places in their communities. Music therapists work with clients of all ages, from paediatric to geriatric. As research in the field has progressed, music therapists have been able to add more clinical tools to their metaphorical tool box, which often come into use in moments of adapting or pivoting.

The profession of music therapy has evolved over time largely by responding to society's shifting needs, figuring out and developing the methods and applications in which they can fill a gap of care and provide something sought-after in trying scenarios (Byers, 2016: 121; Clair, 2007: 76). An example can be seen in the professionalization of music therapy, which was initiated in the United States after the end of World War II, when music was used in the Army's Reconditioning Program (Byers, 2016: 98). The development of the profession can be seen in line with social advancements in history. Moving to the present era, recent advances in technology have influenced clinical work and research in music therapy, allowing advancements in approaches such as Neurologic Music Therapy which uses EEG and fMRI technology in their research in order to better understand music's effect on neural networks (Byers, 2016: 102). Thus, in its evolution, music therapy practice and theory have been shaped in various ways by societal processes and occurrences (Byers, 2016: 98-103; Aldridge, 2005: 21-22).

The ability to adapt to current needs is characteristic not only of music therapy as a profession, but also of music therapists' practices. However, the characteristic qualities of music therapists and the collective identity of the practice must differ from the definition of the profession itself, according to Bruscia (2014: 192-193). Bruscia argues that 'the profession of music therapy has to define itself according to the discipline, rather than according to its socioeconomic or political environment' (2014: 193). It is important to consider that while global crises (such as the COVID-19 pandemic) may put to use music therapists' characteristic ability to shift and respond to what is needed in the moment, the definition of the profession itself remains consistent. This phenomenon, of maintaining the defining pillars of a profession whilst pivoting practice in response to societal crises has the potential to shift the collective professional identity of music therapists.

That being said, it comes as no surprise that the COVID-19 pandemic likely has had an impact on music therapists' practice in one way or another, whether in regards to employment, therapy setting, clinical populations, or the necessary development of new clinical tools to adapt very quickly to a changing society. Consistent with general protocols to slow transmission of COVID-19, it is likely that music therapists working within a healthcare setting were wearing more PPE (personal protective equipment), sanitizing equipment more frequently, and maintaining distance where possible. There are several possible implications of how these practical measures could affect the ability and quality of the practice of music therapy such as vocal projection through a face mask, playing instruments with gloves on, distribution of instruments to clients, and mobility within the facility itself.

Social distancing measures were part of a global response to decrease human-to-human contact in the hopes of slowing down the transmission of COVID-19 (Public Health England, 2020). In an effort to facilitate social distancing conditions, it was recognized that telehealth could, and should play a crucial role in the delivery of healthcare (Smith, Thomas, Snoswell, Haydon, Mahrotra, Clemensen and Caffery, 2020: 309), and thus has seen rapid adoption across international healthcare organisations (Wosik, Fudim, Cameron, Gellad, Cho, Phinney, Curtis, Roman, Poon, Ferranti, Katz and Tcheng, 2020: 957). The term telehealth relates to activities used in delivering care without face-to-face or physical contact with a patient (Wosik et al.; 2020: 957). As it relates to music therapy, telehealth's key strength is in its function to operate as a delivery tool for therapy, assisting in video consultations, ongoing care, and creating a perception of normalcy for its clients (Smith et al.; 2020: 310; Wosik et al.; 2020: 959).

Using technology as part of the music therapy process can be beneficial for numerous reasons, with various scholars reporting on its efficacy in different clinical settings. Given that a majority of music therapists reported using music technology as part of their clinical practice (Hahna, Hadley, Miller and Bonaventura, 2012: 460), this may suggest high relevancy as it relates to technology use and clinical competence. Krout reported positively on how the use of Skype can support song-writing experiences (2010: 84), while Magee argues that using music technologies provide an immediacy to engage the client (2014: 364). Nagler, (2014: 350) argues that the data created by using music technology in relation to clinical interventions can also function as replicable clinical data, giving the therapist a clear view into data most efficacious to practice (for example, a clients' preference in music for listening). In regards to the professional role of the therapist, Magee argues for the requirement of being flexible in one's role while using technologies, with the therapist functioning as teacher, consultant, or observer (2014: 366).

However, such adaptations may pose challenges and risks to music therapy practice. Nagler (2014: 358) continues, stating that it is essential the therapist has considerable mastery of any device used in the therapeutic process as well as establishing best practice methods (for example, a regulatory framework) to maintain and store digital files. Similarly, Hahna et al. (2012: 462) reported a need for training in relation to clinical practice was needed. A challenge not unique to music therapy is the integration of telehealth software in a clinical setting, since there is little standardized information as to how to establish it with common treatment protocols (Rowland, Fitzgerald, Holme, Powell and McGregor, 2020: 4).

If therapists are compelled to adopt telehealth technology as part of their practice, it is unknown, exactly, how disruptive it has been in integrating the technology as part of their practice, and what impact this has had professionally. This gap in the literature is substantial as previous research highlights risks in the use of technology interrupting a music therapy sessions' momentum (Magee, 2014: 362); increasing demands on the therapist to learn how to use technology while being flexible to adjust in their professional role (Nagler, 2014: 356); and navigating an ambiguous regulatory framework surrounding the use of technology in a clinical setting (Choi, Kim, Nah and Kang, 2019: 255; Rowland et al.; 2020: 4). Managing these unique challenges in music therapy practice during the COVID-19 pandemic may require updated methods of practice and treatment methods underexplored as part of the profession.

The purpose of this study was to investigate the COVID-19 pandemic's effect on the professional practice of music therapists. Specific research questions were as follows:

- How has the COVID-19 pandemic impacted music therapists' practices?
- Does a global pandemic change music therapists' self-perception of their professional identity?
- How has music therapists' use of technology in their practice changed during the COVID-19 pandemic?

2. Methods

2.1 Participants

Music therapists from around the world were invited to participate in an online survey focusing on the COVID-19 pandemic's effect on the practice of music therapy. The survey was shared primarily through social media outlets Facebook, Twitter, and LinkedIn, and was also shared via email to the researchers' global professional networks. The survey was distributed for four weeks from May 15, 2020 to June 12, 2020. A total of 77 music therapists consented to take part in the survey. Of the participants, 38.2% (n=29) were from the United States, 11.8% (n=9) were from Canada, 11.8% (n=9) were from the United Kingdom, 9.2% (n=7) were from Spain, and 30% (n=23) were from other countries (1 from Belgium, 1 from Chile, 2 from China, 2 from Estonia, 3 from Germany, 2 from Greece, 2 from Hong Kong, 1 from Latvia, 1 from Lithuania, 1 from the Netherlands, 3 from Norway, 1 from Portugal, 1 from Serbia, 1 from Singapore, and 1 did not indicate their country of practice).

2.2 Procedure

A cross-sectional descriptive survey design was implemented using a self-administered questionnaire that was developed by the authors. After development, the questionnaire was piloted to ensure clarity and to estimate the completion time frame for future participants. The survey included both open- and close-ended questions regarding demographics, current employment situation, clinical setting, practical adaptations, data protection and confidentiality, telecommunications platforms, and professional identity. Consent was obtained after reading the privacy notice as provided by the University of Jyväskylä, and agreeing to continue with the questionnaire. Participation in the study was voluntary, and no personal identifying information or contact information was collected. It took approximately 15-20 minutes to complete the survey.

Webropol was used to collect the data and export data reports for analysis. Reports were exported into a Microsoft Word file. Researchers could then read all of the responses to gain a general understanding of the responses and verify the content of the data before continuing with further analysis. The researchers approached the thematic analysis inductively, by reading the open-ended responses multiple times in order to gain a deeper sense of familiarity of the content as a whole (Braun and Clarke, 2012: 57-70). Themes that reflected the underlying meaning of the text emerged, and were condensed to establish codes. Once the thematic codes were agreed upon by the researchers, the open-ended responses were coded independently by two researchers. Coding analysis was complete once an agreement was reached between the two researchers' coded data.

3. Results

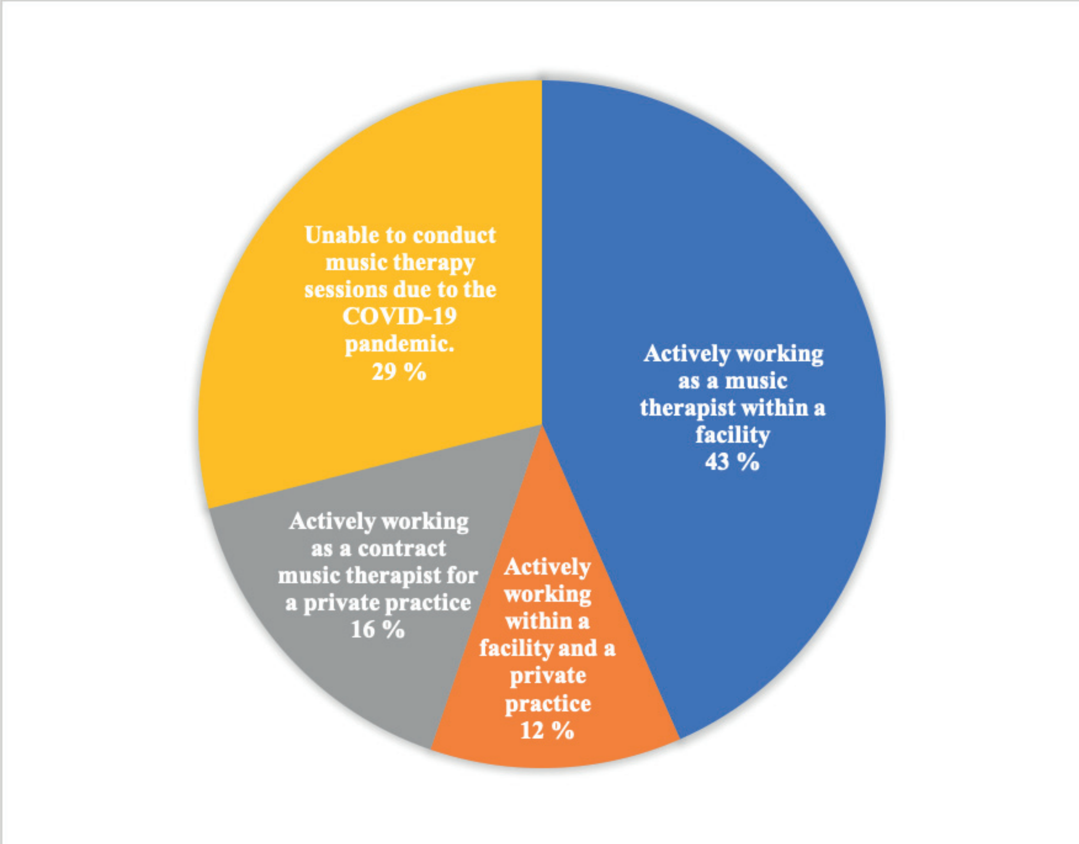
3.1 Demographics

As previously stated, 77 participants from 18 countries responded to the questionnaire, with the most represented country being the United States (n=29). In terms of highest level of education for participants, 59% (n=45) of participants held a Master's Degree, 29% (n=22) had a Bachelor's Degree, 8% (n=6) held a Doctoral/Professional's Degree, and 4% (n=3) held a College Diploma. When asked how long participants had been practicing music therapists, 38% (n=29) had been practicing for less than 4 years, 22% (n=17) were practicing for 5-9 years, 11% (n=8) had been practicing for 10-14 years, 9% (n=7) had been practicing for 15-19 years, and 20% (n=15) of participants had been practicing music therapists for 20 or more years.

3.2 Employment

At the time of survey distribution (between May 15, 2020 and June 12, 2020), 71% (n=54) of music therapists were active in practice, and 29% (n=22) were unable to work due to the COVID-19 pandemic. A complete breakdown of music therapists' employment can be seen below in Figure 1. The therapists who reported being unable to work due to the COVID-19 pandemic were asked a follow up question to briefly explain why they were not able to practice. Four main themes emerged from the responses: 1) externally enforced restrictions or closures prevented therapists from active work, 2) clinical populations (safety concerns working with patients in a vulnerable health state), 3) difficulty/inability for clients to transition to virtual therapy environments (access to the needed technology and internet connection), and 4) the therapist travelling/moving to quarantine elsewhere.

Fig. 1 Music therapists' employment situation during the COVID-19 pandemic

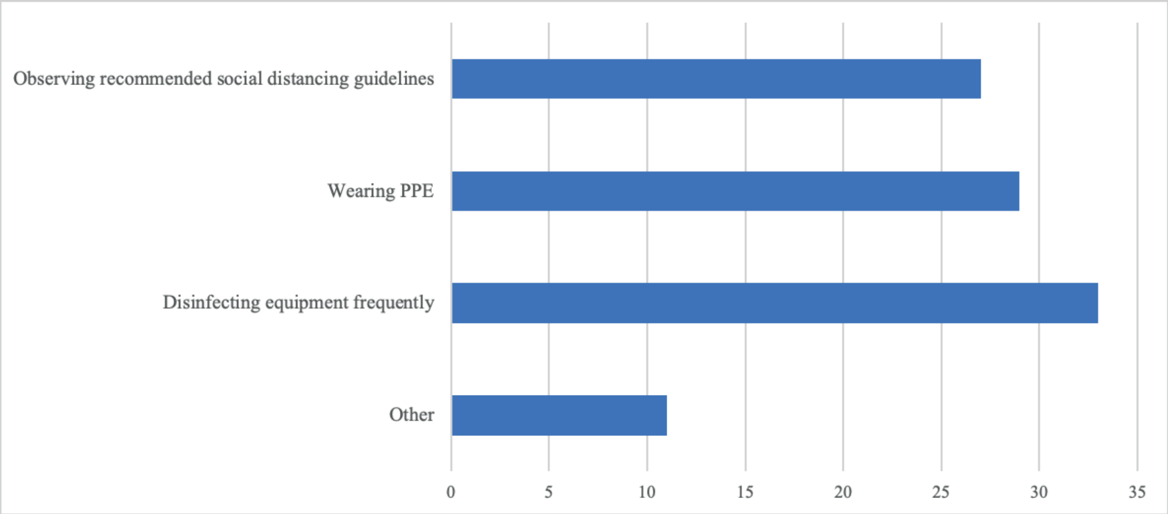


3.3 Clinical Settings

Of the therapists who were actively working within a facility at the time of data collection, 27% (n=12) were working in a psychiatric hospital, 24% (n=11) were working in a long-term care facility, and 22% (n=10) were working in a medical/rehabilitation hospital or clinic. Sessions within these facilities were primarily taking place in the client's room (n=16), a public room within the facility (n=16), music therapy clinic space/office (n=13), a private room (n=8), or virtually (n=6). Other responses indicated that sessions were also taking place in hallways, doorways, balconies, gardens, or other outdoor spaces. Virtual therapy sessions are largely taking place within therapists' homes, in a private room (n=21). Other virtual therapy settings selected by participants were in an open space within the home (n=4), in a clinic space outside of the home (n=3), and in an office outside of the home (n=6).

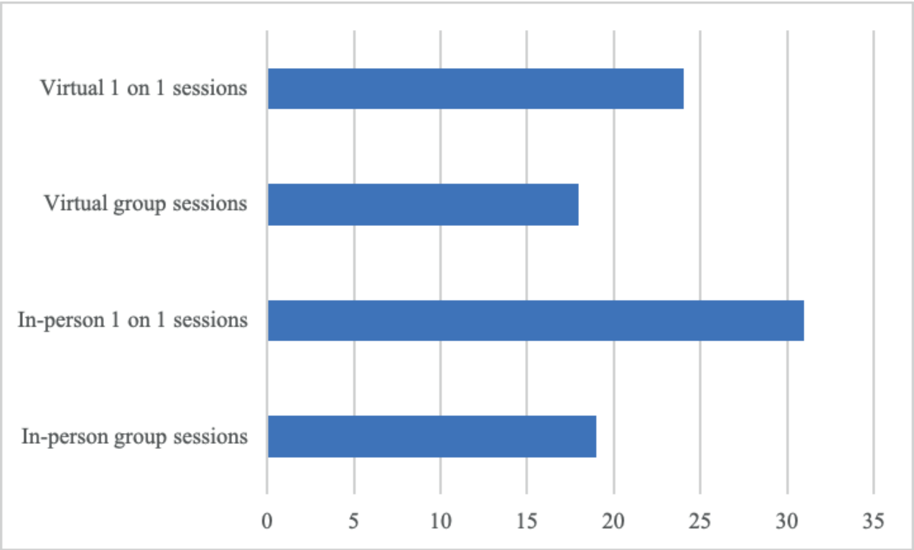
Therapists who were actively working within a facility at the time of the survey, during the COVID-19 pandemic, had to make several practical adaptations to their practice in order to prevent the spread of the virus. Respondents (n=37) were able to select all applicable answers to this multiple-choice question. Results are presented in Figure 2, below. Other responses (n=11) show limiting materials/instruments that are being used in sessions, and a move away from group sessions all together.

Fig. 2 Practical adaptations made to practice within a facility



The types of sessions that were being conducted during the pandemic, were primarily individual sessions, either in-person or virtual. Below, Figure 3 shows the types of sessions that music therapists were conducting during the COVID-19 pandemic. Participants could select all applicable answers.

Fig. 3 Types of sessions conducted during COVID-19



3.4 Case Loads

It appears as though there is not a specific clinical age group that was neglected due to the COVID-19 pandemic. Figure 4 (below) shows the clinical age groups that therapists were working with during the COVID-19 pandemic. Participants could select all applicable answers.

Fig. 4 Clinical age groups seen for music therapy sessions during COVID-19

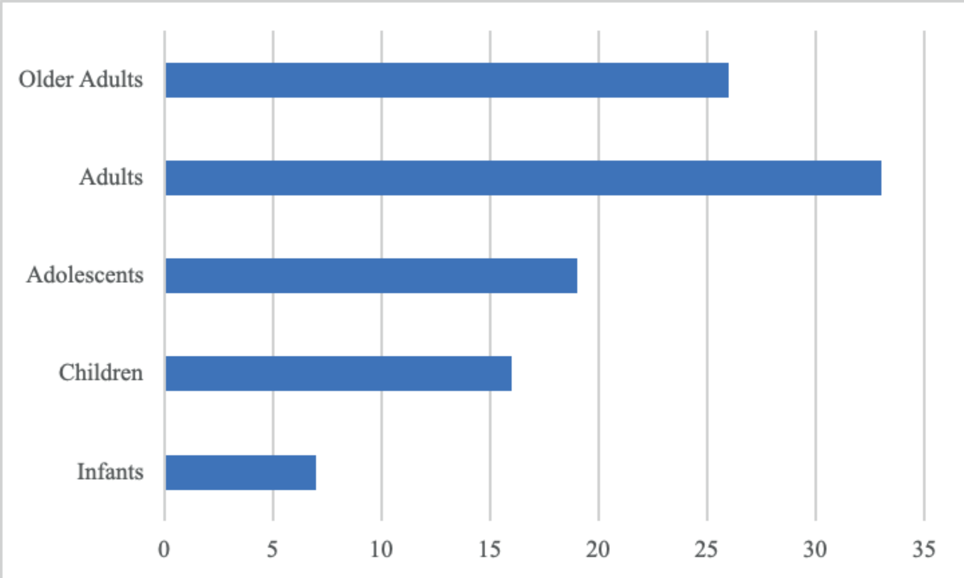
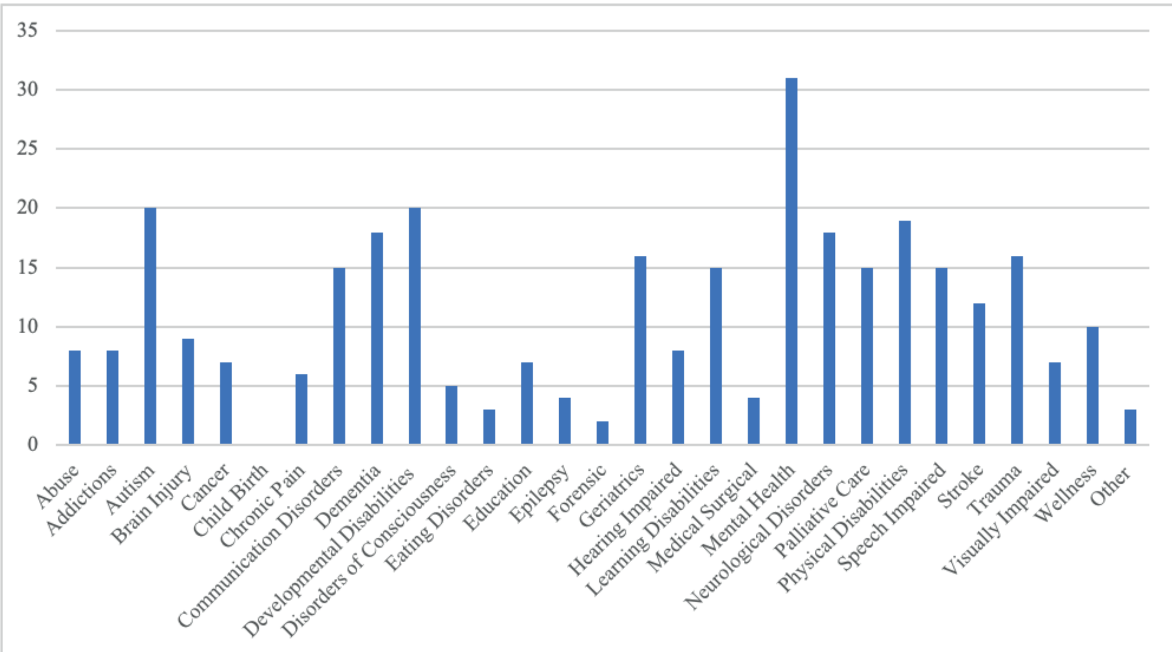


Figure 5 (below) shows the clinical populations that therapists were working with during the COVID-19 pandemic. Participants could select all applicable answers.

Fig. 5 Clinical populations seen for music therapy sessions during COVID-19



The majority of participants (61%, n=32) reported seeing fewer clients than before the declaration of a global pandemic on March 11, 2020. 28% (n=15) are seeing the same number of clients in their caseload, and

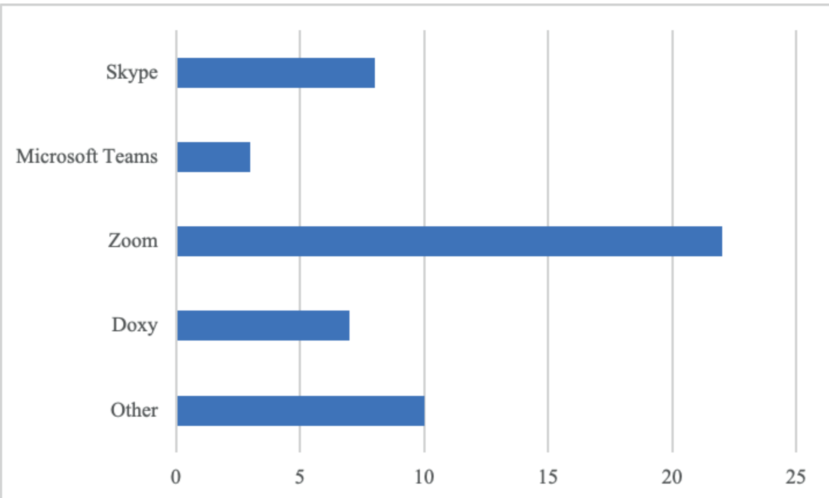
11% (n=6) are seeing more clients than before the pandemic. In terms of referrals, just 11.5% (n=6) of participants had seen an increase in the number of usual referrals since the declaration of the pandemic. 35% (n=18) saw no change to the number of referrals, and 54% (n=28) of participants were receiving fewer referrals, or a stop in referrals entirely since the start of the pandemic. Though 71% of respondents (n=35) did not see a change in the types of referrals they were receiving, those who had seen a change in the type of referrals (29%, n=14) cited differences in clinical populations, changes in referral procedural protocols, or different types of referrals due to the availability and accessibility of virtual work.

It appears as though music therapists were generally not working with clients who had tested positive for COVID-19. Participants who responded that they had worked with clients who had tested positive for COVID-19 (n=5), were asked to briefly describe the primary aims and objectives for these sessions. Of the coded responses, 44% were mental/psychological aims such as addressing anxiety, fear, trauma, and providing stability and security, 31% related to social aims in regard to reducing isolation and loneliness, and 25% of coded responses related to physiological aims, which included substance detox and palliative needs. Some music therapists (17% of respondents, n=9) had conducted music therapy sessions for other health care professionals. Aims for sessions with other health care workers centered around 1) mental health support, with respondents describing anxiety management, grief work, and addressing trauma, 2) preventative aims, primarily in regard to burnout, and 3) staff wellness, often to encourage a sense of unity and increase morale.

3.5 Virtual Music Therapy

Music therapists who were conducting virtual music therapy sessions were asked which telecommunications applications they were using for their sessions. Figure 6 below shows the responses. Therapists could select all applicable answers. Responses under the "Other" category included other professional/business teleconferencing applications such as WebEx and Confrere, personal video/audio calling applications including FaceTime, WeChat, and WhatsApp, and Google software for video conferencing: Google Meet and Google Hangouts.

Fig. 6 Telecommunications platforms used for virtual music therapy sessions



In order to accommodate the use of video conferencing applications as virtual therapy settings, music therapists have made a variety of practical adaptations. Four overarching categories emerged as themes from responses of music therapists (n=28): 1) session planning 2) communication 3) intervention adaptations and 4) skill acquisition (learning technology needed to conduct virtual sessions). Many respondents described using fewer instruments, changing the format of sessions (more, shorter sessions with smaller groups), and making physical adaptations to their therapy space. An increase of communication was seen with clients or clients' caregivers in regard to session planning, or ensuring audio/visual quality. Intervention adaptations included receptive approaches and a move away from collaborative music making.

Many of the same themes were seen in descriptions of how technology has impacted therapists' practice of virtual music therapy. Responses revealed that the impact was seen in four areas of therapists' practice: 1) communicative/connection – therapists commented on a general struggle to establish connection, or to interact in familiar ways with their clients, leading to a change in communicative methods within sessions, 2) visual limitations – because of the restricted view, therapists are only able to view what is in the frame of the client's camera. In addition, poor quality of video connection can make it difficult for therapists to view more subtle responses or facial expressions. 3) Business – results indicate that technology has had a positive business impact, by making it possible for many music therapists to continue seeing their clients. And 4) intervention-specific impacts (see above).

Music therapists who had been conducting virtual music therapy sessions were asked to share positive and negative outcomes that they had noticed. In terms of positive outcomes, four themes emerged from the data: 1) private practice/business practicalities, 2) clinical observations/therapeutic outcomes, 3) external feedback, and 4) personal reflections of the therapist. Therapists saw increased attendance and retention rates, as well as a savings in travel costs and time. They report their clients as feeling more comfortable in their own spaces, leading to higher engagement and fewer distractions in sessions. Therapists responded that co-workers, other staff members, and caregivers who have been more involved in the virtual music therapy sessions have learned more about music therapy and have offered positive feedback. Personal reflections were mainly aimed at qualities music therapists have gained by adapting to a virtual therapeutic environment, and being able to offer a safe place to continue therapy.

The responses for negative outcomes revealed four broad themes: 1) quality of interaction, 2) technology difficulties, 3) private practice/business practicalities, and 4) therapist fatigue. Many therapists noted that the quality of interactions themselves seemed poorer than what they would experience in-person, due to communicative difficulties, and an inability to interact cooperatively with live music. This was often paired with the theme of technology difficulties, those of which included audio latency, poor connection issues, and visual delays. In terms of private practice/business practicalities, music therapists noticed some clients were unable or unwilling to take part in virtual music therapy sessions for various reasons, and an increase in scheduling/administrative tasks. Many respondents commented on a sense of fatigue, due to the increased screen time, and physical strain on posture and the voice.

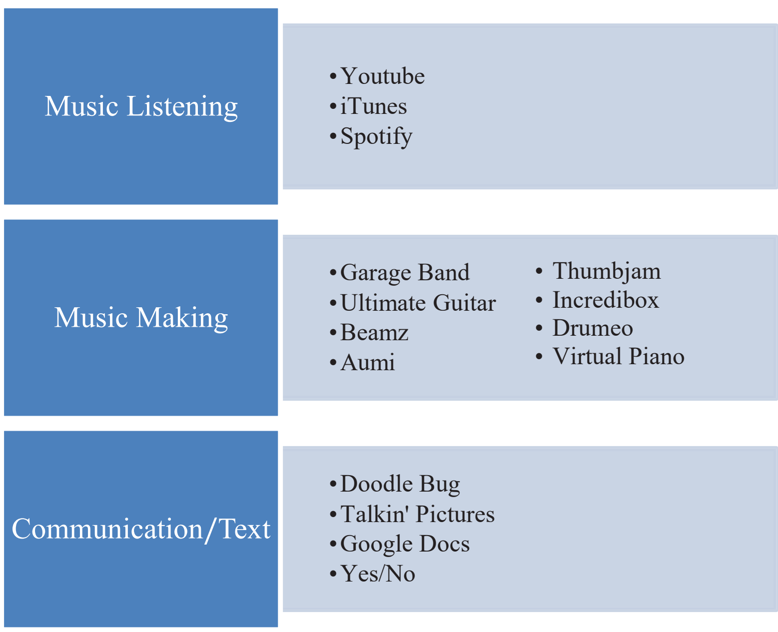
The majority (65%) of respondents (n=19) were following guidelines concerning online work provided by their professional association. Professional associations had not provided such guidelines according to 28% of respondents (n=8), and 6.9% (n=2) stated that they were not following the provided guidelines. When asked to briefly list the guidelines being followed, responses from therapists include guidance from a specific professional board or association such as AMTA, BAMT, CAMT, or the HCPC (Health and Care Professions Counsel), platform specific guidance such as HIPAA compliant or encrypted platforms, additional consent documentation, or practical/physical adaptations to the therapy space.

Specifically, in terms of relevant data protection laws, such as HIPAA (Health Insurance Portability and Accountability Act), HIE (Health Information Exchange), or GDPR (General Data Protection Regulation, 67% (n=20) of respondents have taken into account these precautions for their virtual practice, while 33% (n=10) have not. Music therapists were asked to describe additional precautions made to their practice to ensure relevant data protection laws were being followed while practicing virtually. Four categories emerged from the responses: 1) Environmental adaptations, 2) cybersecurity/encryption/password use, 3) telehealth/organisational compliant software, and 4) additional consent/online agreement.

3.6 App Usage

Whether because of the transition to a virtual therapeutic environment, or using less instruments in sessions for sanitary reasons, some music therapists indicated using apps as clinical tools. Music therapists shared the apps that they were currently using, and those responses are included below in Figure 7 as a resource for readers.

Fig. 7 Reported apps used as clinical tools



3.7 Music Therapists' Professional Identity

Professional identity was defined within the questionnaire as describing "a collective understanding of a profession as well as an individual's sense of self within the professional role". Results indicate a divide in the profession, with 43% (n=23) feeling as though their professional identity as a music therapist had changed since the declaration of the COVID-19 pandemic, and 57% (n=30) of respondents feeling as though their professional identity had not changed. Music therapists were asked to share some words describing their current perception of their professional identity, and the responses were analysed to reveal six themes: 1) feeling/fulfilling a different role/profession, 2) music playing a different role within therapy, 3) no change, 4) positive, 5) limited/negative, 6) client-specific/therapeutic aims. Examples of responses are included in Table 1, below.

Table 1 Respondent's current perception of professional identity

Theme	Example Quotes
1) Feeling/fulfilling a different role/profession	'I honestly feel more like an entertainer than a therapist' 'I feel like parts of my role include social work as well as music therapy'
2) Music playing a different role within therapy	'I have defined my practice as active music making, which I am unable to safely do in the current situation. I have expanded my sessions to incorporate other expressive activities to enhance music listening experience and moved to more receptive experientials and away from directives.'
3) No change	'I believe strongly in a strengths-based, relationship centered approach to music therapy. Although the virtual space does not always allow me to use the same approaches I use in person, I don't believe that my professional identity must change.'
4) Positive	'One aspect of my professional identity has been further reinforced and secured during the pandemic is that music therapists are on par with other mental health professionals. Many colleagues, friends, and members of the public have highlighted the impact of the pandemic on the mental health of society as a whole and I see so clearly how music therapy can assist some people during this time.'
5) Limited/Negative	'… I haven't been able to function as a music therapist and [it] is a profession that becomes fragile when you can't meet your clients.'
6) Client-specific/ Therapeutic aims	'I need to address societal traumas in sessions on a regular basis to support patients during times of increased stress on society.'

Of the respondents who were working as a part of a team of health care workers (n=38), 53% (n=20) reported feeling as though their role within the healthcare team had changed due to the COVID-19 pandemic situation. The changes described were found to belong to three general themes: 1) cross-functional role, 2) interaction/collaboration with colleagues, and 3) limitations. Music therapists feeling that their role within the team has changed to that of a cross-functional one, are adapting their work to respond to the needs of the team as a whole, including tasks typically outside music therapists' scope of practice. Responses indicated that interdisciplinary collaboration had increased, and music therapists within a health care team are feeling more valued, recognized, and needed by their team. On the other hand, some respondents (n=4) experienced limited hours or a cut in services and reduced collaboration.

4. Discussion

4.1 Therapeutic Environments

The settings that music therapists were working in, during the COVID-19 pandemic, had undoubtedly changed, both in terms of physical location, and in the equipment or materials that make up the therapeutic environment. The results indicate that these kinds of practical changes were applicable whether therapists were working in-person or virtually. Though the majority of sessions within a facility were being held in a public room, the client's room, or a music therapy clinic/office space, it was interesting to find out that music therapy sessions were also being conducted in hallways, doorways, and outdoor locations such as balconies or gardens. Presumably these non-traditional therapeutic environments took shape out of necessity for following certain physical distancing guidelines. The use of PPE during sessions, especially face masks, appeared to lead to some symptoms of therapist fatigue such as vocal strain, as mentioned in many therapists' reflections. Therapists who wore facemasks also commented on changing the nature of their facial expressions - making them more obvious and using their eyes more expressively – since the mouth is covered. Though not directly expressed in the results of the questionnaire, from these changes and challenges to the therapeutic environment working in-person with clients, it is plausible to presume there were subsequent alterations to the clinical interventions, approaches, and/or techniques used in sessions.

In terms of virtual music therapy sessions, one may consider the therapeutic environment as having multiple settings - the physical space that the therapist is working in, the telecommunications platform environment, as well as the physical space that the client is located in – each with their own components of equipment or materials. The physical space requires consideration on the parts of both therapist and client, primarily for reasons of confidentiality, but it should also be a space in which both parties feel comfortable and safe to conduct their work. While it is not known from the results of this survey where clients were participating in virtual music therapy sessions, some music therapists reflected that their clients seemed more comfortable and less distracted in their own spaces, and this resulted in some positive therapeutic outcomes.

Availability and accessibility of instruments and other materials that therapists and their clients may have been accustomed to using in their sessions likely was part of the reason that many therapists reported changing their approaches to interventions. However, the most cited reason for adapting interventions or approach to music therapy as a whole was to accommodate the virtual environment – the telecommunications platform itself. Audio delay was a frequent complaint in the questionnaire results, regardless of the telecommunications platform used. Some music therapists reported workshopping with peers to determine the lag, and consciously played behind the beat of their clients to remedy the problem, while most seem to have abandoned collaborative music making all together, opting for more call-and-response or turn taking interventions, pre-recording music components of sessions, or transitioning to an entirely receptive approach to therapy. The difficulties posed by the virtual platforms has certainly shifted the role of live music within music therapy sessions, a quality that is typically the core of many therapists' practices.

4.2 Navigating Virtual Music Therapy

The use of telehealth technology is recognized as crucial to the delivery of healthcare during the COVID-19 pandemic, ensuring adherence to social distancing conditions while maintaining ongoing care as facilities closed/were partially restricted for use. Despite results demonstrating the increased accessibility and ability to implement the delivery of music therapy during the COVID-19 pandemic, the challenges reported to overall practice outweigh positive responses. While the use of telehealth technology enabled therapy to continue, the external demands (adaptation in professional role, need for technological competence, lack of instruments to use) and internal demands (therapist fatigue, lack of connection with client) suggest challenges to practice. Conversely, therapists also reported positively on operational outcomes while using telehealth technology, illustrating a benefit to workflow.

While the present study is unprecedented due to music therapy being conducted using telehealth technology during a global pandemic, the results are consistent with current literature regarding telehealth in general. Smith et al. (2020: 310) and Wosik et al. (2020: 957) argue that telehealth's strength supports communication by video consultations, and creating a perception of normalcy for clients, as reported in the present study. Moreover, findings by Magee (2014: 363) in relation to how music technologies encourage cross-functionality of the therapists' role (for example, becoming a teacher, consultant or observer while using technologies) is asserted in these findings. Further, the inclination that technology requires a high degree of competence to use is consistent with Nagler's (2014: 356) findings. Similar to research by Hahna et al. (2012: 462), there is an indication in the present study that the practical training of music therapists on the use of telehealth technology would be beneficial.

The study shows an apprehension regarding use of organisational guidelines related to online clinical practice. The evidence is curious, as it may reflect poor clinical practice, or factors within organisational guidelines not adequately associated with the implementation of online music therapy. In a study regarding clinical practice guidelines in occupational therapists, Stergiou-Kita (2010: 84) states there is no evidence to support use of one implementation strategy over another due to factors within guidelines, patient requirements and clinical settings. It follows that, as music therapists adapted their interventions and clinical spaces due to the COVID-19 pandemic, adhering to organisational guidelines may have proved impractical. Speculatively, established guidelines may have not accompanied music therapists' transition to online practice, and were therefore not implemented by some. Consequently, in light of the COVID-19 pandemic, the evidence suggests organisational guidelines may require updating to augment robust online music therapy practice.

4.3 Ethical Considerations

In addition to navigating the practicalities and accommodations associated with establishing a virtual environment for music therapy, there are accompanying ethical considerations. There is very little guidance in music therapy literature regarding the ethical concerns around using technology in practice and how to resolve the ethical dilemmas surrounding technology use (Bates, 2014: 136). Ethical codes or guidelines of music therapy associations (for example, AMTA, CAMT) seldom directly mention the use of technology in practice, and neither of these examples address virtual therapeutic environments specifically. However, three primary areas of concern broadly covered in these ethical guidelines are those of confidentiality, protection under applicable laws, and competence.

Questionnaire responses indicated that many music therapists had taken the additional step of preparing an additional consent document with specific reference to transitioning to an online, virtual therapeutic environment. This, for example, successfully meets the AMTA code of ethics item 1.6, which calls to protect and respect the client's confidentiality, follow applicable laws and institutional regulations, and to inform the client of limitations to confidentiality (American Music Therapy Association 2019). However, our results also indicated that a third of respondents were not following applicable data protection laws and regulations, which is concerning, given that these regulations are referred to in the AMTA and CAMT ethical codes. AMTA code of ethics item 1.7 refers specifically to the Health Insurance Portability and Accountability Act (HIPAA) (American Music Therapy Association 2019), and CAMT item II.18 also refers to the precautions set in place by law and institutional regulations to ensure the confidentiality rights of clients (Canadian Association of Music Therapists 1999). Based on the results of this study, there is evidence to suggest that data protection laws within virtual music therapy face challenges in implementation, and that adherence to data protection laws in music therapy were found primarily in downstream processes (for example, password use, requiring additional consent) (Terry, 2017: 21).

Even if national or regional music therapy associations have not released explicit guidelines to ensure its professionals are following the applicable laws and regulations in terms of data protection as it pertains to virtual music therapy practice, it is absolutely crucial that music therapists do their own due diligence to ensure the utmost safety and protection of their clients' personal health information. Many professionals (not only music therapists) are navigating unchartered territory right now, with the transition to virtual therapies and telehealth. Research by Choi et al. (2019: 255) and Rowland et al. (2020: 4) affirm this ambiguous regulatory framework to be navigated by any practitioner using technology in a clinical setting, and report that clinicians lack the necessary training to counsel patients on important factors such as data privacy, and highlighting the lack of clear guidance on how to integrate digital technologies into established treatment protocols. It is important that as healthcare professionals, music therapists take the initiative to educate themselves on the applicable data protection laws for their own region, country and/or state or province in order to be as well-equipped as possible in navigating this new area of practice.

Being well-equipped in terms of knowledge of data protection and applicable laws is just one area of competence, which is another item covered in ethical codes that applies to the transition to virtual care. Though conducting virtual music therapy likely is not a course that is available in training programs (yet), one can see the relevance in item II.6, for example, of the CAMT code of ethics, which states therapists should only perform services for which they have established competence through sufficient training and supervision practices (Canadian Association of Music Therapists 1999). Competence is a far-reaching element in ethical practice. This can be seen through the defined boundaries of offered professional services as set by the area of expertise or scope of practice (Bruscia, 2014: 65), to competence in and of the tools and materials themselves that music therapists use in their practice. Nagler (2014: 358) claims that it is essential the therapist has considerable mastery of any device used in the therapeutic practice. Bates (2014: 138) insists that therapists who use technology in practice must be competent in all aspects, including computer and internet technology, data security, and client record confidentiality. With no existing benchmark of achieving competence in this area, music therapists must now be reliant on self-education and peer supervision resources. Looking forward, one can see the need for implementing virtual music therapy as a topic to music therapy education and training programs.

4.4 The Essential/Non-Essential Divide

With the rise of the COVID-19 pandemic, many governing bodies deemed different categories of professions as ‘essential’ or ‘non-essential’ to ensure the public’s safety and reduce the spread of COVID-19. The profession of music therapy, however, seems to have been divided as well, between music therapists deemed as essential in their work place(s) and those who have been deemed non-essential workers. Though defining workers as essential and non-essential was a necessary step in preventing the spread of COVID-19, one must wonder how these labels have affected music therapists, seeing as the results from this study demonstrate a clear divide. The researchers believe that this divide is seen in the results not only in employment status and workplace environments, but through to music therapists’ professional identities. Looking at professional identity as both an individual’s sense of self within the profession and a collective understanding (Bruscia, 2014: 192-193; Feen-Calligan, 2012: 150), we must consider whether this divide of the essential and non-essential worker will have a lasting impact on our collective understanding of the profession.

Open-ended responses of the survey showed stark contrast between those who felt a sense of recognition, of being needed by clients and co-workers in crisis situations, and those who felt neglected, or overlooked as a healthcare professional and thus unable to provide care. Optimistic respondents commented on increased collaboration with co-workers in order to accommodate the changing needs of the work environment and their clients/patients. There were multiple responses referring to co-workers or managers understanding and recognising the benefits of music therapy, and feeling on par with other mental health care workers. Other respondents noted the limitations to the profession that COVID-19 had uncovered, commenting on the fragility of the profession – knowing that clients needed care but being prevented from actually providing that care. Only time will tell how music therapists transition out of the COVID-19 era, and perhaps future studies can inquire if the essential/nonessential divide had a lasting impact on the collective understanding of music therapists’ professional identities.

4.5 Limitations

This was an online survey involving self-reporting, thus the accuracy and subjectivity from participant reports may have led to limitations in the results. Due to the limited data collection period, some may consider the participant sample as relatively small, however it is important to note the relative size of the profession on a global scale as well. The researchers found the sample size and global representation to be acceptable. Given that the survey was distributed during the early stages of the COVID-19 pandemic, it is quite possible that certain responses will change over time, as society adjusts to the constantly shifting pandemic situation. Follow-up research would be valuable to determine how these adjustments and alterations to practice have had an impact over time.

5. Conclusion

In a time of global uncertainty and crisis, it is tempting to focus on the challenges of the era. However, one can see many positive implications for the field of music therapy from the results of the current study. Though some music therapists were unable to practice during the height of the COVID-19 pandemic, many of those who were practicing (in-person or virtually) felt recognized. As a profession who prides itself on its constant advocacy, education, and promotion in order to be recognized as a valid and valuable healthcare profession, there was an underlying tone of relief in many responses – of finally being understood by co-workers, managers, nurses, families. If we are to take some positivity out of this global pandemic, perhaps it is that in some cases, music therapy was valued as a valid and effective form of care during a health crisis - that music therapy had a role to play during a global pandemic. Music therapists who were working as part of a health care team proved the profession's adaptability and functionality, and as part of the crisis-response mentality of 'all hands on deck', were able to function in a cross functional role. Family members of clients who had to assume the role of therapy assistants were able to witness first-hand progress made towards clinical aims. The implications of this renewed recognition in multiple settings are seemingly endless. In healthcare facilities especially, exists the potential for continued collaboration among health care teams, increased music therapy referrals, and interdisciplinary practice and research opportunities.

Looking forward, this surge of telemedicine and the proven necessity of having such options available, has pointed to the need of updating educational curricula and training programs in many disciplines to accommodate these needs and ensure safety, security, and competence in practice. Previous literature has called for more education for music therapy students regarding the use of music technology in practice (Hahna et al.; 2012: 463; Magee, 2014: 38-40), and we hope that the current situation and results of this questionnaire will expand that call to include the use of telecommunication software in music therapy practice as well.

Despite the changes and challenges that the field of music therapy has had to face due to the COVID-19 pandemic, it is fair to say that the definition of the discipline itself has remained consistent, though many aspects of practice have been adapted to suit the current situation. As Bruscia stated, 'music therapy can no longer be defined in terms of what I do, or in terms of what you do – it is what we all do, and it is constantly growing' (2014: 193). The multiple adaptations and changes to music therapy practice have all contributed to a recent growth of the profession, and it will be interesting to see which factors remain an influence long after the COVID-19 pandemic is over. What is known, however, is that the characteristic ability of music therapists to adapt and pivot in response to the moment, has been sufficiently tested and proven on a much broader scale in this era of COVID-19.

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II

NEGLECT, VIRTUAL REALITY AND MUSIC THERAPY: A CLINICAL REPORT

by

Andrew Danso, Mikaela Leandertz, Esa Ala-Ruona and Rebekah Rousi (2022)

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Full-Length Article

Neglect, virtual reality and music therapy: *A clinical report*

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Abstract
Neglect is typically experienced after suffering from a stroke. Despite various rehabilitative interventions used in treatment for neglect, there is no consensus about the most effective intervention or treatment. Virtual Reality (VR) combined with music therapy practices may offer a promising intervention for use during neglect rehabilitation. This review summarises evidence of existing interventions and assessments used for post-stroke and neglect rehabilitation on patients in VR and music therapy research. Non-systematic searches of the PubMed and PsycINFO databases were conducted to retrieve relevant articles. Overall, literature found in small studies suggests promising findings for symptom reduction during neglect rehabilitation through the use of VR and Musical Neglect Training interventions. This was coupled with a demonstration of feasibility and safety. Novel evidence is found in stimulation of specific neurological regions in neglect patients during exposure to a VR intervention. However, larger trials with consistent assessments are needed to arrive at generalisations. Based on the evidence reviewed, the article explores intersections of VR and music therapy interventions with the purpose of neglect rehabilitation.

Keywords: ***Stroke; neglect; rehabilitation, music therapy, virtual reality***

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Introduction

Focus of the Review

Despite various rehabilitative interventions used for treatment of neglect, there is no consensus about the most effective intervention or treatment [1]. Given the lack of research exploring the combined use of VR and auditory cues to neutralise neglect bias, a review identifying and describing interventions and assessment in VR and music therapy research applied to stroke and neglect populations would provide an understanding of whether or not such an intervention is applicable for treating neglect. Therefore, this review summarises evidence of existing interventions and assessments used for post-stroke and neglect populations in VR and music therapy research.

PRODUCTION NOTES:

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The Neglect Syndrome

Neglect is a common result of a right hemispheric stroke in the brain. This affects approximately 60% to 70% of stroke populations. [2,3,4] State that neglect is caused due to damage to the multisensory cortex, where the auditory and visual input combine to construct spatial representations of our body's position in relation to our environment. Neglect may also be referred to as hemineglect, spatial neglect, visuospatial neglect, visual neglect, unilateral spatial neglect (USN), paresis, and hemiparesis. [5] indicate the frequency of patients suffering with neglect in the United States is estimated to be from 13% to 81% in populations who have experienced a right hemisphere stroke. They also describe rates in other countries that exist at approximately 50% of the stroke population.

Areas of Functioning Affected by Neglect

Neglect can affect various areas of functioning. Often the functions affected include impaired neurological performance, motor performance of the limbs and perception. According to [6], the distinct deficit in patients experiencing neglect is an orientation bias to the right. There are two categories of neglect that affect functioning. These categories are: 1) how neglect affects behaviour (e.g., physical sensation, and motor movement) and 2) how much it disrupts perception (e.g., personal awareness or spatial awareness) [1,7,8,9]. In a recent review, neglect is described as causing comorbid visual conditions such as strabismus, greatly increasing the risk of a fall [10]. There is further evidence that patients suffering from neglect cannot accurately perceive time. This is known as time discrimination [11], which causes disruptions to visual attention when directing it over time [12]. Furthermore, neglect weakens the accuracy in perceiving sounds when audio tones are presented in the neglected area, e.g., the left ear [13,11,14]. Due to the combined auditory (perception of sounds) and visual (directing visual attention) impairment caused by neglect, these disabling effects can impede patient participation and adherence to rehabilitation programs. It may also decrease patient independence in activities of daily living (ADL). Furthermore, patients with neglect report higher scores for depression than non-neglect patients [15].

Neglect Rehabilitation and Recovery

Following neglect, rehabilitation and recovery is needed by patients. Differences between rehabilitation and recovery are important to outline. [16] defines rehabilitation "as any aspect of stroke care that aims to reduce disability and promote participation in activities of daily living" (p. 239). [16] also describes rehabilitation as being a "process… to prevent deterioration of function, improve function, and achieve the highest possible level of independence" [16, p. 239]. Recovery associated with neglect is defined as "improvement across a variety of outcomes, beginning with biological and neurologic changes manifesting as improvement on performance and activity based behavioral measures" [16, p. 239].

Typical neglect rehabilitation is closely related to stroke practices, and may involve its associated interventions. These may be the following, but not limited to: a) Physical interventions, such as muscle strengthening, repetitive task training, constraint induced mobility therapy, mirror therapy, gait rehabilitation and botulinum toxin; b) Regenerative interventions, such as cognitive rehabilitation, non-invasive brain stimulation, neuromodulators and drugs to enhance motor recovery; c) Remote rehabilitation interventions, such as telerehabilitation, biotechnology and wearable sensors, and brain-computer interfaces; and d) Intervention technologies for rehabilitation such as robotic devices, VR and electrical stimulation [17].

Neuroplastic Changes post-stroke and Musical Stimuli

A fundamental aspect of post-stroke and neglect rehabilitation is inducing neuroplasticity. Neuroplasticity is generally understood as the capability of the nervous system to respond to intrinsic and extrinsic stimuli through reorganization of its structure, function and connections [18, 19]. Evidence for understanding neuroplasticity and the nature of how the brain functions when exposed to musical stimuli has been found through studies engaging in music, actively or passively, as well as the use of music-based interventions on various populations [20, 21]. The multisensory and multimodal actions of music engagement and music-making activate various neural pathways in the brain - this multi-modal aspect of music may be the reason for its role in supporting plastic changes in the nervous system [19]. Recently, music-based interventions have been used in the rehabilitation of traumatic brain injury [22] and stroke [23, 24].

Neurological Music Therapeutic Approaches

In recent years, music therapy practices have been researched, developed and applied to stroke and neglect rehabilitation. [25] states that "music therapy is a systematic process of intervention wherein the therapist helps the client to promote health, using music experiences and the relationships that develop through them as dynamic forces of change (p. 20)". According to the American Music Therapy Association [26] music therapists assist the following client populations: developmental and learning disabilities; Alzheimer's and other aging related conditions; substance abuse problems; brain injuries; physical disabilities; acute and chronic pain. An accepted model put into practice within music therapy and neuroscience is Neurologic Music Therapy (NMT) [27].

Music listening and musical activities such as playing an instrument, induce neural plasticity in various brain regions, with an emphasis in frontotemporal areas [3, 28, 29, 30, 31]. Examples of effective music listening have been reported in the recovery of discharged patients after different types of major surgery. This is measured via indicators such as pain and anxiety level, use of analgesics and patient satisfaction [32], providing support that music may also enhance neurological rehabilitation [3]. Evidence exists for the use of auditory stimuli as an effective training stimulus during the rehabilitation of neglect. Significantly, the use of auditory stimuli enhanced visual perception during neglect rehabilitation studies [33, 34].

Based on the data of NMT, Musical Neglect Training (MNT) has been developed for patients with visual neglect [27, 35]. MNT is a (NMT) technique employed by music therapists that uses active musical exercises with participants. In the exercises, participants are required to play musical patterns (that can be melodic or rhythmic) on musical instruments that extend to the neglected visual field. The musical patterns should be well known to the participants to drive an attentional search in applying and completing music-related events in the neglected field.

VR Rehabilitation

VR is a technology that has been researched and subsequently utilised as an intervention for stroke and neglect rehabilitation. VR systems rely on computer hardware and software in creating and mediating interaction between the user and the virtual environment [36]. VR rehabilitation typically involves providing its user with visual-audio stimuli presented through a head-mounted device (HMD) to foster real-time feedback. Feedback can also be provided through the patient's senses (e.g., by movement, touch, or sound) [37, 38] by means of using different interaction devices. Thus, the patient can interact with these virtual environments utilizing different input (e.g., joysticks, cameras, sensors or haptic devices) [38].

VR rehabilitation has been noted for its ecological validity, with the technology's capability to simulate realistic environments in which stimulus control can support consistent repetitive delivery that is hierarchical [39]. Specifically, the feedback stimuli delivered by VR can appear graded and manipulated across multiple sensory modalities (e.g., audio, visual and tactile), as well as tailored to the goals of the patient, therapist and functional capability of the patient. VR application design and research with clinical populations has been focused on developing functional activities which can be completed safely. The activities are monitored with degrees of accuracy using kinematic tracking (i.e., motion capture) found in VR systems to provide a naturalistic record of the patient's bodily movement.

Limitations to VR rehabilitation are found in aspects of development and user experience. For example, finding the most suitable manner to use and interact with VR during rehabilitation is usually costly and time-consuming, depending on user testing [39]. VR applications may also lack clinical ease of use, with back-end data extraction providing raw data that is sometimes not accessible to healthcare teams. Then, there is the problem with VR's main stimulus delivery device, the HMD. While HMDs provide rich immersive experiences and stereoscopy, they are sometimes difficult for the user to use, tethered to a system by cable and provide a limited field of view. Side effects after using HMDs include, *cybersickness* and *aftereffects*. Cybersickness is a form of motion sickness, with reported symptoms in nausea, vomiting, eyestrain, disorientation, ataxia, and vertigo [40]. Aftereffect symptoms include flashbacks, drowsiness, fatigue, and perceptual-motor disturbances [41, 42, 43]. User eyestrain and headaches are also reported after using HMDs. The use of headphones with HMDs has also been reported as uncomfortable to wear for some users.

VR Intervention Use for Neglect Populations

VR interventions for neglect rehabilitation have been developed, with studies tracking the upper-limbs of the patient using motion-capture technology related to task cueing stimuli [44]. The therapeutic goals associated with these interventions varied widely, with some using prism adaptation methods [45] removing parts of the ipsilesional visual field to promote contralesional orientation [46], and having patients reach for objects on the ipsi- and contralesional spatial side [47, 48]. In [47, 48], therapist support was given to some patients while they used the VR interventions. [44] writes that much of the visual stimuli used in these VR interventions was simple, using block shapes and colour to represent environments or task-related items the patient would interact with virtually.

VR and MNT Adjunct Use

Given that neglect is typically a multisensory phenomenon, [6] recommends using sensory signals from different modalities to counteract the rightward bias in neglect patients. Adjunctive use of VR rehabilitation with MNT tasks may provide a music therapist and/or multidisciplinary healthcare teams with an effective multi-modal tool to include during neglect rehabilitation. This is because of VR's multi-modal capability that includes immersion in a virtual environment via visual and audio stimuli, access to motor tasks in games with applications simulating realistic bodily movement associated with ADL, a safe environment to practice rehabilitation, and its kinematic tracking capability using motion capture technology that may be applied to patient assessment.

Methodology

To construct this narrative review, non-systematic searches of the PubMed and PsycINFO databases were conducted to retrieve relevant articles, using English language restrictions. The data search included terms for virtual reality, neglect, music therapy, and rehabilitation.

Selection Criteria

1. Study Type: Published peer reviewed primary studies.
2. Study Group: Patients (>18 years old) in a general hospital, family medicine clinics, sports medicine clinics, chiropractor clinics, physiotherapy clinics and/or

rehabilitation clinics, with a diagnosis of neglect, hemineglect, spatial neglect, paresis and hemiparesis, using established diagnostic criteria.

3. Study Intervention: VR practice delivered/accompanied by specialists in physical medicine, rehabilitation, paediatricians, orthopaedics and physiotherapists. Music Therapy delivered by a Music Therapist (defined by possession of professional Music Therapy qualification and/or registered with the appropriate governing body).
4. Study Outcomes: Changes in stroke or neglect symptoms as measured by validated rating scales, clinical study report, case study report.

Articles deemed relevant to all authors, including randomized controlled pilot trials, VR rehabilitation effects on ADL studies, observational case studies, a neurologic music therapy study, VR rehabilitation used adjunctly with physiotherapy, VR rehabilitation used with fMRI studies and feasibility trials were included. Data were examined and reviewed based on their clinical relevance.

Results

Topics and Study Designs

The study design results show one pre- and post- test design, three between group designs, two case studies, one between group design and within subject's design, and one quasi-experimental design: Non-equivalent control group design, one two-arm pilot RCT clinical trial. The largest study population includes 36 participants with the smallest study population including one participant (one case study). Information about the study designs and populations are summarised in table 1.

Table 1. *Summary of the 9 studies reviewed, their objectives/goals, interventions, study designs, and study outcomes reported. Note the asterisks (*) indicate intervention, assessment, and follow-up periods.*

Study Title	Author(s) and Reference	Study Objective/Goals	Intervention	Study Design	Number of Participants	Outcomes
Musical Neglect Training for Chronic Persistent Unilateral Visual Neglect Post-stroke	Kang and Thaut [49]	Spatial Neglect Symptoms	Musical Neglect Training *6-weeks follow up	Pre- and Post-Test Design	2	AT, LB *1-week follow-up
Rehabilitation in Chronic Spatial Neglect Strengthens Resting-state Connectivity	Wåhlin, Fordell, Ekman, and Lenfeldt [50]	Stroke severity, Awareness of physical sensation, Unilateral Neglect severity, Neglect severity, DAN Analysis, Brain Functional Anatomy	RehAtt®	Between Group Design	13	fMRI *1-week before intervention *1-week after intervention SCT, LB, BTT, VET, RBIT (VR-DISTRO). *1-2 weeks between assessments *1-week follow-up
Increase of Frontal Neuronal Activity in Chronic Neglect Training in Virtual Reality	Ekman, Fordell, Eriksson, et al. [51]	Stroke severity, Unilateral Neglect severity, Neglect severity, Awareness of physical sensation, Attention Behaviour	RehAtt®	Between Group Design	12	CBS, SCT, LBT, VET, BTT, PCT *PCT 1-2 weeks between sessions * fMRI scan 1-week before intervention and 1-week after intervention

Differing Effects of an Immersive Virtual Reality Programme on Unilateral Spatial Neglect on Activities of Daily Living	Yasuda, Muroi, Hirano, Saichi, and Iwata [52]	Visual Neglect severity, Unilateral Neglect severity, Stroke severity	Immersive VR programme	Case Study	1	LCT, LB, CBS.
Increasing Upper Limb Training Intensity in Chronic Stroke Using Embodied Virtual: A Pilot Study	Perez-Marcos, Chevalley, Schmidlin, et al. [53]	Motor Impairment, Awareness of physical Sensation, Safety of intervention, Patient Motivation	Mind-Motion ™ PRO	Between Group Design	10	FMA-UE, AROM, Muscle Strength, Functional Independence, Pain ratings, Safety and Acceptance of Technology, Tolerance to VR Intervention, Adverse Event Monitoring, Self-evaluation, Acceptance of technology, Motivation
Use of Virtual Reality In Improving Poststroke neglect: Promising Neuropsychological and Neurophysiological Findings From a Case Study	De Luca, Lo Buono, Leo, et al. [54]	Cognitive Impairment, Motor Impairment, Attention Behaviour	Bts-Nirvana System	Case Study	1	MMSE, Repeatable Battery for Neuropsychological Status, BIT, TCT.
Virtual Reality Application for the Remapping of Space In Neglect Patients	Ansuini, Pierno, Lusher, and Castiello [55]	Unilateral Neglect severity, Stroke severity	Hollow Box, Computer Monitor, DataGlove.	Between Group Design, Within Subjects Design	9	AT, SCT.
Virtual Reality Games as an Adjunct in Improving Upper Limb Function and General Health among Stroke Survivors	Ahmad, Singh, Nordin, Nee, and Ibrahim [56]	Motor Impairment, Patient Motivation, Patient functional independence, Stroke severity	Virtual Reality Games	Quasi-Experimental Design: Non-equivalent Control Group Design	36	FMA-UE, WMFT, IMI, IADL, SIS.
Feasibility, Safety and Efficacy of a Virtual Reality Exergame System to Supplement Upper Extremity Rehabilitation Post-Stroke: A Pilot Randomized Clinical Trial and Proof of Principle	Norouzi-Gheidari Hernandez, Archambault, Higgins, Poissant, Kairy [57]	Motor Impairment, Strokeseverity	Jintronix System	Two-arm pilot randomized clinical trial, pre-post follow-up design.	18	FMA-UE, BBT, SIS, MAL. *Baseline *Post-intervention *4-weeks follow up

Assessments

In all of the studies reviewed, various assessments are used to assess the patient's presence or severity of stroke and neglect symptoms. The different methods of assessment used are outlined below under the following categories: brain activity, computerised measures, standardized health measures and kinematic Tracking. Brain Activity was inclusive of Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Functional Magnetic Resonance Imaging (fMRI).

The Standardized Health Measures included Activities of Daily Living (ADL), Albert's Test (AT), Behavioural Inattention Test (BIT), Barthel Index (BI), Catherine Bergego Scale (CBS), Fugl Meyer Assessment of Upper Extremity (FMA-UE), Functional Independence Measure (FIM), Intrinsic Motivation Inventory (IMI), Line Bisection Task (LB), Line Cancellation Test (LCT), Mini Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), Motor Activity Log (MAL), Muscle Strength, Stroke Impact Scale (SIS), Trunk Control Test (TCT), Visual Extinction Test (VET), Wolf Motor Function Test (WMFT).

The Computerised Measures were Posner Cueing Task (PCT), Star Cancelation Test (SCT), Extinction Test (ET), Baking Tray Task (BTT), Rehabilitation Gaming System (RGS). Kinematic Tracking showed VR motion capture, Active Range of Motion (AROM).

Rehabilitation Strategies

Rehabilitation strategies are referred to as the processes to how interventions function and what neurological and behavioral mechanisms they aim to engage during rehabilitation [49, 51, 57]. There are two different post-stroke rehabilitation strategies. These are known as top-down and bottom-up. Top-down examples involve visual scanning training and visuomotor imagery therapy, while bottom-up techniques involve arm activation and prism adaptation training. Many of the existing top-down and bottom-up strategies and techniques have not demonstrated significant clinical efficacy, specifically for persons suffering with visual neglect [58, 59, 49]. Hence, there is a need for novel interventions to be used for neglect rehabilitation purposes.

One study [51] reveals what areas in the brain are typically stimulated most with top-down and bottom-up rehabilitation techniques. For instance, the Dorsal Attention Network (DAN) is a goal driven network, controlling spatial attention and stimulus selection and these are occupied with top-down rehabilitation strategies. On the other hand, the Ventral Attention Network (VAN) is described as a stimulus driven network, involved in reorientation, alerting responses and vigilance, and therefore, it is occupied with bottom-up rehabilitation strategies.

Interventions

In all of the literature reviewed, the two primary types of interventions used are VR and music therapy (specifically the MNT method of Neurologic Music Therapy). Some of the interventions are used as a primary mode of rehabilitation e.g., MNT in [49], VR in [55], VR in [52], and some of the interventions are used adjunctly with other modes of rehabilitation such as physiotherapy [57, 56] and standard cognitive therapy [54].

Descriptions of VR Applications, Devices and Games

Table 2. *A description of the VR applications, devices and games used from the literature reviewed. The table reads horizontally from the authors (researchers who applied the VR applications) to the VR applications and games used in the studies, to descriptions of the studies.*

Authors	VR Applications and Games	Descriptions
Ahmad, Singh, Nordin, Nee, and Ibrahim [56]	VR Games with Cy-Wee Z Game Controller	VR Games (including Mosquito Swat, Music Catch, Rebounce, Bejewelled, Balloon Popping, 10-pin Bowling, Air Hockey, Mah-Jong, and Solitaire) with Cy-Wee Z Game controller. The game controller is equipped with accelerometer, gyroscope and magnetic sensors enabling display of free movement in 3-dimensional space and capacity to detect depth.

Ansuini, Pierno, Lusher, and Castiello [55]	DataGlove	A VR controller (called DataGlove) with a computer program designed to allow neglect patients to reach and grasp an object, while simultaneously enabling the patients to observe the grasping of the virtual object in VR by a virtual hand. The virtual hand was controlled by their real hand which was placed in the DataGlove.
De Luca, Lo Buono, Leo, et al. [54]	Bts-Nirvana	Bts-Nirvana is a VR system connected to a projector or a big screen, reproducing a series of exercises. The system analyzes the patient's movements to create interactivity. Audio-visual stimuli produced from the system are presented on both sides of the virtual environment.
Ekman, Fordell, Eriksson, et al. [51]	RehAtt®	RehAtt® involves the patient to complete intense scanning activities, with levels of the game adjusted according to the patient's difficulty. The RehAtt® environment is also enhanced by sound, visual and vibrotactile stimuli which are integrated in the game. The patient's contralesional hand controlled the 3D game using a force-feedback robotic pen.
Norouzi-Gheidari, Hernandez, Archambault, Higgins, Poissant, Kairy, [57]	Jintronix	The Jintronix application is used by therapists to record a patients' physical activity and adjust the difficulty of a motor task.
Perez-Marcos, Chevalley, Schmidlin, et al. [53]	MindMotion PRO™	A VR-based system used for rehabilitation of the upper limbs after brain damage. Exercises of the MindMotionTM PRO™ are presented in game-like scenarios designed to increase patients' motivation and therapy dose. A motion tracking camera and touch with an embedded computer is included. The 3D motion tracking camera captures participant's movements, and quantifies upper limb and trunk joint angles using passive colored markers
Yasuda, Muroi, Hirano, Saichi, and Iwata [52]	Immersive VR Program (including a motion-tracking device called Leap Motion)	The Immersive VR program is a 3D room environment, in which a desk is seen. In front of the desk a virtual screen is placed and seven visual stimuli. Three objects are placed on the table in the VR space. The patient moved their right hand freely and was able to see their hand in the VR space. When the VR hand touched an object, the object turned red. To draw attention to the left side in the VR environment, they included a moving slit and slowly drew the projected image seen by the patient towards the left.

MNT Method of Neurologic Music Therapy

MNT emphasizes left-field visual processing by using musical exercises on music making equipment. MNT uses active musical exercises structured in pitch, time and tempo, using musical equipment purposefully configured to focus active attention toward the neglected field [49]. Theoretically, the combination of spatial orientation and motor execution in the perceptual and physical set up of MNT is a crucial component of the intervention, as it addresses these processes together.

In the study by [49], participants sat in a chair and played tone bars placed on the desk by using their non-paretic arm (right arm). The first tone bar (D) was placed toward the centre of the participants, (which was also aligned with the midsection of their faces). Following this, two tone bars (B, C#) were set to the right side before starting a scale or triad in order to begin the playing movement from right to left side. The participants followed five protocol levels by playing three ascending scales to full scale. A hi-hat cymbal was placed in the final position to provide a strong sound for completion of the pattern. In each pattern, the cymbals' edge matched the end of the very last tone bar's edge. The researcher was positioned on the patients non-neglect side (their right side) to provide instruction and play a keyboard accompaniment for each pitch. The participants repeated these patterns five times before moving to the next level.

Intervention outcomes

Musical Neglect Training Outcomes

MNT was used on two individuals with chronic visual neglect. These participants underwent six individual MNT sessions. Two standardized health measures were used on the participants, the AT and Line Bisection test [49]. The AT tests for visuo-motor neglect, while the Line Bisection test tests for egocentric perceptive neglect. The findings show significant improvements from pre- to post- intervention on one outcome measure, which was the AT, indicating improvement in visuo-motor neglect.

VR Rehabilitation with Daily Living Outcomes

[52] tested VR technology on a patient with near and far spatial neglect, evaluating if the VR application had an effect on the patient's ADL. They reported an improvement on post-stroke symptoms in tests assessing near and far space neglect (LB, and LCT) in their single participant. However, the study found no change in the patients' CBS scores that were used as a measure of ADL throughout the intervention period. The results of the study suggest the participant unsuccessfully translated visual search task skills used in spatial detection to ADL, thus the VR intervention had little effect on ADL. Despite this, the results in symptom improvements of the study are described as replicating previous findings, indicating the immersive VR intervention is beneficial for performing visual search tasks in cases of far space neglect.

VR Rehabilitation with Neurological Outcomes

[51] used functional magnetic resonance imaging (fMRI) scanning before and after patients used a VR intervention designed for neglect rehabilitation with the aim to evaluate if clinical improvements could be seen in chronic neglect after rehabilitation sessions. In addition, the team aimed to evaluate if such changes were represented by changes in neurological attention networks and in other areas.

Following a neuroimaging evaluation, results from the study indicate that regions of a neglect patient's brain are affected in a potentially beneficial way after training using a multisensory VR intervention for rehabilitation. Specifically, results show an increase in the neglect participants' task-evoked brain activity after the VR intervention was used for rehabilitation sessions. The brain regions activated include the prefrontal and temporal cortex during attentional cueing. Correlations were also found between brain and behavioural changes during use of their VR intervention and monitoring via fMRI scanning. The data show blood oxygen level-dependent signal (BOLD) signals in the brain increase as their patients (who have neglect) use their VR intervention for rehabilitation. This neurological activity correlated with behavioural improvements, reporting increased cue-induced focus of attention, found in the prefrontal cortex, bilateral middle and superior temporal gyrus after 15 hours of training.

The same team [50] used fMRI scanning to explore neural mechanisms associated with recovery and neglect. They present data on resting-state functional connectivity within the DAN in chronic neglect patients undergoing rehabilitation using VR, aiming to improve left-side awareness. The fMRI results from this study indicate that as patients completed training using a VR intervention, a region responsible for saccadic eye movements to the left became more integrated with the left posterior parietal cortex. In addition, fMRI scanning showed results indicating a longitudinal increase in interhemispheric functional connectivity between the right frontal eye field and left intraparietal sulcus following VR rehabilitation. Further analysis revealed that VR rehabilitation influenced DAN connectivity more than other networks. This is highlighted as potentially a new mechanism that can be used during the rehabilitation of patients with visuospatial neglect.

VR with Motor and Physical Rehabilitation Outcomes

[53] investigated upper limb function using VR as an intervention for post-stroke rehabilitation. The study reported findings in a high-efficiency rate (the relationship between the time of a therapy session and the time spent in active therapy) of 86.30% in favour of the VR intervention, as well as improvements in FMA-UE and AROM scores of the patient. No changes were found in the patient's functional independence. FMA-UE was tested at post-intervention and AROM was observed at follow-up. The results of this study conclude that task-specific VR training may be advantageous for motor recovery in stroke survivors.

To investigate upper limb motor function in stroke survivors, VR was used by [57]. They reported outcomes favouring the VR technology ($M =$ 1.0%, 5.5%, and 6.7% between the intervention and control group, post-intervention) when compared to traditional stroke therapy (e.g., physiotherapy and occupational therapy). Furthermore, the study reported VR gamification technology as feasible and safe during post-stroke rehabilitation.

[56] studied the use of VR games (including Mosquito Swat, Music Catch, Rebounce, Bejewelled, Balloon Popping, 10-pin Bowling, Air Hockey, Mah-Jong, and Solitaire) applied adjunctly to traditional stroke therapy (e.g., physiotherapy) on a stroke population. The results report no significant difference between VR and traditional therapy interventions (e.g., physiotherapy).

VR with Cognitive Rehabilitation Outcomes

[54] used a VR system called Bts-Nirvana on a single patient suffering with USN. [55] demonstrated a significant improvement on a USN patients' motor and cognitive function. In addition, a minor improvement in the patients' mood is found, with a reduction in depression.

Discussion

Focus of the Study and Commentary

The focus of this review was to summarise evidence of existing interventions and assessments used for post-stroke and neglect populations in VR and music therapy research. The review includes studies that employed VR and MNT as interventions for post-stroke and neglect rehabilitation. In general, the authors came to similar conclusions as shown in other studies in this field [1, 7], with the exception of the fMRI scanning of neglect patients during the use of VR [51, 52]. This review is in line with [1] and [7] commentaries regarding the use of novel interventions in post-stroke rehabilitation studies. They argued that promising findings are found in smaller trials but appear more difficult to reproduce in larger ones. Such findings are abundantly clear in this review, where pilot studies, case studies and feasibility studies were reviewed but larger studies could not be identified. For instance [57, 56, 53, 54, 55], all produce positive findings in safety and feasibility regarding the use of VR for stroke and neglect rehabilitation. Yet, the efficacy of their interventions requires further investigation in larger trials. This finding is also emphasised in the MNT study. The number of participants involved in the studies was relatively small, with a maximum participant total of 36. In addition to small sample sizes, most of the study designs pose challenges to the integrity of the findings. Furthermore, no large scale RCT was reviewed.

This review highlights promising neurological outcomes seen in [51] and [50] studies, finding stimulation of specific neurological regions during exposure to a VR intervention in neglect patients. Specifically, [51] found the neurological activity in the prefrontal cortex, bilateral middle and superior temporal gyrus correlate with behavioural improvements, transferring to increased focus of attention. While [50] reported DAN activity of neglect patients as being positively influenced during exposure to VR rehabilitation, transferring to saccadic eye movement to the left becoming more integrated with the left posterior parietal cortex. [7] points out that such data is crucial for future study due to a lack of understanding of the neurological mechanisms that can be exploited during neglect rehabilitation. Yet, the sample sizes used in these studies are small, and the challenge remains to investigate their results in a larger trial. It is also unclear if the patients reported outcomes specific to the intervention used in both studies (i.e., RehAtt®).

The heterogeneity of the interventions reviewed during neglect rehabilitation make it difficult to assess their evidence with clarity, echoing findings from [1] scoping review. The lack of consistent selection of assessments used make it difficult to evaluate which intervention was most effective on its population and why. Indeed, the studies reviewed had a reliance on standardized assessments which are not neglect specific. This confirms findings from [7] review, that the general lack of common standards in this field obscures its findings.

Study Goals and Outcomes

Another reason for the lack of high-quality evidence could be that the goals of the studies were not consistently aligned in reducing disabilities and improving independence. Instead, they were focused on aspects pertaining to the feasibility (if the interventions functioned correctly or not) in using the interventions in post-stroke and neglect rehabilitation. [58] argues that the focus of studies in post-stroke rehabilitation should be in reducing disability and improving independence, rather than testing if interventions function or not. To demonstrate this, [52] reports that VR tasks used for neglect did not transfer to improvements in ADL outcomes, yet argued for the feasibility of their Immersive VR Program when used with neglect patients. Thus, the efficacy of the VR application is not promising when associated with daily living outcomes.

On the other hand, the review broadly points to preliminary evidence that VR used as an adjunct intervention for neglect rehabilitation with physical and occupational therapy practice is beneficial. This is indicated in the studies conducted by [56, 57, 53] who combined VR with physiotherapy, occupational therapy and physical therapy rehabilitation, producing positive therapeutic outcomes.

Exploring VR's purpose as an Adjunct Intervention in Music Therapy Practice

For VR to be used as an adjunct intervention during neglect rehabilitation by music therapists, its relevance for music therapy practice requires further examination. First, the lack of clinical evidence from this review to support the inclusion of VR technology with established music therapy practices, does not imply immediate adoption by music therapists. This suggests that acknowledgment of this review's results are used as a preliminary guideline to how VR can be applied to outcomes associated with music therapy practice. Second, the clear benefits in using VR adjunctly with music therapy practices must be developed. Third, using VR adjunctly with music therapy practices must be done in a safe and feasible manner. In order to investigate this, music therapy must be placed in a multidisciplinary context, acknowledging the healthcare practices which have previously used VR for different purposes. Therefore, the remainder of this review will briefly explore potential intersecting areas of research, as indicated from the results in relation to VR and music therapy rehabilitation, which may be applied to neglect rehabilitation.

Intersecting Purposes in VR and Music Therapy Interventions

Based on this review's findings, we explore how VR and music intervention purposes intersect in similar areas during neglect rehabilitation, such as the music therapist utilising VR for assessment purposes. We also discuss the multimodal capabilities of both interventions. Specifically, we consider VR's kinematic tracking capability as a motor assessment instrument that can be utilised by the music therapist, as this provides clinical data regarding the patient's limb movement based on practice. Furthermore, the multimodality of the intervention can be given importance due to its support in rehabilitating the multiple areas of dysfunction caused by neglect [9, 12, 8, 6, 11, 10].

Assessment

As indicated by use of the MindMotion PRO™ by [53], quantitatively tracking a neglect patient's kinematic behaviour (e.g., motor movement of the limbs) to audio stimulus during VR usage provides feedback about the patient's limb movement. This could be applied to music therapy sessions, measuring the range of motion and training intensity during music therapy sessions in order to provide real-time feedback to support music therapists regarding intervention outcome. Specifically, this feedback supports an accuracy in motor assessment, allowing for the therapist to observe the effects (or lack of) of the audio stimulus on a patient's motor movement during, between and after sessions.

Multimodality

A multimodal approach to rehabilitation sees multiple approaches contributing to a therapeutic process. Multimodality highlights the multidisciplinarity of a rehabilitative protocol or treatment plan. By focusing on common aims of each discipline, or how the work towards these aims can contribute to one another, treatment becomes streamlined and cooperative. If therapists could combine the use of VR and MNT during neglect rehabilitation, there is the possibility to address neurological, physical, and perceptual needs of a patient simultaneously within one therapy session.

Initially, thorough assessment would be needed to determine the suitability for such an intervention. This would likely require involvement of physical therapy, occupational therapy, and music therapy. It is possible with future research that a specific multidisciplinary assessment tool be established for use of this intervention specifically, to determine patients' suitability. When considering implementation of this intervention, it is feasible to consider that with the proper safe-guards and training in place, this proposed method of rehabilitation could be implemented as an adjunct intervention for rehabilitation by music therapists, physical therapists, or occupational therapists. This aspect would need to be addressed in future research, in formal development and evaluation of the clinical protocol. Some of these safe-guards are embedded in the VR application experience, which allows the user to safely participate in task-based activities without the risk of dysfunctional movement within a real-world setting as well as the considerations of cybersickness and aftereffects [40, 41, 42, 43]. However, future training among professionals will be crucial, especially regarding safety in physical rehabilitation, competence training in using VR in practice, needed when using music interventions.

For the patient, the collective work towards common aims and a streamlined process seen in a multimodal approach to rehabilitation could result in fewer appointments over time. This would ideally result in cost savings for the patient, in addition to the reduced time spent in, and traveling to, appointments.

Intersecting Purposes Outside this Review

Evidence not accounted for in the outcomes of this review includes intersecting purposes between VR and music therapy interventions associated with restoring function in damaged areas of the brain caused by the stroke with motivating task-based activity. Both interventions contain purposeful activity (task-based or movement induced) by focusing attention or inducing movement toward the left side of the patient (e.g., inducing patient motor movement to the left side, having the patient look toward the left side, or play musical tone bars toward the left side) to make rehabilitation enjoyable, as well as maintain patient adherence to the rehabilitation. This psychosocial aspect of patient adherence and motivation to rehabilitation is regularly discussed in the background literature of the articles reviewed, but not accounted for in the study outcomes. Therefore, we discuss patient adherence and motivation to neglect rehabilitation below as an intersecting purpose of VR and music therapy interventions for neglect rehabilitation.

Task-based activity, Patient Adherence and Motivation to Neglect Rehabilitation

The experience of music is known to have not only an emotional role, but also a motivational role. The music component itself in music therapy practice has been proven to contribute to specific motivating neurobiological systems and mechanisms, activating the dopaminergic mesolimbic system, while regulating mechanisms in memory, attention, executive functions, mood and motivation [3, 60]. Dopamine plays a significant role in the neurobiological workings of reward, learning, and addiction. Naturally occurring rewards, such as positive music experiences, activate these dopaminergic systems and contribute to one's attention and learning [62]. Furthermore, the multimodal activity of music through engagement or creation supports plastic changes in the nervous system [19, 23, 24].

Following this, the music component within an intervention is a large part of what motivates the patient to complete a task, work towards goals, and/or to actively participate in the work with the music therapist. Much like the inclusion of VR in neurological rehabilitation, music interventions also provide an added purposefulness to the activity. A patient's motivation towards rehabilitation exercises is critically important, as these exercises can seem repetitive, and at times uncomfortable. Adding a purposeful element to the rehabilitative exercises contributes to patient motivation [62].

As illustrated in this review, both VR and music therapy interventions produce recovery in domains afflicted by neglect, with VR providing some evidence in improving patient adherence to treatment. It is conceivable then, that by combining a purposeful music intervention with an already motivating rehabilitation environment by using VR, that rehabilitation and progress towards aims may be somehow streamlined or further beneficial for patients and healthcare systems alike.

Limitations

As previously outlined, there are challenges to generalising the findings from this review, due to small trials, small sample sizes, heterogeneous assessments, goals, and outcomes. This implies the need for caution when interpreting any evidence reviewed for use in clinical settings. Similarly, some of the studies reviewed here are not directly applied to the treatment of neglect but are primarily investigating feasibility of the interventions.

Due to the narrow scope of this review, there are many opportunities for further inquiry. This includes understanding in greater detail the function of neurological mechanisms of neglect patients when exposed to VR and music, and then designing interventions around beneficial neurological exploitation. There is a need for a rigorous practical understanding of how to use VR in neurologic music therapy settings, and the development of a formal clinical protocol will be needed. Furthermore, the costs of VR equipment may also burden some music therapists and multidisciplinary teams, and how these equipment costs can be justified without rigorous clinical evidence remains unclear.

Conclusion

In this review, the use of VR during stroke and neglect rehabilitation produces findings regarding feasibility and safety, however the clinical findings are ambiguous. Larger trials with similar assessments are needed to arrive upon generalisations. Promising neurological outcomes were found in stimulation of specific neurological regions during exposure to a VR intervention in neglect patients. Specifically, neurological activity in the prefrontal cortex, bilateral middle and superior temporal gyrus was associated with increased focus of attention during VR rehabilitation. In addition, saccadic eye movement to the left became more integrated with the left posterior parietal cortex during VR rehabilitation.

Based on the review's findings, the authors explored how VR and music-based interventions purposes intersect in similar areas used for neglect rehabilitation. These are in assessment, patient adherence and motivation to treatment, as well as the multimodal capabilities of both interventions. Using VR and music-based interventions adjunctly for neglect rehabilitation is theoretically promising, and development of a clinical framework to practically use these interventions with neglect patients is suggested.

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III

MUSIFICATION OF ACCELEROMETRY DATA TOWARDS RAISING AWARENESS OF PHYSICAL ACTIVITY

by

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Musification of Accelerometry Data Towards Raising Awareness of Physical Activity

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ABSTRACT

Previous research has shown that the temporal dynamics of human activity recorded by accelerometers share a similar structure with music. This opens the possibility to use musical sonification of accelerometry data to raise awareness of daily physical activity. In this study a method was developed for quantifying the daily structure of human activity using multigranular temporal segmentation, and applying it to produce musical sonifications. Two accelerometry recordings of physical activity were selected from a dataset, such that one shows more physical activity than the other. These data were segmented in different time-scales so that segmentation boundaries at a given time-scale have a corresponding boundary at a finer time-scale, occurring at the same point in time. This produced a hierarchical structure of daily events embedded in larger events, which is akin to musical structure. The segmented daily data of each subject was mapped to musical sounds, resulting in two short musical pieces. A survey measured the extent to which people would identify the piece corresponding to the most active subject, resulting in a majority of correct answers. We propose that this method has potential to be a valuable and innovative technique for behavioural change towards reducing sedentary behaviour and increasing physical activity.

1. INTRODUCTION

Miniature sensors, wearable devices and mobile technologies can track daily activity of people, both in extent (i.e., amount of movement) and type (e.g., walking, sitting). This capability has been utilised as a behavioural change technique [1] in interventions to promote a healthier lifestyle, increase physical activity and reduce sedentary behaviour [1] [3, 4]. These technologies may be effective aids in interventions to increase physical activity and reduce sedentary behaviour [5], but only in the short-term. Long-term adherence is still a major challenge [6–10]. Recent reviews suggest that more engaging methods are needed to effectively produce a change in behaviour [11].

Sonification is a potential strategy to increase long term engagement and adherence, especially since it has been shown that the temporal dynamics of human motion and activity share similarity with that of music [12, 13]. Several studies have explored the use of real-time sonification of movement to aid sports performance and rehabilitation [14]. For example, Ley-Flores et al. [15] found that sonification of exercise with metaphorical sounds affect body perception, causing people to feel strong and thus increase their amount of physical activity. Other studies investigated presenting activity patterns as musical sound to raise awareness about behaviour. For example, Krasnoskulov [16] developed a system in which data measured by an accelerometer and optical heart-rate sensor were mapped to musical parameters such as pitch, timbre, tempo, space and loudness. This form of musical sonification is rather direct and may not result in a clear representation of events. Consequently, some

[1] A short article by O'Keeffe, Scheid and West [2] explains the differences and similarities between physical activity and sedentary behaviour.

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studies have considered segmentation of data, so that the resulting sonification is structured in blocks that preserve the temporal relations of events. Last and Usyskin [17] developed a sonification paradigm that segments data into a user-defined number of segments, which was successful to convey the desired information. Vickers and Höldrich [18] progressed this to produce segments using zero-crossing of a one-dimensional data-stream. Then the segments were mapped to sound. These studies show that sonification and musical sonification are feasible ways to convey activity data. Temporal segmentation may be a relevant part of the process, as it allows for mappings between data and sound that have a clear correspondence. However, the temporal segmentation methods used by the mentioned studies have important limitations, as they are based on threshold, zero-crossings or clustering. These methods require careful calibration of input parameters and do not generalise well when patterns in data are multidimensional.

The present study has focused on the development of a system to produce musical sonification (also referred to as *musification*) of daily activity data recorded by wearable devices. The method employs a novel approach to multi-granular temporal segmentation, that results in a clear correspondence between daily events and sound. Additionally, the system does not require the final user to do any fine-tuning of segmentation parameters. We propose this system as an aid in behavioural change, by raising awareness of people's own daily physical activity in an engaging way.

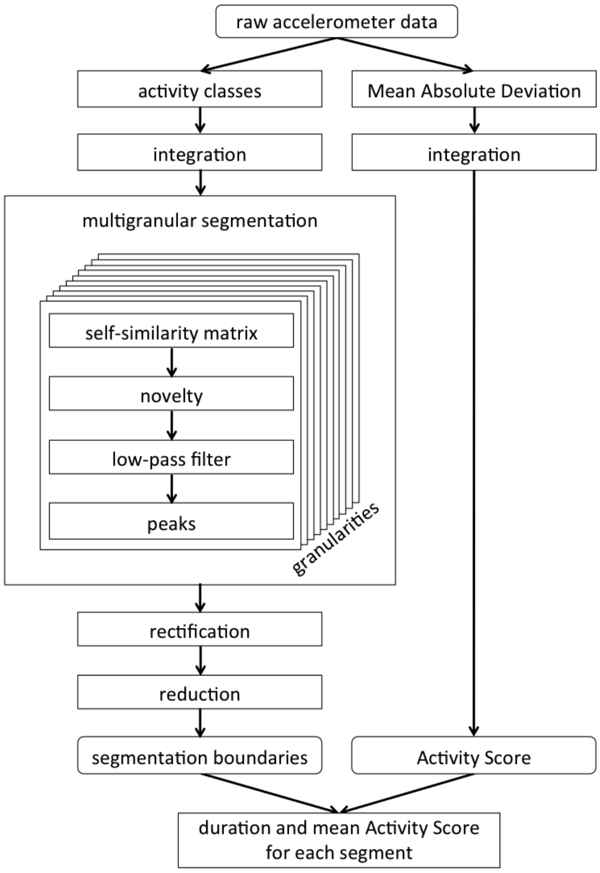

Figure 1. Multigranular segmentation of daily activity.

2. METHODS

2.1 Accelerometry Data

We used two multiple-day recordings of accelerometry from 75-year-old adults. These were chosen from the AGNES database [19, 20] so that one corresponds to a low-activity sedentary subject while the other corresponds to a high-activity non-sedentary subject. The data was obtained by two tri-axial accelerometers, one chest-worn and the other thigh-worn. These data were pre-processed to obtain features for successive non-overlapping epochs of 5 seconds. One feature is the Mean Absolute Deviation (MAD) of the square norm [21], from the thigh-worn accelerometer (Fig. 2a). The other features are the activities identified from the orientation of the accelerometers: lying, sitting, upright posture and walking [22] (Fig. 2b).

2.2 Segmentation

The segmentation procedure is shown in Fig. 1. After MAD is computed and activities are identified, numerosity is reduced by integrating in windows of 120 data points of 5 seconds each (10 minutes) with an overlap of half the length of the window. For MAD the integration is

$$A_i = \log_b \left(1 + \sum_{j=1}^{n} w_j\right), i = \{1 \ldots N\},$$

where vector A of length N is the Activity Score, N is the number of windows, the logarithmic base b is a free parameter to rescale A, and w is one window of length n. The logarithm preserves the data distribution, as the relation between time of inactivity and activity follows a power-law distribution [12]. For the examples reported in this article the logarithm has a base $b = 3$. Each activity is a binary vector, where an activity is represented by a one, otherwise a zero (Fig. 2b). The integration of each activity vector is the sum of the window, with the same length and overlap as for MAD. Additionally, integration acts as a low-pass filter removing unnecessary detail.

The next step is segmentation of the integrated data using the algorithm described by Foote [23]. That algorithm has been used for segmentation of musical audio and video. It can detect boundaries of segments at different *granularities* (i.e., time-scales). It has also been tested for segmentation of accelerometry data of dance [24] and daily activities [25].

The segmentation algorithm first computes a self-similarity matrix of the integrated activities (Fig. 3a). Then, a checkerboard kernel (i.e., a small matrix of four sections where the diagonal is negative units and the anti-diagonal is positive units) tapered by a normal distribution, is correlated along the diagonal of the self-similarity matrix. This was done several times, each with a checkerboard kernel of minimally different size. The size of the kernel corresponds to the granularity of the

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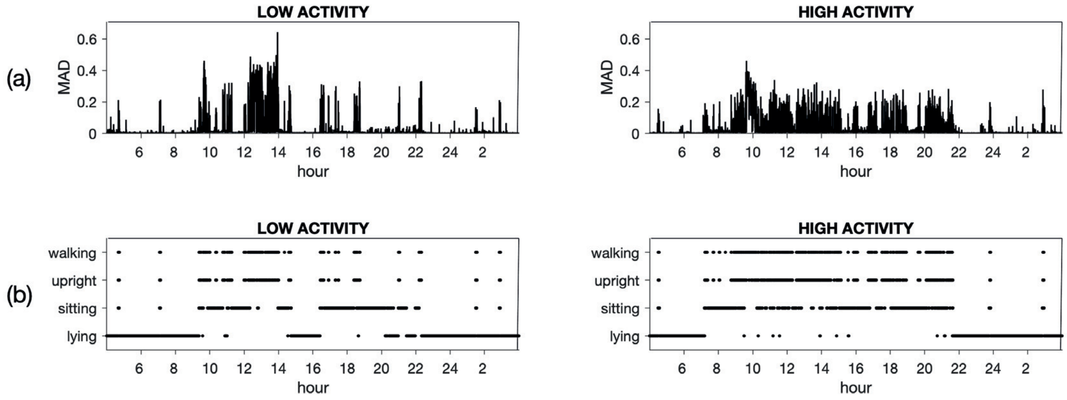

Figure 2. a) Mean Absolute Deviation every 5 seconds of accelerometer data; b) Classification of daily activities.

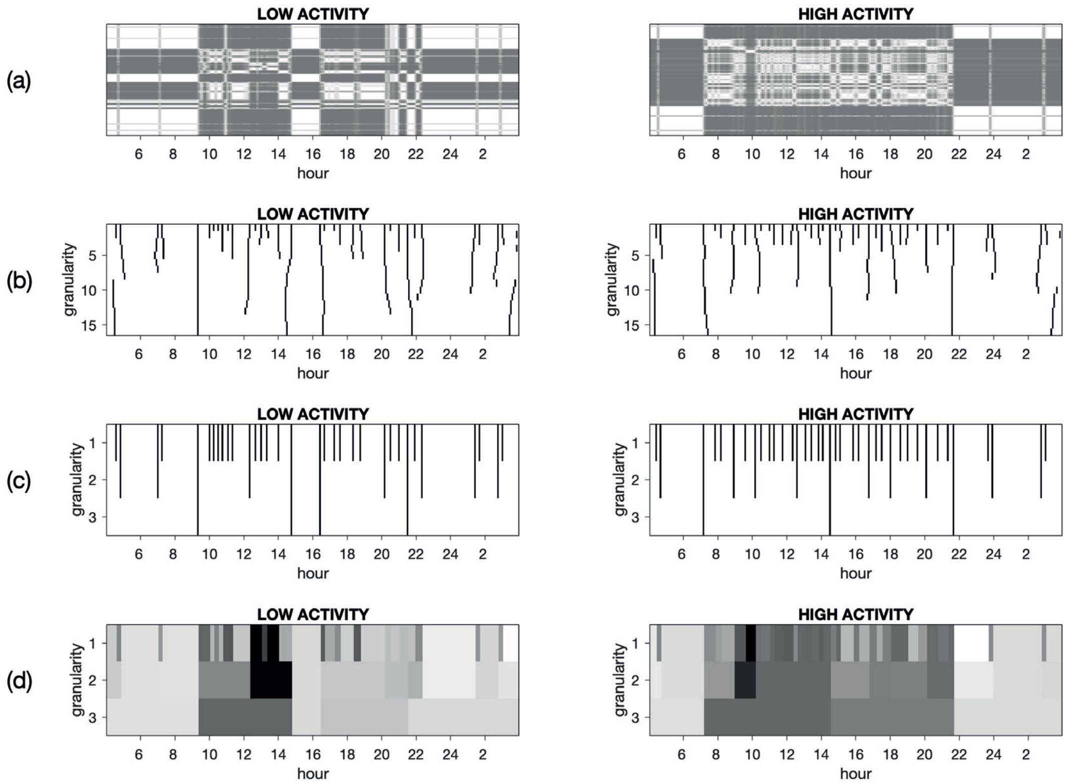

Figure 3. a) Self-similarity of activities; b) multigranular raw segmentation boundaries; c) rectified and reduced multigranular segmentation boundaries; d) segmented Activity Score, darker shades show greater average activity for a segment and vice versa.

segmentation. A smaller kernel detects finer granularity segments and vice versa. The size of the kernels was specified as the standard deviation σ_k of their normal distribution tapering. For the examples shown here, $\sigma_k = \{2, 4, \ldots, 32\}$ windows. This resulted in several novelty scores, one for each granularity, each of which was then smoothed with a normal-distribution (i.e., Gaussian) low-pass filter to remove irrelevant peaks. The peaks of each novelty score represent segmentation boundaries (Fig. 3b). The size of each filtering vector was set to each corresponding value in σ_k, while the standard deviation was set to 0.4 for all of them.

The segmentation boundaries at different granularities are not perfectly aligned in time (Fig. 3b) because, as the checkerboard kernel gets larger, it incorporates more information causing the novelty peak to move slightly in

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Table 1. Segmented Activity Score

fine		medium		coarse	
duration	mean Activity	duration	mean Activity	duration	mean Activity
5	0.45	8	0.45	38	0.48
3	1.11	-	-	-	-
30	0.48	30	0.48	-	-
8	1.03	21	0.92	88	1.48

First 4 lines of "high activity" segmented (corresponding to Fig. 3c and d). Duration is windows of integrated data. The headers of this table are not part of the actual list.

either direction. However, because the granularities were set with minimal difference ($\Delta\sigma_k = 2$ windows), it is safe to assume that they correspond to the same segment. Following this logic, every coarser granularity boundary has an origin in a finer granularity boundary, except for those at the borders. The temporal structure is hierarchical, where segments are embedded in larger segments. This reflects the structure of human daily activity. For example, a large portion of the day such as the morning, may contain activities like waking-up and getting ready, breakfast, commuting, and so forth. This hierarchical structure is also analogous to musical structure. For example, a song has sections like introduction, verse and chorus, each of which have sub-sections, such as melodic lines. However, in music the boundaries of each section exactly match in time, unlike the structure resulting from the procedure described above. If that multigranular structure were to be used as musical structure for sonification, it would result in a seemingly unnatural performance. For example, each granularity level may be assigned to a different musical instrument. If so, then instruments would begin and change sections of the song at different times.

Therefore, the segmentation boundaries were aligned to the finest-granularity boundary. Also the boundaries at the borders were removed. This resulted in sequences at different granularities being identical or slightly different. Thus, the finest and coarsest granularity sequences were kept, as well as the sequences that provide greatest variety in number of boundaries. For the examples given here, the reduction resulted in sequences at 3 levels of granularity: fine, medium and coarse (Fig. 3c). Finally, the median Activity Score was computed for each segment at each granularity level (Fig. 3d).

2.3 Musical Sonification

The result of the segmentation procedure is a list of paired columns, where the paired values are segment duration, in windows, and the mean Activity Score for the segment. If a segment's boundary doesn't have a corresponding boundary at a coarser granularity level, the values are omitted. The first line assumes a boundary at all levels of granularity. Table 1 shows an example.

The list was formatted as a CSV file and has a header line composed by the number of windows, the sum and grand mean of Activity Scores (from the matrix depicted by Fig. 3d), and the number of granularities. This file is the input to a separate sonification program consisting mainly of a sequencer and two synthesis modules (Fig. 4.). The sequencer loads the CSV file and immediately reads the header. The user specifies how long the performance will last and the program computes the duration of each window in real time units (e.g., milliseconds), using the first value in the header (number of windows). The second value of the header (sum of Activity Score) is used as the seed for all pseudo-random generators, to obtain a deterministic performance (i.e, the sonification of a CSV file will always be the same). This may help to perceive a strong connection between sonic material and actual daily activity information. The third value in the header (grand mean Activity Score) sets the tempo. The mean between the values of both subjects was mapped to 120 BPM (beats per minute) for crotchet notes (60 BPM for minim notes), as the typical healthy average heartbeat at rest is just over 60 BPM [26] and both preferred musical tempo and average walking steps have a period of about 120 BPM [27]. Hence, the sonification for the high-activity subject will have a slightly higher tempo than the sonification for the low-activity subject. The last element of the header (number of granularities) is used to compute the mean Activity for each combined segment. For example, for the first row in Table 1, all mean Activity values will be added and divided by 3. For the second row, the only value is for the finest granularity and will be divided by 3.

The user inputs a duration in seconds and clicks a button to start the performance. Then, the first line in the CSV file (i.e., the first row of Table 1) will be read and it will wait the duration given by the leftmost value multiplied by the duration of each window, then it will read the next line and so on. When each line is read, the values are sent to the synthesis modules as described below. This process continues until the final line is reached or until the user interrupts it by the click of a button.

Synthesis module 1 is composed by three synthesisers that produce bell-like sounds, whose pitches are pseudo-randomly produced according to a distribution that smoothly transitions from chromatic (i.e., all 12 tones allowed) to a user-selected scale. For this study a pentatonic scale was used. The transition is given by the mean Activity of all segments at the start of a finest-granularity segment. The higher this value is, the closer the distribution will be to the selected scale. For example, when the program begins playing the list in Table 1, it will compute the mean of the "mean Activity" values of the first row, which will determine the distribution of the pseudo-randomly produced notes. Given this distribution, each synthesiser produces a note at the start of each segment and the duration of the note is the duration of the segment. Each synthesiser has been set to play only at a distinct octave, with the synthesiser allocated to the coarsest granularity playing the lowest octave and vice versa.

The resulting sounds are somehow dissonant when activity is low and consonant within the user-defined scale, when the activity is moderately energetic. This defines

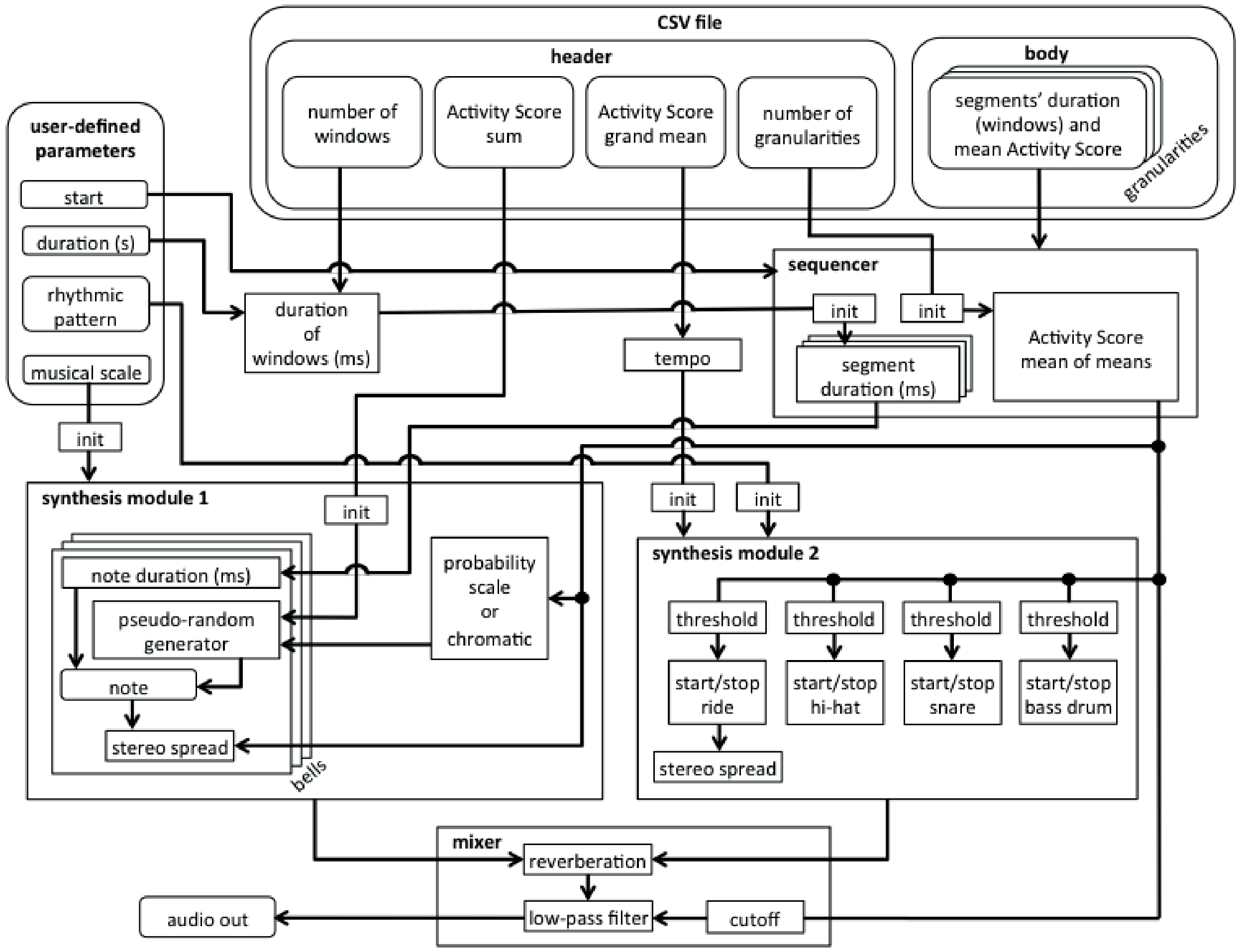

Figure 4. Sonification program.

high amount of activity as consonant and low amount of activity as dissonant. Also each synthesiser has a "stereo spread" capability that has been mapped so that the higher the mean Activity, the wider the stereo allocation of the notes, meaning the pseudo-random balance between their output to the two main output audio channels.

Synthesis module 2 is a drum-machine with 16 steps (quaver notes) and 5 voices produced by frequency modulation: ride cymbal, open hi-hat cymbal, closed hi-hat, snare drum and bass drum. The rhythmic pattern can be programmed by the user. The tempo is given by the grand mean Activity Score as explained previously and each instrument is activated when a level of mean Activity of the current segment exceeds a defined threshold. For this study the bass drum was set to be permanently active, while the ride cymbal was set to fade in when activity changes from very low to moderately low. Also the ride cymbal was set to permanently have a full stereo spread, resulting in a subtle and surrounding rhythmical noise. The open hi-hat was set to a medium threshold and the closed hi-hat was not used for this study. The snare drum was set to a moderately high threshold. The full drum set is active when activity is energetic.

In the examples (see Fig. 2 and Fig. 3), the full drum set and only notes within the defined scale play between about 12:30 and 15:00 for the low-activity subject and from about 9:00 to 10:00 for the high-activity subject. The output from the bell synthesisers and drum-machine is mixed and subtle reverberation is added to blend the sounds. Finally, a low-pass filter is applied to the final mix and its cutoff frequency is controlled directly by the mean activity of the current segment, so that the resulting sound is slightly brighter as there is more energetic activity and vice versa.

2.4 Perceptual Assessment

Two audio files were produced with the method described above, using excerpts from 6:00 to 23:00 of the data presented in the figures. These audio files were used as stimuli for a perceptual assessment. Data for this assessment were collected during 31 days by means of a short survey using QuestionPro, a service to make and publish questionnaires which can be answered with an internet browser, and Twitter. Participants were recruited via Twitter and Facebook using both free and paid adverts, the latter targeting Finland and major English-speaking countries, and via authors' direct contact within their acquaintance networks. In the survey, participants were asked to listen to each audio file, and indicate which of them represented the more active person. The order of presentation was randomised. The survey included the researchers' con-

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tact information, notified participants that no personal information would be collected, and that data collection complied with the General Data Protection Regulation of the European Union. The stimuli can be listened on Twitter: `https://twitter.com/listeningsurvey` and Facebook: `https://www.facebook.com/ListeningsurveyJYU`.

3. RESULTS AND DISCUSSION

The methods described in this report are firstly, a system that processes accelerometry data of daily activity, resulting in multigranular hierarchical segmentation akin to musical structure. The second method is a program devised as a proof of concept, to demonstrate a possible musical sonification of the daily activity data utilising the segmentation obtained. The resulting sonification has, by design, one main property, which is that there is a clear association between sonic events and daily activity. The perceptual assessment of two example sonifications produced with the system described measured the extent to which a person would correctly identify the sonification for high activity data, when presented along the sonification for low activity. A total of 1847 responses were collected by a survey on the internet, of which 1225 (66.3%) correctly identified the sonification corresponding to high activity. A one-proportion z-test was performed to evaluate the statistical significance of the results, yielding $z = 14.03$, with a p-value $< 1 \times 10^{-5}$. This may be sufficient to reject the null hypothesis, suggesting that the proportion of correct responses is significant.

The described musical sonification system may be useful in public health interventions towards increasing healthy physical activity or reducing sedentary behaviour, by making a person aware of their intraday activity in an engaging manner. In practice, the musical sonification system would be part of a portable system comprising hardware and software. Such a system would record daily activity, produce the musical sonification and possibly recommend actions to the user. The hardware may be composed of already existing technologies such as miniature accelerometers and mobile computing devices like a smartphone or smartwatch. Future research shall be carried out to implement the system and test it in ecologically valid conditions. Preliminary testing shall be carried out in order to explore the extent to which the musical sonification may work as an engagement strategy, and to identify the conditions in which it may be effective. These conditions may include personal characteristics of target users such as age, personality or income, as well as environmental conditions. Also it would be useful to compare the multigranular segmentation daily profiles of users with self-reports on their activities, to assess the extent of their correspondence.

While this report describes a method for multigranular segmentation and musical sonification of intraday activity of one subject, it is trivial to expand the method to work with different data. First, instead of using classified data for the segmentation, the Activity Score may be used alone. Also instead of using a single time period, like a day, an average of several days may be used, resulting in a representation of a typical day. Furthermore, instead of using data for a single subject, a group of subjects may be used. A population may be pre-clustered in groups with homogeneous characteristics, such as age, gender, and so on. The resulting multigranular temporal segmentation may be useful to examine the typical intraday behaviour of the group. Its musical sonification will represent the group and this may open new and interesting doors for community music making. For example, daily data of a person may be uploaded to a server, where it would be combined with data of other people in their social circle. This would enable them to produce music as a group, instead of individually. This way of collaborative music-making may be a relevant avenue for exploration in further research, as it has been observed that social support through collaboration was the primary motivator for adults to maintain activity tracker use [28].

4. CONCLUSION

This study has developed a system to produce musical sonification of daily activity data recorded by wearable devices. The sonification may be used as a tool for raising awareness and behaviour change by conveying daily activity information to users in a clear and engaging way. This capability may be used in interventions to increase physical activity (i.e., total amount of bodily motion) and reduce sedentary behaviour (i.e., proportion of time sitting or lying down) in hard to reach populations such as older adults, teenagers or people with visual or learning difficulties. A key property of the musical sonification is that it shows clearly not only the overall physical activity over a period of time, but of the temporal structure within, such as commuting to work, or taking a lunch break. This property would allow someone to identify, by listening to the sonification, the times of the day they were more or less active and spent more or less time sitting. That was achieved by devising a novel multigranular temporal segmentation procedure that preserves the time relations between events.

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Petri Toiviainen suggested using probability to generate musical notes.

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IV

NOVEL AND EXPERIMENTAL MUSIC TECHNOLOGY USE IN THE MUSIC CLASSROOM: LEARNING PERFORMANCE, EXPERIENCE AND CONCENTRATED BEHAVIOR

by

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NOVEL AND EXPERIMENTAL MUSIC TECHNOLOGY USE IN THE MUSIC CLASSROOM: LEARNING PERFORMANCE, EXPERIENCE AND CONCENTRATED BEHAVIOR

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Abstract: *In recent years, music technology in the classroom has relied on general devices such as the iPad. In the current study, we used a mixed-methods approach to examine the learning performance, learning experience, and behavior of two class groups of primary school music students (*N *= 42), using established music technology (i.e., the iPad with the Keyboard Touch Instrument app) and novel music technology (KAiKU Music Glove). Results show a significant difference of change in test scores during learning (*p *= <.01) and a medium effect-size is found (*d *= .75), indicating use of the iPad and Keyboard Touch Instrument app contributed to increased learning when compared to the KAiKU Music Glove. Perceived ease of use ratings of both technologies and observable levels of concentration exhibited by the students are also discussed in the paper. Implications provide insights into the usage and development of embodied music technology in the music classroom.*

Keywords: *music education, music technology, learning experience, learning.*

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INTRODUCTION

The creative use of information technology (IT) in the music classroom rarely is associated with concepts found in human–computer interaction (HCI) research. Thus, HCI, IT, and music education are peripheral disciplines that have not been bound together adequately to understand student behavior when engaged with embodied music technology. This represents a missed opportunity for understanding the phenomenon. In the present study, we sought to investigate the research gap among these peripheral disciplines by using HCI and IT research to understand children's behavior in the music classroom while students used embodied music technology as part of their music class. IT is a widely integrated aspect of teaching and learning in today's Nordic childhood music class. For the students, IT affects their learning performance and, crucially, their experience of music. For the teacher, IT can support the teaching of music education with technology's advanced technical capabilities (e.g., data storage, access to the Internet, variety of applications, gamification), enabling activities that are engaging to children. IT can also help the teacher to manage the students' learning performance.

In this study, we aimed to understand better novel and experimental music technology use and interactions in childhood music education. For this, we employed a mixed-method approach to examine quantitative and qualitative data. The quantitative data derived from learning performance tests and the qualitative data emerged from subjective experience surveys and behavioral observations. A mixed-methods approach appropriately supported the purpose of this study, which was to understand established and experimental embodied digital music technology usage in childhood music education. We achieved this by examining students' learning performance, their experience of using the technology in the context of music learning, and their behavior while using either the iPad with the Keyboard Touch Instrument app or the KAiKU Music Glove, a tactile wearable device that activates musical notes via touch. The three research questions directed this study:

RQ1. What is the difference in musical knowledge before and after using the iPad with the Keyboard Touch Instrument app and the KAiKU Music Glove connected to the iPad in children's music classes?

RQ2. What are the students' ratings of perceived ease of use before and after using the iPad only or the KAiKU Music Glove in the music classroom?

RQ3. What is the difference in concentration-related behavior patterns of the student's while interacting and playing the iPad or KAiKU Music Glove in children's music classes?

Within this paper, a review of related literature will be presented first, which discusses concepts in embodiment and cognitive concentration in particular. Having established a theoretical background for this research, an empirical investigation of two student groups assigned either the iPad or the KAiKU Music Glove as the primary device for music learning is carried out. These devices were used in the music classes over a 6-week period

PRIOR AND RELATED RESEARCH

Historically, technology use in the music classroom has been associated with IT from broader society, as computers and, in particular, MIDI (musical instrument digital interface) sequencing stimulated a musical revolution (Gall & Breeze, 2007). Accordingly, the following section looks at tablet computer use in education, specifically how tablet computer integration has impacted childhood music education. The subsequent section provides an overview of experimental hand-sensor music technology included and used in this study, KAiKU Music Glove, and then placing it into a HCI theoretical paradigm we have called human music technology interaction. Play and concentration in childhood music education are discussed, in addition to a theoretical concept from the original technology acceptance model (TAM; Davis, 1985) reviewed and used in the study.

The Tablet Computer in Education

As a result of the physical properties of tablet computers in terms of their screen size, lightweight design, multimedia support, ease of use, and long battery life, they can serve as optimal devices for encouraging student engagement in multiple actions and activities in many classroom subjects and learning situations (Churchill, Fox, & King, 2012; Henderson & Yeow, 2012). Studies have shown that tablet usage in learning situations encourages high levels of student productivity, creativity, engagement, autonomy, and self-regulation in class situations (Clark & Luckin, 2013; Henderson & Yeow, 2012).

Over recent years, substantial technological developments in music classrooms have involved integrating innovative devices as part of the learning process in order to encourage interaction through tactile input and haptic feedback. The most established of these innovations is the iPad, a tablet computer manufactured by Apple. The iPad has been widely integrated into contemporary classrooms. Burnett, Merchant, Simpson, and Walsh (2017) stated that the iPad's integration into the classroom has been less problematic than other similar devices, past and present. Studies by Wario, Ireri, and De Wet (2016), Wang, Teng, and Chen (2015), and Heinrich (2012) demonstrated that iPad use in classroom settings has a positive impact on learning. Rowe, Triantafyllaki, and Pachet (2016) reported that the creative utilization of the iPad, as well as its playfulness, transfers seamlessly into the experimentation involved in the creation of music. Flewitt, Kucirkova, and Messer (2014) found evidence that the iPad was useful to children in the classroom, reporting that children were motivated to use the technology and held concentration for longer periods of time when using the technology. In addition, a diverse range of music apps (for the iOS and Android operating systems), often readily available on tablet computers and iPads, allows the teacher and student access to creative music educational experiences (Hillier, Greher, Queenan, Marshall, & Kopec, 2016). The sensory interface of the tablet computer's touch screen facilitates student interaction with the digital interface of its apps in an intuitive way, (e.g., pressing on a piano key shown via the user interface or enabling gestures during music creation). To that end, Burton and Pearsall (2015) found that children as young as 4 years old preferred playing music in apps that required very little musical manipulation—meaning the apps were mostly open-ended in user interaction and allowed the children freedom in music making. Consequently, the 4-year olds preferred music-making apps that made them the source of music making rather than the apps' output. With this in mind, Burton and Pearsall (2015) claimed that apps used in childhood music education should have qualities that enable play and open music creation.

However, evidence is inconclusive regarding usage of tablet computers in the childhood music classroom, as Hutchison, Beschorner, and Schmidt-Crawford (2012), Ruismäki, Juvonen, and Lehtonen (2013), and Stretton, Cochrane, and Narayan (2018) stated. They reported that research on tablet computer technology in childhood music education is relatively unexplored.

Observations of tablet computer use show overuse in the classroom, misuse, and lack of user confidence. In addition, Heinrich (2012) found that young students using tablets as part of their learning curriculum may require support or familiarization with the device's features and functionality before actively using them.

The KAiKU Music Glove Device

The KAiKU Music Glove is a musical MIDI controller with touch sensors (see Figure 1). The glove fits on one's hand, while the sensors embedded within the glove's fingers are pressed with the other/opposite hand. The manufacturer, Taction Enterprises Inc., has organized the sensors within a practical and ergonomic perspective, and the devices are produced specifically for pedagogical use in teaching music theory (see, Danso, 2019; U.S. Patent No. 9,905,207, 2018).

The positioning of two rows of touch sensors is presented as a potentially effective method for teaching the musical scale. It also is effective in the teaching interval and chord structures when both the teacher and students are wearing the glove. This approach is an attempt to optimize the process of music teaching and learning (Paule-Ruiz, Álvarez-García, Pérez-Pérez, Álvarez-Sierra, & Trespalacios-Menéndez, 2017) based on the Kodály method (Harrison, 2021) that emphasizes the use of the hand during singing lessons. A theoretical premise behind the KAiKU Music Glove is that the glove encourages the embodied learning of music (Myllykoski, Tuuri, Viiret, & Louhivuori, 2015). Children can learn music utilizing different modalities (visually, auditorily, and kinaesthetically, or by combinations of these; Burton & Taggart, 2011; Persellin, 1992). Acknowledging the integration of multimodality into the embodied learning of music through the hands is a design principle of the KAiKU Music Glove device (Myllykoski et al., 2015). Targeting

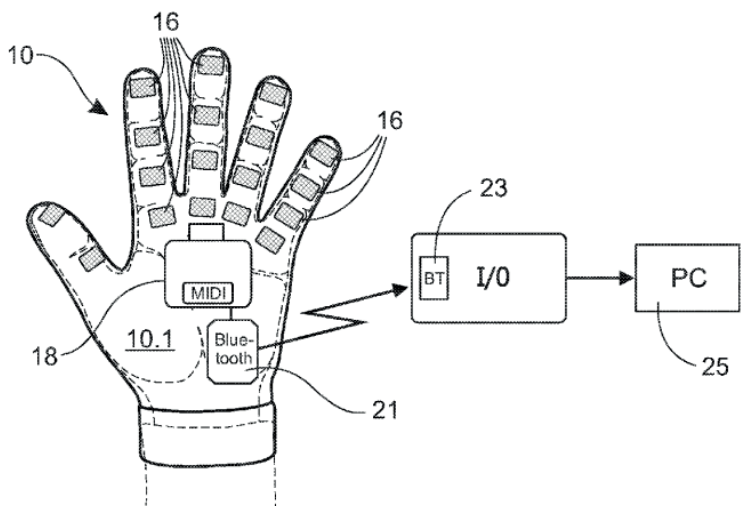

Figure 1. A diagram of the KAiKU Music Glove with a musical instrument digital interface (MIDI) and Bluetooth (BT) connected to a personal computer (PC). The KAiKU Music Glove generates musical data through a glove embedded with touch sensors and electronic units. It connects via Bluetooth or Universal Serial Bus (USB) to a host device (i.e., laptop or personal computer) to produce musical sound.

The numbers in the diagram correspond to the hardware that the KAiKU Music Glove implements: 10. A Glove device. 16. Touch sensors. 18. Central MIDI electronic unit. 21. Bluetooth transmitting MIDI code. 23. Bluetooth receiver. 25. Personal Computer (host device) (U.S. Patent No. 9,905,207, 2018).

the hands for musical knowledge and instrument development is not exclusive to the KAiKU Music Glove device (Voustinas, 2017). Other technologies recently developed also focus on the hands for use in a performance setting.

Human Music Technology Interaction: Placing KAiKU in Paradigm

User interfaces may be seen as embodiments, or "skins," of technological systems (Sampson, 2019). At this level of design, the user encounters, affects, and is affected by the system. Moreover, the interface represents how data is made meaningful to the user through design (O'Brien & Toms, 2008). From a phenomenological perspective, how the user encounters these designs is always through the body and its senses (Höök, 2009; Höök & Löwgren, 2012; Rousi & Silvennoinen, 2018). This is furthered by how the body connects the sensory design of the technological interface to human action (Bødker, 1989; Dewey, 1934/2005; Gayler, Sas, & Kalnikaite, 2019). Music is intrinsically connected not only to the evolution of human cultural activities but also is tightly coupled with the development of language—the most permeating and fundamentally cognitively defining communication technology there is (Justus & Hutsler, 2005). Thus, the multitechnological layering of music and its associated instruments or tools are connected with human action and interaction. From this perspective, music can be understood as linguistic and/or expressive communication technology. Musical instruments are tools facilitating music expression, and IT-enabled devices may serve as instruments in their own right or extend (augment) the capabilities of traditional instruments, such as the electronic violin or piano, to name a few. Furthermore, in addition to being one of the most embedded technologies throughout human evolution, music and its instruments have always been fully embodied and multisensory (Lee & Noppeney, 2011, 2014; Zimmerman & Lahav, 2012), involving several human sensory channels simultaneously.

Both the tablet computer and the KAiKU Music Glove, for instance, integrate the tactile and haptic experience of music making with IT. These directly connect multiple senses (touch, sound, sight, perhaps even smell, depending on the device materials) to digital interaction, strengthening the link between the mind (thought) and the body (physical movement, control, and sensations) within digitally facilitated music production. Although embodied multisensory experience always has been one of the main characteristics of the body–music experience (production and consumption), IT extends the traditions and nature of tool/instrument-assisted music making through its informational layering. This informational layering refers to the nature of IT where form does not always follow function and, through informational manipulation, some sensory characteristics of the devices (i.e., sound and haptic feedback) may change entirely. When considering the connection between people and technology, or people and musical instruments, one may ponder the augmented nature of the tool. We use *tool* here to highlight the characteristic of instruments and technologies as enablers for human action, while simultaneously alluding to Heidegger's (1927/1962) ideas of tools (i.e., technologies are "ready-to-hand") as augmentations of the human body and cognition (see also Harman, 2011). Furthermore, musical instruments may be seen as augmented human capacities to act and affect: Engagement with a musical instrument also is an embodied interactive activity among multiple human actors (Leman, 2008; Yu, 2013). In other words, music and its instruments can be seen as tools for social experience and collective cognition, linking the embodied consciousness of multiple individuals through sound and other sensory effects (Himberg & Thompson, 2009). Leman (2008) supported a premise called "transparent technology," a means of musician-based technology integration whereby the instrument/technology becomes seamless in its use and experience from the perspective of the music maker. Thus, conscious cognition of the instrument and its properties gradually become embodied and automatized in the musician's practice, transferring the coupling of musician and instrument from thought to feeling (emotional and sensory−motoric).

Play and Concentration in Childhood Music Education

Play provides experiences and opportunities for learning. This has formed a much-discussed basis for research in the context of educational technology (Said, 2004). Moreover, from an HCI perspective, the concept of play has been associated with increased frequency of and satisfaction in system use (Atkinson & Kydd, 1997). Additionally, researchers have attributed play to increased motivation, challenge, and positive affect (e.g., Woszczynski, Roth, & Segars, 2002). Other studies have shown that playing increases players' concentration in their experience of the activity (Huizinga, 2004). "Play has a deep biological, evolutionarily important, function, which has to do specifically with learning…. Many scientists think of much of their work as play, often linking the idea of play with high creativity" (Prensky, 2001, pp. 5–6).

People learn from experience, and learned matter influences how individuals subsequently experience phenomena (see constructivist views on learning, e.g., Steffe & Gale, 1995; see also Helfenstein & Saariluoma, 2006; Putnam, 2012; Rousi, 2013; Saariluoma, 2003; Symeonidis & Schwartz, 2016, regarding apperception). "An experience" in terms of an event (see, e.g., Batterbee & Koskinen, 2005) may be understood as a narrative with a beginning, middle, and end. How this experience unfolds, however, is determined by how the minds of those involved (or observing) make meaning. The engagement with devices and software for the purposes of producing something new—whether music, a performance, and/or an interactional engagement—can be likened to play. It is a constructive process in which creative expression or representation is produced (McArdle & Wright, 2014).

Through play, new literacies are realized and involvement in the process encourages concentration (Koo, 2009). Concentration refers to a sustained period of attention. From the perspective of concentration, meaningful learning can be achieved, as long as one of three forms of interaction (i.e., student–teacher, student–student, student–content; Tsang, Kwan, & Fox, 2007) is of a high level. Concentration derives from genuine engagement in learning as the student cognitively and affectively is attuned to acquiring, integrating, assimilating, and applying the information and other content presented within the lesson time (Dansereau, 1985). Bester and Brand (2013) argued that the amount of time and effort spent in a classroom is worthless unless the students are learning, and this process happens within the concentration span of learners.

Ready-to-learn: A Tool View to Information Technology in Musical Education

The theory of reasoned action (TRA) is a model developed to represent the reasons people behave in an intentional way (Davis, Bagozzi, & Warshaw, 1989; Fishbein & Ajzen, 1975). An adaptation of TRA is the TAM (Davis, 1985). TAM provides the general reasons for technology acceptance, clarifying the user behavior involved in choosing to use and then using a technology. Davis (1989) argued that not only was TAM originally designed to predict user acceptance behavior but also to explain it. Thus, TAM fundamentally helps researchers and those working in the IT industry understand why a particular system may be either acceptable or unacceptable to the user. Such information then could be used as a basis to pursue corrective development action.

TAM contains two factors critically relevant for computer acceptance behaviors: perceived usefulness and perceived ease of use (Davis, 1985, 1989; Davis et al., 1989; Venkatesh, 2000). Perceived usefulness is the user's own perception that using technology improves task performance. This may indeed be likened to what social psychologist James Gibson (1977) referred to as "affordance," whereby designs and their qualities are understood for what they may afford the user—that is, how they assist in the attainment of goals that align with intention. Perceived ease of use is the degree of effort that the user expects to place into interaction while using the technology (Davis et al., 1989). Behavioral intention represents a person's attitude toward and perceived usefulness of a system. This makes the concept slightly different within TAM than in TRA. An attitude and behavioral relationship implies that a person may form the intention to carry out behaviors that have a positive affect (Davis et al., 1989). TRA and TAM have been used widely in the social sciences and information systems research communities and include extended versions, such as TAM 2 (Venkatesh & Davis, 2000), TAM 3 (Venkatesh & Bala, 2008), the unified theory of acceptance and use of technology (UTAUT; Venkatesh, Morris, Davis, & Davis, 2003), and UTAUT2 (Venkatesh, Thong, & Xu, 2012). The latter models expand on the dimensions of affect and emotion, adding detail to the expectational components of technological engagement (i.e., performance expectancy and social influence) in addition to greater importance placed on the role of context (i.e., facilitating conditions).

Theoretical Concept: Perceived Ease of Use

We chose perceived ease of use from the original TAM as a theoretical concept to examine the degree of effort the students expected to place into technology interaction within the music classroom. Accordingly, perceived ease of use as a concept is a good fit for providing theoretical and practical insights relative to this study's purpose and research questions. We applied perceived ease of use to the analysis of the study's results to capture the relationship between the participants' behavior, learning performance, and report of their experiences with their assigned technologies. Figure 2 presents the original TAM theoretical framework (Davis, 1985).

METHODS

We conducted an exploratory, descriptive mixed-method study involving two elementary school classes in Central Finland. One class was assigned only the iPad with a music-producing app as the device to use within their music class. The other class was assigned the KAiKU Music Glove as a device, but also used the iPad with the app as an apparatus to generate sounds only.

Participants

Participants comprised two classes of 21 students each ($N = 42$). All participants were students, aged 8 to 9 years, enrolled at Jyväskylän Normaalikoulu in Central Finland and participating in regular music classes. The average age of students was 8.3 years ($SD = 0.5$). To protect the students'

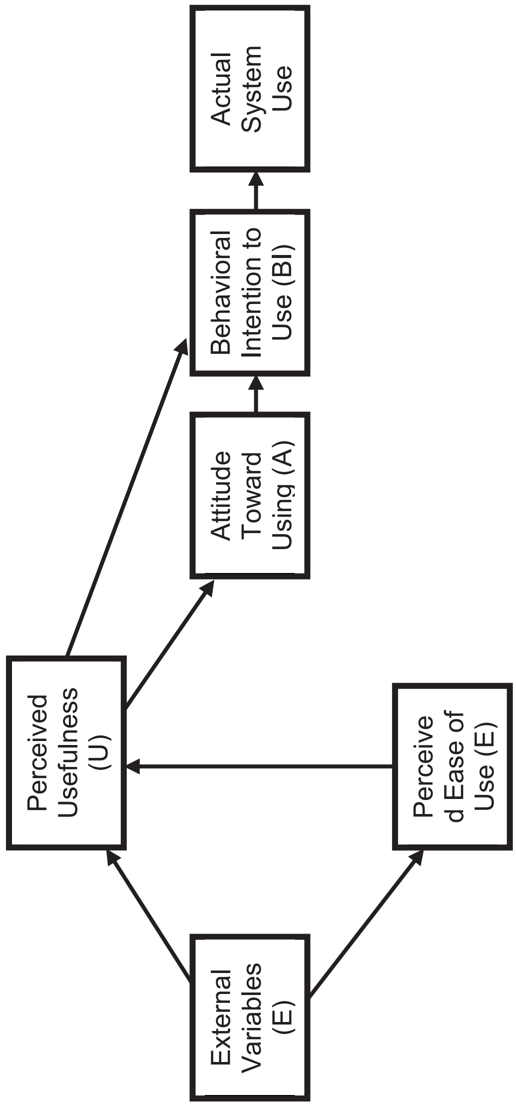

Figure 2. The technology acceptance model (TAM; Davis, 1985). The use of technology is determined by the person's behavioral intention to use (BI) the system, which is influenced by the user's attitude (A), described as an emotional response or a positive/negative experience when using the technology. Feeding into A is the perceived usefulness (U) and perceived ease of use (E). U also directly influences the user's BI. External variables may include social norms, such as an institution's access to technology and infiltration of use (Davis, 1985; Davis et al., 1989).

anonymity, each child received a number from 1 to 21 (each class separately) so that he or she could be identified consistently across the three data gathering processes.

Convenience sampling was used to address the specific aims related to our research questions. Specifically, the sampling method used in the current study is referred to as concurrent mixed method sampling (Teddlie & Yu, 2007) in that our sample serviced the requirements of our quantitative and qualitative strands of data. The quantitative and qualitative data were collected simultaneously, and the analysis of the quantitative data informed the analysis of the qualitative data (and vice versa). The procedure was convenient in that gaining access to the school to study both classes was made readily available by the existing common collaboration between the University of Jyväskylä and the Jyväskylän Normaalikoulu. Serving as a teacher training school for the University of Jyväskylä's Faculty of Education students, the Jyväskylän Normaalikoulu also collaborates with various departments at the university as an accessible location to conduct research. In addition, all of the subjects were willing to participate.

We obtained ethical clearance to conduct this research with children prior to commencing the study by receiving signed parental consent forms for each child that granted us permission to video record and use any data produced by the minor students in this study. Following the completion of the study, we researchers destroyed all video recordings.

Context

The study was carried out in two music classrooms at the Jyväskylän Normaalikoulu based in Jyväskylä, Finland. The school is responsible for educating students enrolled in Grades 1 to 9. Parents of the students attending the school typically permit their children to participate in associated research as well as work with student teachers.

Materials

iPad

The iPad is a multitouch screen tablet that runs on the iOS operating system. The device can serve as a platform for a variety of programs. In the case of this study, it was fitted with a music-producing app; the iPad created the audio output from the app. Students used headsets to hear the output.

Keyboard Touch Instrument App (iPadOS)

The Keyboard Touch Instrument app provides access to various MIDI-based keyboard instruments. For this specific music class—and thus this study—the app was set to the grand piano keyboard instrument, which was accessed via the iPad. The range of keys on the MIDI-based grand piano keyboard on the app was similar to the physical piano used in class by the teacher as well as emulates a standard piano sound. Thus, this digital instrument was deemed practical by the classroom teacher for the students to use. Tactile input from the both the iPad's screen and KAiKU Music Glove's sensors (see below) triggered the Keyboard Touch Instrument app to generate specific sounds.

KAiKU Music Glove

The KAiKU Music Glove device is a musical MIDI controller, fitted with touch sensors and an electronic unit. On the glove, touch sensors form more than two rows to format a musical scale (see Figure 3). To work the sensors, the user presses them with a finger from the other hand. The sensors are connected to an electronic unit that produces musical data.

The touch sensors are arranged from the index finger to the little finger. The tips of the fingers correspond to the notes of a first octave, C, D, E, F, so that semitone E-F is located between the ring finger and the little finger. The data signal created by touch on the glove transfers an output

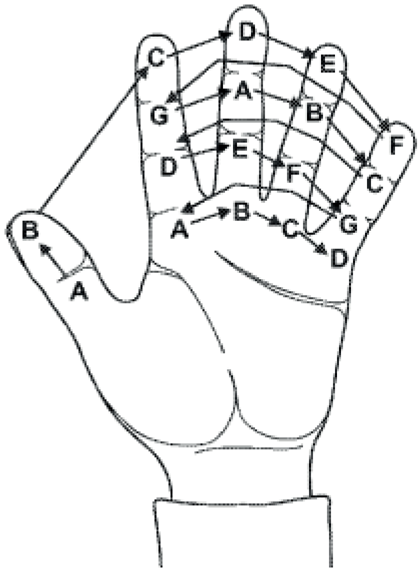

Figure 3. The progression of the music scale on the hand via the KAiKU Music Glove. The arrows show the position of the notes in relation to the fingers (U.S. Patent No. 9,905,207, 2018).

to a selected external device, for example, a MIDI device, a PC, or a computer tablet. In the current study, the glove's output was facilitated by a USB-connected iPad. The iPad functioned as a host device to the glove, decoding MIDI-information and producing sound accessed by headphones.

Study Design

This exploratory, descriptive mixed-method study involved two elementary school music classes. One class was assigned only the iPad as the device to use, which allowed students to play music from the Keyboard Touch Instrument app accessed via the iPad. The other class was assigned the KAiKU Music Glove as the primary music-creating device. However, this class also used the iPad with the Keyboard Touch Instrument app, but only as an apparatus to generate sounds. Because we compared the outcomes of the students using the KAiKU Music Glove device to the students using the iPad for learning, this quantitative aspect of the study can be considered quasiexperimental.

This mixed-methods approach served to address the multiple research questions. First, we worked with the music teacher to create a pre- and posttest assessment tool to measure any growth related to the participants' knowledge of music and musical listening abilities. This provided quantitative data on all students participating in this study and addressed RQ1. We also created an instrument to determine the participants' user experience associated with their assigned technology, employing a Likert-type scale. Students were asked to undertake these tests daily, before commencing use of their assigned devices and then once again after they used them. The responses to these user surveys were analyzed to answer RQ2. Thus, this survey provided both quantitative and qualitative information. Finally, we video recorded the 6 weeks of lessons so that we could analyze the behaviors of selected students regarding their concentration behavior, the analysis of which would address RQ3. These data were analyzed in light of perceived ease of use data results to draw inferences to generate a better understanding of the implications of utilizing established and experimental embodied digital music technology in childhood music education. This process provided our qualitative data. Figure 4 provides a visual summary of the research design. Each of the processes and materials are described more fully below.

Familiarization with KAiKU Music Glove and Researcher Integration Sessions

Two researchers were present in the classroom during the data collection phase of this study. Cozby and Rawn (2012) explained this allows the researchers to immerse themselves fully within the research setting, while Bogdan (1983) proposed this approach allows researchers to develop an understanding of complex social situations. Using the participatory observation method raises the problem of participant reactivity to being observed, known as the Hawthorne effect (Croucher & Conn-Mills, 2014). To account for this, we conducted familiarization sessions for each class so that we were able to integrate ourselves into the environment and introduce the KAiKU Music Glove technology into the experimental classroom. These pre-experiment sessions also allowed the researchers to pilot the data collection processes (i.e., test the Likert-type user experience survey questions and responses with the students and test the video recording process).

We researchers held two familiarization sessions before the prestudy test of knowledge was given to the students as well as Week 1's user experience survey. These sessions fulfilled a two-fold purpose: (a) to allow the children to learn and experience the equipment before the actual study, and (b) to allow children and researchers to become acquainted with one another. This important aspect of conducting research with children develops a trust relationship in which children are more willing to express themselves in the ways they normally would (Barley & Bath, 2014).

We structured the familiarization sessions similarly. The sessions started with the researchers introducing themselves. One class was given five KAiKU Music Gloves connected via USB to an iPad (with the Keyboard Touch Instrument app used on a iPad to generate sounds only) to interact and play music with, and the other class only used iPads with the Keyboard Touch Instrument app to interact and play music with. The class assigned the KAiKU Music Glove had five students at a time using the technology. This was timed closely by the class teacher, with four groups of students in total using the technology for approximately 10 minutes (total = 40 minutes). Five KAiKU

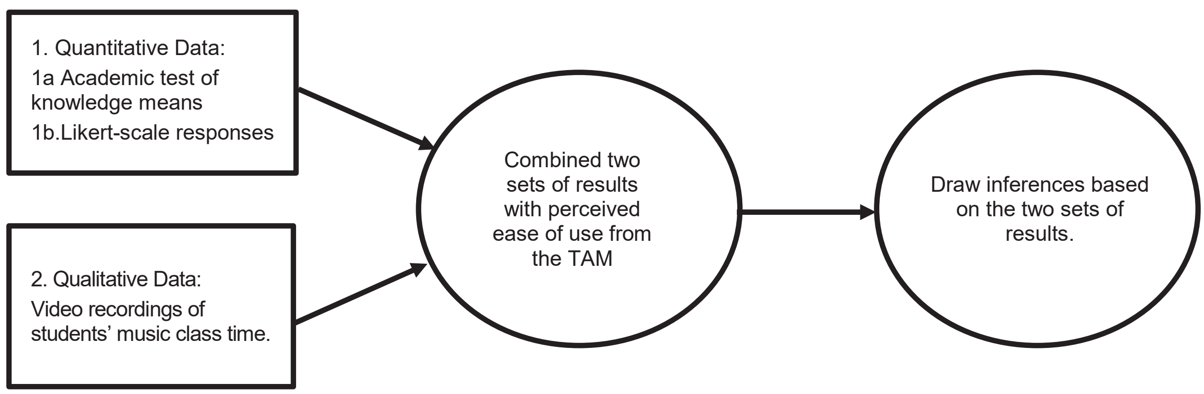

Figure 4. Mixed method study design of qualitative and quantitative data.

Music Gloves were deemed ready for use by their manufacturer before the study commenced, which is why we choose to use a limited number of them during these familiarization sessions. The students interacted and played with their KAiKU Music Gloves by touching the sensors of the glove to trigger and generate sounds in the Keyboard Touch Instrument app. When the students were not using the KAiKU Music Glove for their 10 minutes, they were instructed by the classroom teacher to complete musical exercises using an assigned iPad with the Keyboard Touch Instrument app. In the class assigned only the iPads, students played music by touching the iPad's screen to activate the sounds in the Keyboard Touch Instrument app for the entire class period. In both groups, the audio generated from the Keyboard Touch Instrument app played back through headphones plugged into the iPad and worn by each student. The familiarization sessions included small amounts of content, such as students playing four-bar simple rhythms, whole notes, half notes, quarter notes, and whole rests using one note.

After these familiarization sessions were completed, the KAiKU Music Glove manufacturer provided 22 of the gloves to the experimental class for the study's 6-week data collection period: 21 for all the students and one for the teacher to use. Additionally, in the week following the final familiarization session, the 6-week data collection period began with the following measures: the test of knowledge, the user experience survey to assess the students' perceived ease of use, and the qualitative video analysis.

Measures

Test of Knowledge

The students in both classes completed a test of musical knowledge at the beginning and end of the study. The pre- and posttests examined the students' musical knowledge retention and learning growth before and after using their assigned technologies. The classroom teacher (i.e., the teacher of all the students' subjects) and researchers discussed the nature of the test of musical knowledge, and the teacher developed the instrument. We researchers considered the teacher an expert at determining the validity of the content of the test because the teacher had taught primary and childhood music education classes at the Jyväskylän Normaalikoulu since 2012. The teacher designed the content of the test based on a Finnish childhood music education curriculum and teaching syllabus. The curriculum and syllabus integrates theoretical and practice-based music learning (Ruismäki & Ruokonen, 2006).

The development of the test of knowledge encompassed three stages. The first stage involved the researchers planning and discussing with the teacher the structure of the test and defining the content of the test. Following this, the teacher designed five open-ended questions in the Finnish language (see Table 1; these questions were answered by the participants in Finnish language and, for the purposes of this paper, have been translated by the classroom teacher from Finnish to English) based on the music class syllabus to examine theoretical (e.g., an examination of musical notation names) and practical questions (e.g., an examination of music listening skills). The test of musical knowledge consisted of five questions: one each testing the children's aural skill, pitch identification (these two were achieved by the teacher playing a musical notation by using a piano; the subjects listened to the notation and answered questions related to aural recognition of rhythm and pitch identification of melody), remembering musical notation names, and identifying piano keys and rhythmical markings. The second stage established face validity

Table 1. The Five Questions and Maximum Points from the Test of Knowledge.

Question	Maximum Points
What is the correct rhythm listened to?	1
In what order do you learn to play these melodies?	4
Name the piano keys.	8
Name the note names on the stave.	8
Identify the musical symbols from listening and match them to the phrase.	10

Note. The maximum points from the test are 31 and the minimum points are 0. The questions here were translated from Finnish to English by the music teacher.

of the test with the researchers. The researchers agreed that the test appeared to examine theoretical and practical questions. During the third stage, the teacher assembled the test in paper form. The students would complete their tests by using a pencil. The test—created in the Finnish language, one of two main official languages of Finland, which students of the age of the participants typically are able to read and write sufficiently—was administered by the music teacher before and at the completion of the 6-week study. The teacher also assessed the students' responses to the tests at both collection points and provided the results to us researchers.

User Experience Survey: Perceived Ease of Use

To examine how the two classes of students experienced using their respective technologies during their music class, the students completed a subjective experience survey each class, before and after using their assigned iPad or KAiKU Music Glove (see the Appendix for the survey in English). This user experience survey included one question on perceived ease of use; the balance of the survey presented questions not related to the scope of this paper and thus we focus only on Question 2 during the analysis in this paper.

We developed the questions for this user experience survey instrument thematically, based on Gasparini and Culén (2012), who explained that the perceived usefulness and ease of use of the iPad in the classroom are important factors for their acceptance. The Likert-type scale was designed pictorially in line with Kano, Horton, and Read (2010), who found that a thumb-scale employed for children's self-reporting on computer experience was effective with children as young as 7 years old. As a result, the students' responses to the statements on user experience required them to circle Likert-like scale thumb pictures (two thumbs down = *Not at all* to two thumbs up = *Very much*) to reflect their perspectives.We created this user experience survey employing the thumb scale in English, which the teacher then translated into the Finnish language. Again, all the participants were sufficiently skilled in Finnish.

We piloted the survey for reliability during the familiarization sessions (see below). Students responded to the test statements by circling thumb pictures. We then reviewed the initial responses between the familiarization sessions and at the start of the experiment to identify any inconsistencies in the intended response. For instance, we could determine if students from either class was responding incorrectly to statements (i.e., by writing numbers instead of circling thumb pictures to indicate their response, per instructions, or by drawing on the page arbitrarily). We did not find such inconsistencies in their responses to the user experience survey, indicating preliminary validity.

Qualitative Video Analysis

To observe the differences in students' concentration-related behavior patterns while using both music technologies, we conducted a qualitative video analysis of the recordings of the students using their assigned technologies in class. These data were collected and analyzed by two researchers (the first author of this paper and a master's graduate who is a classroom teacher), qualitatively observing the students using the technologies in the form of qualitative video analysis. To record each of the six classes, we set up a stationary video camera in the classroom in a position to capture the widest angle and the largest number of students possible. The camera setup recorded both audio and video. From the audio data, we could determine the students' verbal communications (i.e., a discussion with his/her peers related or unrelated to the music class activities, see Figure 5, or asking the teacher for help). We started the camera recording as the students entered the classroom and left the device to record without any action for the duration of the class. The qualitative video analysis was completed after the 6-week study was complete.

The general inductive approach for qualitative data analysis involves a research methodology suited for many research purposes. In the current study, we extended the approach to analyze video recordings of participant behavior. The primary goal of the inductive analysis was to allow research findings to emerge from the recurrent and prevailing themes in the data (Thomas, 2006). In inductive analysis, an iterative process, the raw data is read multiple times with codes, themes, and categories continually defined, refined, clarified, and amended (Braun & Clarke, 2006). The inductive analysis was driven by our interest in determining any differences in the concentration level of students using each of the devices, as articulated in RQ3. Thus, in our study, because our data comprised video recordings, we employed the iterative process by repeatedly viewing video clips containing behavior of interest.

We analyzed the behavior of four participants, two from each study condition, to identify concentration-related behavior patterns as the students' played and learned with their assigned technology during each lesson. The restricted camera angle used in the study and the quality of video that could be observed consistently for analysis limited our ability to expand beyond the four students. We focused our analysis on the four participants' nonverbal behaviors, such as looking around the classroom, and verbal communications, such as asking for help from the teacher or asking for help from another student. Criteria for selecting the four study participants involved (a) the student must be within the video frame consistently throughout the class, (b) the student must be present in class for the entire duration of the study, and (c) one student in each class scored high in learning performance (above median in the pre- and postlearning test of knowledge) and the other low on the same measure. Students 7 and 12 from the iPad class and Students 3 and 10 from the KAiKU Music Glove class were selected for observation via the videotaped data. However, both students selected for video analysis from the KAiKU Music Glove class scored below the median in the prelearning test of knowledge. Considering the limitations apparent in both the technical and selection challenges and because both students fully met the first two selection criteria and Student 3 scored above the median in the postlearning test of knowledge, the researchers agreed to modify the requirement of the third criterion and observe these students for the video analysis. In this instance, the high quality of behavioral observation that could be made via the videotaped data was considered of primary importance. We acknowledge this exemption in the study's limitations.

The two researchers chose lessons from Weeks 1, 3, and 6 for video analysis (as these lessons represented a beginning, middle and end point of the study for analysis), employing a three-stage process for the analysis of the video recordings. The first stage of analysis involved a first-pass inductive coding of the data to place identified data into preliminary analytic categories. In the first stage, the two researchers worked independently to identify segments of the video recordings with occurrences of student verbal and nonverbal behaviors suggesting a lack of concentration. Following this, the researchers negotiated and agreed on the following codes: boredom, no attention, task focus, and raising hand for help. In the second stage, the researchers concurred on a subset of the video recording sections where specific student verbal and nonverbal behavior was observed. The results of the second stage were lists of segmented descriptions, along with time codes; these were identified individually and entered into a shared spreadsheet. This stage of analysis led to the refinement of the previous identified codes. From this second stage, four themes emerged: looking away from technology, looking around the classroom, teacher–student interaction, and students discussing the task with fellow students. In the third stage, classifications for student verbal and nonverbal behaviors regarding their concentration-related behavior in the classroom were further revised. After independent analysis, we agreed upon two classifications at this selective coding stage: off-task behavior and on-task behavior (see Table 2). Patterns in off-task and on-task behavior have been the focus of much research (see, e.g., Baker, Corbett, Koedinger, & Wagner, 2004; Baker, D'Mello, Rodrigo, & Graesser, 2010; Cozby & Rawn, 2012; Ziemek, 2006).

Off-task behavior relates to the users' cognitive–affective states as they interact with technology. These include boredom (Csikszentmihalyi, 1990; Miserandino, 1996) and engaged concentration. Engaged concentration is a state of engagement with a task that is intense. During this state, attention is focused and involvement is complete. However, it does not involve the various task-related aspects that Csikszentmihalyi associated with flow (e.g., clear goals, balanced challenge, direct and immediate feedback). Baker et al. (2010) identified these cognitive–affective states as looking at or away from the object or looking around the room for something other than the user interface. Meanwhile, Ziemek (2006) associated off-task actions with disruptive behaviors, such as talking about things not related to the activity and disrupting their classmates. On-task behavior is identified by Baker et al. (2004) as asking for help from the teacher or another student and commenting on achievements. For our study, the frequencies of the occurrences of the students' nonverbal responses and verbal communications were considered indicators of their concentration during class.

Classroom Activities

The process of the music instruction conducted was typical for this teacher and this age group of students, other than the introduction of an experimental condition in form of the KAiKU Music

Table 2. Actions of On-Task and Off-Task Behaviors.

Off-Task Behavior	On-Task Behavior
Looking away from, the screen	Asking for help from the teacher
Looking around for something other than the user interface	Asking for help from others
Talking about things unrelated to the activity or disrupting others.	Commenting on achievements

Note. Based on the research of, e.g., Baker et al., 2004; Baker et al., 2010; Cozby & Rawn, 2012; Ziemek, 2006.

Glove and the data collection processes (i.e., measurement instruments and video recording). This 6-week period of time was blocked off during the students' academic semester, and as such the students had music education with this classroom teacher prior to our study. This classroom teacher is specifically a music teacher in this school and thus teaches music subjects only. All 42 students participating in this study have specific teachers in the following subjects: special needs teachers, language teachers, craft teachers, physical education teachers, class teachers, music teachers, and religion teachers. The class assigned the iPad had class on a Monday; the class assigned the KAiKU Music Glove had class on a Thursday. The teacher was the same for both music classes; the same classroom activities were assigned to the iPad and the KAiKU Music Glove classes. The teacher integrated both technologies into the existing curriculum of the lesson plans, ensuring students who participated in this study did not fall behind in the level of education they received. As the technology was incorporated into the lessons, the students were able to participate in the study without sacrificing the amount of material covered. Figure 5 briefly provides information on the content of the weekly lessons. The weekly classes followed the same procedure, as shown in Figure 6.

Week 1	The teacher instructed the class about incorporating three notes, C-D-E, into four-bar melodies. The teacher then demonstrated the location of the musical note positions, C-D-E, on the keyboard (or, in the class assigned the KAiKU Music Glove, on the device). The students incorporated three notes, C-D-E, as part of four-bar melodies while using and playing their iPad or KAiKU Music Glove.
Week 2	The teacher instructs the class about different note names found on the musical stave. Following the new instruction, the students then continued practicing playing three notes, C-D-E, as part of four-bar melodies while playing their iPad or KAiKU Music Glove.
Week 3	The teacher instructed the class on the location of the musical note positions found on the keyboard (or the KAiKU Music Glove) as well as the note names of *Twinkle, Twinkle Little Star*. The students learned, and practice playing the melody of *Twinkle, Twinkle, Little Star* while using their iPad or KAiKU Music Glove. The classroom teacher accompanied the students' by playing *Twinkle, Twinkle, Little Star* on the electric keyboard or on the KAiKU Music Glove.
Week 4	The teacher instructed the class on the note positions found on the keyboard or on the KAiKU Music Glove as well as the note names of a traditional Finnish Christmas carol (*Joulu on taas; It's Christmas Again*). The students learned and practiced the melody of *Joulu on taas* using their iPad or KAiKU Music Glove. The students sang to accompany the melody and harmony of the Christmas carol. This was the first-time students accompanied the use of their technologies with singing.
Week 5	The teacher instructed the class on the theoretical background of time signatures and ¾ time. The students learned about time signatures, and ¾ time playing. The students continued to practice the *Joulu on taas* using their iPad or KAiKU Music Glove. Also, the students sang *Joulu on taas* while playing it simultaneously on their technologies.
Week 6	The students continued to practice *Joulu on taas* using their iPad or KAiKU Music Glove. At times, the young musicians were accompanied by the classroom teacher on the electric keyboard, no matter which technology they were using.

Figure 5. An Overview of Activities in Both Music Classes.

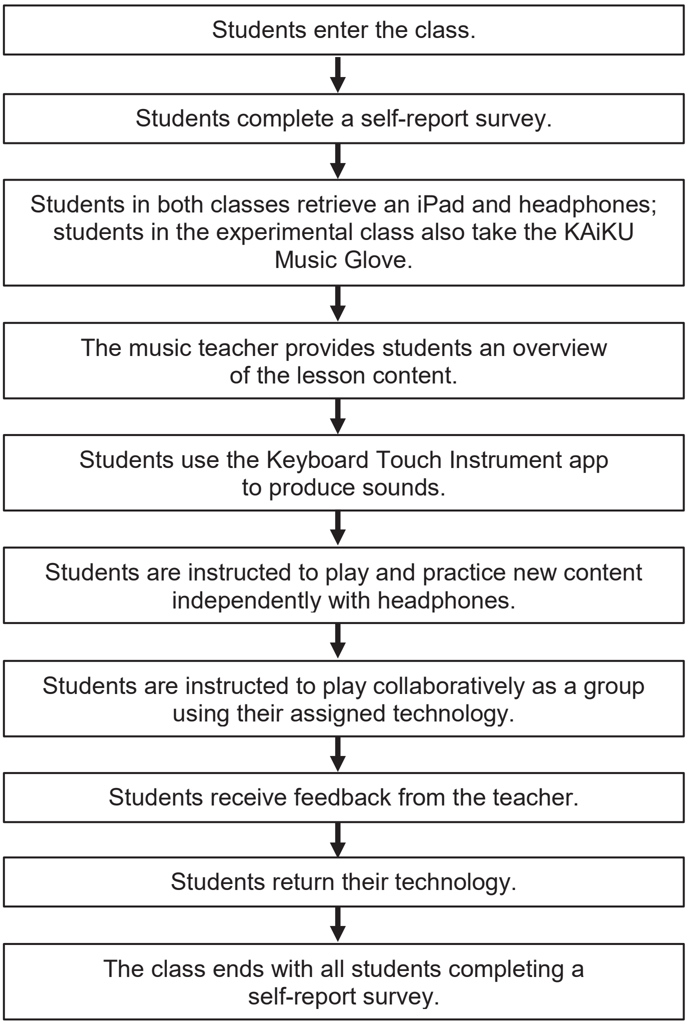

Figure 6. The session procedure during the 6-week-long experiment. Each box represents an essential component in the organization of each music lesson, observed and agreed on by researchers. The weekly lessons maintained a regular schedule and were held in the same room.

RESULTS

The results from the test of knowledge are presented first, followed by the responses on the perceived ease of use question of the user experience survey, and finally, qualitative observation tallies. The results report and compare learning outcomes between the iPad and KAiKU Music Glove classes and perceived ease of use responses before and after each time the students used their assigned technologies. Statistical analysis in the form of a Mann-Whitney U test was used to examine whether or not the difference in change in test scores between the student groups is significantly different after using their assigned technologies during the study's duration. To analyze the change in perceived ease of use responses before and after the students used their assigned technologies, we used a Wilcoxon Signed-ranks test to examine their perceived ease of use survey responses. The qualitative observation tallies were made by the researchers viewing video recordings of the classroom lessons. The observation tallies were the result of behaviors coded by both researchers. Observation tallies were made by both the researchers. Following the comparison of tally totals, both researchers negotiated and agreed upon final codes for behaviors and the total instances of each observed behavior.

The test of knowledge was completed by all students in both classes. Before the students used their devices, the test of knowledge established a baseline measurement of the students' knowledge regarding the musical syllabus. After using the technologies, the same test of knowledge was completed by the students to examine whether the use of the technologies had increased or decreased their musical knowledge.

Pearson's correlation coefficient was carried out to assess the relationship between the group of students using only the iPad for music learning (n = 21) and the group of students using the KAiKU Music Glove (n = *21*) for the same purpose. We also computed test of knowledge scores at the beginning of the experiment (Week 1) and retest scores (Week 6). The Pearson's r data analysis revealed a moderate positive correlation between the test and retest scores for both groups, with an r of .73 (iPad only group) and an r of .77 (KAiKU Music Glove group). Results from the test of knowledge before and after using the technology are in Figure 7.

We performed a statistical analysis of the posttest of knowledge scores using a Mann-Whitney U test. The purpose was to compare whether the change between the two groups from pre- to posttest scores was significant. The Mann-Whitney U test indicated that the difference in change in test scores between the students after using their assigned iPad (*Mdn* = 7) and KAiKU Music Glove (*Mdn* = 0) technologies is significant, U = 115, z = 2.641, p = .008 two-tailed, and a medium effect-size was found d = .75.

As shown in Table 3, results from the daily survey indicate the technologies were rated similarly before they were used in perceived ease of use, as Week 1, Week 3 and Week 6 report median results of between 4 and 4.50, and a small effect size (d = .20) was found. After the technologies were used, the daily survey results indicate that both technologies were rated lower in perceived ease of use, as Week 1, Week 3, and Week 6 report median results of between 3 and 1.50, and a small effect size (d = .20) was found. In addition, results from the daily survey indicate that both devices were rated similarly in perceived ease of use, post-use, at Week 6 (iPad, *Mdn* = 2.00, KAiKU Music Glove *Mdn* = 1.50) and a small effect size (d = .31) was found.

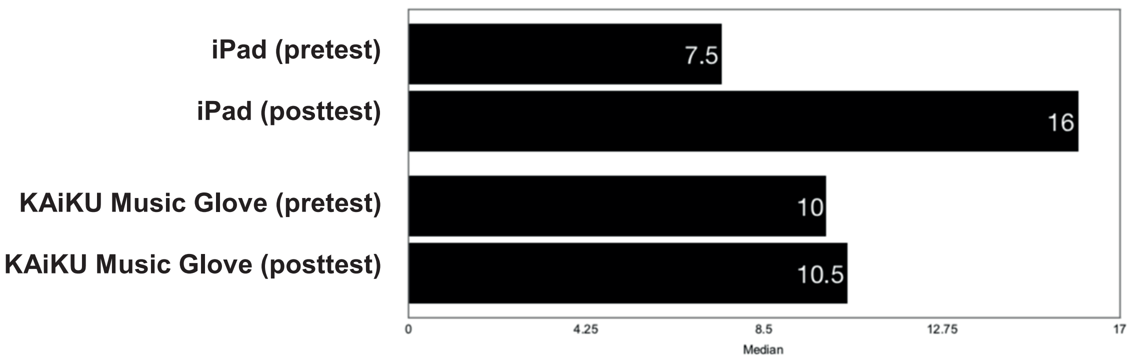

Figure 7. Medians comparing the pre- and postlearning test of knowledge results from the iPad and KAiKU Music Glove classes. The maximum test score is 31.

Table 3. Descriptive Statistics of the Perceived Ease of Use Responses During Weeks 1, 3, and 6 for the iPad and KAiKU Music Glove Classes.

	Week 1			**Week 3**			**Week 6**		
Item	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
I think the iPad will be easy to use today (iPad)	3.84	4.00	1.12	3.50	4.00	1.43	3.76	4.00	1.25
Today I found the iPad easy to use (iPad)	2.84	3.00	1.07	2.80	3.00	1.28	2.53	2.00	1.55
I think the glove will be easy to use today (KAiKU Music Glove)	4.30	4.50	0.95	3.95	4.00	0.95	3.70	4.00	1.17
Today I found the glove easy to use (KAiKU Music Glove)	2.80	3.00	1.06	2.35	2.00	1.82	2.10	1.50	1.21

We performed a Wilcoxon Signed-ranks test on the change in perceived ease of use ratings. The Wilcoxon Signed-ranks test indicated the change in perceived ease of use rating before using the iPad at Week 1 (*Mdn* = 4.00) and after using the iPad at Week 6 (*Mdn* = 2.00) is significant, $T = 118$, $z = -2.5854$, $p = .009$; a large effect-size was found, $d = .80$. The Wilcoxon Signed-ranks test indicated the change in perceived ease of use rating before using the KAiKU Music Glove at Week 1 (*Mdn* = 4.5) and after using the KAiKU Music Glove at Week 6 (*Mdn* = 1.5) was significant, $T = 214$, $z = -3.4236$, $p = .001$, and a large effect-size ($d = .80$) was found.

To analyze the difference in change between the students' ratings in perceived ease of use of both the devices from Week 1 to Week 6, a Mann-Whitney U test on the ratings was performed. The Mann-Whitney U test indicated the difference in change of perceived ease of use ratings between the students who used the iPad (*Mdn* = 0) and the students who used the KAiKU Music Glove (*Mdn* = 2) across the 6 weeks of study was not significant, $U = 165$, $z = -1.384$, $p = .168$ two-tailed; a small effect size ($d = .40$) was found.

To analyze the difference in perceived ease of use ratings of both the devices between the two groups of students, after rating their devices at Week 6, we performed a Mann-Whitney U test on the ratings. The Mann-Whitney U test indicated the difference in the two groups of students perceived ease of use rating after using the iPad (*Mdn* = 2) and after using the KAiKU Music Glove (*Mdn* = 1.5) at Week 6 is not significant, $U = 217$, $z = -0.07547$, $p = .936$ two-tailed, and a small effect size ($d = .31$) was found.

We conducted a video analysis to understand the students' behaviors while using their assigned technologies. Video of the classes was recorded at 2-week intervals during the survey period (i.e., Weeks 1, 3, & 6), and the observations were of two students from each class, selected by specific conditions. The students' coded behaviors refer to their concentrated-related behavior while using their assigned technologies. These were labeled as Off-task Behavior and On-task Behavior.

Two researchers rated and coded behavior of the selected students at each observation point independently. Interrater reliability was measured to ensure that the data collected in the study were represented correctly. We completed statistical analysis in the form of Cohen's kappa (*k*) to examine the reliability between the observed scores of the researchers. The results of the kappa were $k = .81$, indicating strong agreement between the researchers on their coded categories.

Tables 4 and 5 display the tallies of the researchers' analysis of the two representative students' behavior in the iPad-using and KAiKU Music Glove-using classes. Each student in both the classes were designated a number (from 1 to 21). Within the iPad-using class, students numbered 7 to 12 were selected for video analysis of their behavior, and within the KAiKU Music Glove-using class, students numbered 3 to 10 were selected for video analysis of their behavior.

Table 4. Tallies of the Researchers' Analysis of Two Representative Students' Behavior in the iPad Class.

Week	Student Number	Instances of Off-Task Behavior	Instances of On-Task Behavior
1	7	3	0
	12	2	0
3	7	0	0
	12	0	0
6	7	1	0
	12	4	0
Total		10	0

Note. Each student in the iPad-using class was designated by a number (from 1 to 21). Students 7 and 12 were selected for video analysis of their behavior.

Table 5. Tallies of the Researchers' Analysis of Two Representative Students' Behavior in the KAiKU Music Glove Class.

Week	Student Number	Instances of Off-Task Behavior	Instances of On-Task Behavior
1	3	0	0
	10	0	0
3	3	0	0
	10	0	0
6	3	0	3
	10	0	3
Total		0	6

Note. Each student in the KAiKU Music Glove-using class was designated by a number (from 1 to 21). Students 3 and 10 were selected for video analysis of their behavior.

DISCUSSION

The current study found that the students using, playing, and learning music with the iPad-only scored higher in their test of knowledge posttest result. When analyzing the difference in change between the students' posttest results during the 6 weeks of lessons, a Mann-Whitney U test showed a statistically significant result. When the change in perceived ease of use responses is analyzed before using both technologies, statistically significant results were found. The results of the qualitative video analysis tentatively suggest that concentration-related behavior may have been observed to be higher in the two students using, playing, and learning with the KAiKU Music Glove, than the two students using the iPad-only. The results above provide evidence for discussion of the study in terms of the three research questions.

RQ1. What is the difference in musical knowledge before and after using the iPad with the Keyboard Touch Instrument app and the KAiKU Music Glove connected to the iPad in children's music classes?

As indicated in the analysis of the posttest differences, the students who used the iPad with the Keyboard Touch Instrument app improved more in their musical knowledge after using the technology over the 6 weeks of lessons as compared to the students who used the KAiKU Music Glove. When the posttest results comparing the difference in change are compared to one another, the difference was significant and the effect size was medium. These findings suggest that use of the iPad with the Keyboard Touch Instrument app contributed to increased learning more so than the KAiKU Music Glove. The findings in this study are in line with a previous research that also used these data (Danso, 2019). However, a distinct difference in this study's use of the data is the analysis of change in posttest score after the students used their technologies, which highlights the potential significance of the iPad with the Keyboard Touch Instrument app's contribution to the students' increased learning. In addition, the increased learning of the students who used the iPad with the Keyboard Touch Instrument app supports the literature of Wario et al. (2016), Wang, et al. (2015), and Heinrich (2012), who found interacting with the iPad in the classroom may have a positive impact on learning. On the other hand, the difference may have resulted from students being more familiar with the iPad device and thus able to use its touch screen more efficiently, helping their learning performance.

Moreover, the students using the iPad as their music-education platform learned with the piano keys presented via the Keyboard Touch app. Touching the piano keys presented in the app may have supported the students' learning better than the students assigned the KAiKU Music Glove due to familiarity from prior lessons in understanding how notes are positioned on a keyboard. In addition, the Keyboard Touch Instrument app has a wider range of musical notes (27 keys in total) available for the students to play compared to the KAiKU Music Glove (17 sensors in total). This may have encouraged more freedom for the students in the iPad group to express themselves musically. The KAiKU Music Glove has a fixed mapping system placing notes across the fingers (see Figure 3), which may have presented a practical challenge for the students playing music and their subsequent learning. In this instance, the Keyboard Touch Instrument app used by the student group assigned the iPad could be seen as unrestrictive to the students' musical expression while supporting their learning outcomes. The unrestrictive nature of the app as the primary learning tool supports the findings of Burton and Pearsall (2015), who stated that apps used in childhood music education should allow children freedom in music making. To achieve a similar positive learning outcome, the KAiKU Music Glove may benefit from future development in placing additional sensors on the device and allowing users similar access to the range of musical notes the Keyboard Touch Instrument app provides, both which may encourage freedom in music making.

Consequently, the KAiKU Music Glove may have been a hindrance to learning in the music class. This could be due to the fact that it was too unfamiliar, thus diverting attention from the music learning in general. We had identified this potential obstacle already before the study's implementation and attempted to mitigate it with the familiarization sessions. Despite two familiarization sessions, we must acknowledge that the children assigned to the KAiKU Music Glove condition already had prior experience in using the iPad with the Keyboard Touch app that mirrored the piano keyboard and thus were presented with a significantly different musical interface when we entered the classroom. Although the question about how prior experience with iPads (or other tablet computers) and specific software programs may have contributed to the lower test scores for the KAiKU Music Glove condition is an important issue to explore more deeply, it is out of the scope of this current study.

RQ2. What are the students' ratings of perceived ease of use before and after using the iPad only or the KAiKU Music Glove in the music classroom?

We asked the students at the start and conclusion of each lesson about their anticipated and post-use perceived ease of use for their assigned technology. The students' rated both technologies higher in perceived ease of use across Week 1, Week 3 and Week 6 before using the devices, and rated them lower after they were used across Week 1, Week 3, and Week 6. This is indicated by two sets of results. First, the descriptive statistics reporting medians of between 4 (iPad-only pre-use Week 1) and 4.50 (KAiKU Music Glove pre-use Week 1) before the technology were used, and medians of between 3 (iPad-only Week 1, and Week 3 post-use) and 1.50 (KAiKU Music Glove Week 6 post-use) after they were used. Second, the analysis of the change of score between the students' rating their anticipated ease of use of the iPad and KAiKU Music Glove use at Week 1 and the final rating at Week 6 are statistically significant, in part due to their higher ratings before use at Week 1, and lower final ratings post-use at Week 6.We speculate the higher ratings before using the iPad-only may have been due to the familiarity of using the device prior to the study, and the lower ratings after they used the device may have been due to having to play music by using the Keyboard Touch Instrument app interface while completing the lesson content. On the other hand, the students rating the KAiKU Music Glove high before using it in perceived ease of use may have been due to the novel design of the KAiKU Music Glove, as it places musical notation across the hand in the form of sensors. Consequently, the children anticipating playing music on their hand may have influenced these responses in a positive manner. However, the lower ratings in overall perceived ease of use after the KAiKU Music Glove is used show that the device may have impeded playing music while completing the lesson content.

In line with Davis et al.'s (1989) conception of perceived ease of use, we can observe that students may have anticipated less effort in engaging the technology before using their assigned devices at Week 1 but then perceiving more effort was necessary in using them after the course at Week 6. Regarding the iPad, some of the students' high ratings in perceived ease of use before and after its use is in line with the works of Henderson and Yeow, (2012), Churchill et al. (2012), and Clark and Luckin, (2013), who indicated that tablet computers are supportive for use in classroom settings. Regarding the KAiKU Music Glove, some of the students' high scores before use suggest that novel hand-sensor technology is seen as easy to play music with.

RQ3. What is the difference in concentration-related behavior patterns of the student's while interacting and playing the iPad or KAiKU Music Glove in children's music classes?

Several explanations are possible in analyzing the difference in the concentration-related behavior of the students while using, playing, and interacting with their assigned iPad or KAiKU Music Glove. The teacher interacted more frequently with the two observed students who used the KAiKU Music Glove, as requested by these students. This was coded in the observation tallies as on-task behavior, in line with Baker et al. (2004). Thus, a tentative association with KAiKU Music Glove usage encouraging the students' to remain on-task might be identifiable, as they were asking for support from the teacher. Crucially, these data must be interpreted with caution because the students using the KAiKU Music Glove may have found the instructions from the teacher needed clarification, prompting a request for help and corrective guidance about the lesson content and how the lesson content was associated with playing on the KAiKU Music Glove.

It follows that the students using the KAiKU Music Glove may have needed additional help and support from the teacher because of the novelty of the technology and the technical difficulties students experienced while using it. Evidence of this can be seen from the results discussed in RQ2, where the KAiKU Music Glove was rated lower in perceived ease of use. But these circumstances also were noted clearly in the observations of the researchers. For example, the researchers observed that both students using the KAiKU Music Glove experienced practical difficulty in strapping the device to their wrists, making the glove properly cover their hands. In these cases, the wrist strap was slightly too large and the students requested the teacher's help in tightening the wrist strap appropriately. These difficulties can be seen to impede the embodied learning experience of the children by preventing—or at least delaying—them from engaging in the immersion of the music-making interactions. As the user interface skin (Sampson, 2019) of the KAiKU Music Glove did not always fit the students' hands easily, the sensory design of the technology prompted the students to interact more with the teacher instead of playing music with the sensory aspects of their hand (Höök, 2009; Höök & Löwgren, 2012; Rousi & Silvennoinen, 2018). This observed difficulty in usability of the KAiKU Music Glove also may have been embodied in the students' actions, as the improperly fitted technological design prompted the request for help (Bødker, 1989; Dewey, 1934/2005; Gayler, et al., 2019). Naturally, from this arises the importance of social interaction and experience from not only the perspective of music but also those of educational (music) instruction and technological usage. These are issues that deserve full attention in their own right.

In addition, the differences in observed concentration-related behavior of the two students from each group may have been due to the students observed being more familiar with the iPad and less familiar with the KAiKU Music Glove. As noted above, all participants in this study had used the iPad with the Keyboard Touch Instrument app in their music classes before we initiated this experiment. Thus, on-task and off-task behaviors could have been complicated—or perhaps even caused—by the students' struggle or unfamiliarity with their assigned technology.

The comparatively high off-task behavior of the students using the iPad only that we observed may have relevance to the evidence in RQ2. Because the iPad device and software were easier to use and more familiar than the KAiKU Music Glove, the off-task behavior may reflect that these students were freer to interact with one another more often (peer-to-peer) and provided opportunities for them to play with one another. This freedom in play and social interaction may have encouraged the students to concentrate more in the process of the lesson (Koo, 2009), which contributed to genuine engagement with the classroom activities and educational content (Dansenreau, 1985). As an effect of the iPad's design, the technology may have enabled the iPad-only students more opportunity for a social experience with the learning content. This social experience is described as coexperience by Batterbee and Koskinen (2005), who noted that children experienced music while using and playing with the technology together, as well as being engaged in play and social experience with one another. Hence, the iPad may have enabled a creative (McArdle & Wright, 2014) coexperience of playing music for these students to be occupied completely in.

This corresponds to a simultaneous creative coexperience of music enabled through design of the iPad, perhaps evidenced by its high ratings in perceived ease of use by the students and their familiarity with the device from prior use. In this class, this could be viewed as a benefit in using the iPad further, as it fostered coexperience between the students while maintaining their concentration on classroom activities. The familiarity of technology and coexperience may go hand in hand, and having the students become more familiar with the KAiKU Music Glove may have enhanced this. In addition, the KAiKU Music Glove's slightly lower ratings in perceived ease of use compared to the iPad-only after it was used, suggest it was practically difficult to use, somewhat hindering interaction with others. For this reason, the role of social learning in relation to the introduction of both established and new technologies in the music classroom should be explored in greater detail in future studies.

Moreover, concentration-related behavior was quite similar across both classes of students' using their assigned technology as evidenced by their overall low off-task behavior tallies. Speculatively, the respective low off-task behavior recorded by both classes of students' using their assigned technologies may associate with literature by Huizinga (2004), who suggested that students can be engaged in classroom task activity while using, playing, and interacting with their devices during class even if this involves peer interaction and other behaviors that might reflect loss of concentration.

As the students used their assigned devices, one must remember that they were engaged in an embodied music experience. Thus, the experience itself may be seen to extend beyond the human−device interaction toward the larger scope of the musical engagement per se. Because of the overall respective high concentration-related behavior, these findings resonate with findings by Huizinga (2004) by reporting that play supports children in concentrating on learning when engaged with the interaction of objects.

Associating perceived ease of use data with the current observation data indicates that the students' expectations of the studied technologies may have affected concentration-related behavior, which in turn resulted in their actual system use. It follows that the higher performing class in the test of knowledge (the class who only used the iPad with the Keyboard Touch Instrument app) may have perceived their technology as easy to use, which resulted in less effort invested in interaction while using the technology. Indeed, the data show the students observed for concentration-related behavior while using the iPad only engaged in more off-task behavior than the students using the KAiKU Music Glove, suggesting the students using the former technology were not concentrating as fully as the students using the latter during the 6-week study. We suggest that, in the current study, higher perceived ease of use corresponded to less interaction effort while using the familiar technology (i.e., the iPad), resulting in lower levels of concentration-related behavior. On the other hand, the higher concentration-related behavior recorded by the students using the KAiKU Music Glove most likely is linked to their increased effort toward interaction while using the technology. Consequently, applying the perceived ease of use conception from TAM (Davis, 1985) illustrates the students' strong intentions to anticipate how easy to use both device interfaces appeared before playing music, while their concentration-related behavior may be an instance of how challenging these technologies are in action.

LIMITATIONS AND FUTURE STUDY

The current study found practical information about novel and experimental technology use in the music classroom, particularly the strengths of the iPad regarding academic performance and overall ease of use during interaction. The current study also provides new insights into the use of experimental hand-based sensor technology in the childhood music classroom, finding the students had strong intentions about using it to play music throughout the duration of the class. Both technologies helped the students' learning performance, and the observed students appeared to concentrate in class. However, several limitations with the study design and implementation are apparent and thus the results should be considered preliminary and used with caution.

The current test of knowledge did not control for the effects of the students' history, maturation, and familiarity with the iPad device (see, e.g., Dimitrov & Rumrill, 2003); these aspects of student knowledge should be built into the development of any future iterations of the test of knowledge. Additionally, more sophisticated quantitative measures (such as ANCOVA) on the pre- and posttest data may produce a truer analysis of the scores than what was used in this study. Finally, the current study's duration was quite short. The 6 weeks represented a short component within a larger, ongoing class. A longer study period with both technologies, and particularly more time for the students to use the KAiKU Music Glove and practice with the technology in advance of research measurements, may provide more reliable interpretations about student usage of their respective technologies in their childhood music class.

Regarding the perceived ease of use items (adapted from TAM; Davis, 1985), we see a threat to the internal validity within the current study. Although the use of the perceived ease of use investigation was used only descriptively in this study, the current study's findings cannot provide distinct evidence that perceived ease of use was accurately measured as this has been determined less subjectively using construct validity scales. To provide clear evidence of TAM concepts in our data (such as those sought through our perceived ease of use survey), construct validity tests should be completed to ensure that the instrument is measuring the associated trait accurately.

In addition, the study itself is limited in its measurement of student concentration-related behavior. The qualitative video analysis used to analyze concentration-related behavior was problematically influenced by a fixed video camera angle. More video angles or a wider angled device is necessary to repeat a similar analysis, which would have helped us to adhere to our conditions for selecting subjects for observation. A larger population (or sample) of observed participants would also be beneficial. To further increase the reliability of the study, stratified sampling could be used to represent a larger swath of the population for analysis (e.g., test of knowledge scores). Moreover, we believe that the students' familiarity—or lack thereof— with the devices used in this study may have skewed the observation data. Thus, having students' equal familiarity of their respective devised would be important for future study. Furthermore, testing and analysis of a sample that uses KAiKU Music Gloves of the same physical size is necessary to draw more precise conclusions about its usage in the music classroom.

Other factors affecting learning experience, particularly in the music education context, were not accounted for during this study, such as the role of social experience and social learning in relation to music learning and technology usage. One worthwhile theory to investigate in relation to the function of the devices within the learning process would be Albert Bandura's (1977a) social learning theory (SLT). This theory significantly relates to behaviorist traditions in which researchers understand or investigate how people behave in specific ways to achieve specific outcomes (e.g., attain direct reward—e.g., financial, food, etc.—or achieve social acceptance). SLT is a complex construct in that it helps researchers understand not only how humans behave in ways to influence specific social outcomes but also to attain states of influence and agency within themselves. For instance, self-efficacy alludes to one's own experience of being able to do (capabilities) and affect (agency) in various circumstances (Bandura, 1977b). According to Bandura, these social and intrapersonal outcomes may be exercised through media and objects in relation to group dynamics. Thus, the social learning dimension of an iPad or KAiKU glove study could open interesting perspectives to examine in further studies. Within these further studies, attention could be placed on the devices as, for instance, boundary objects within the facilitation of music education and social interaction in the classroom.

CONCLUSIONS

The purpose of this study was to explore established (e.g., iPad) and experimental (e.g., KAiKU Music Glove) embodied digital music technology usage in childhood music education. We pursued this by examining students' learning performance, their experiences of using the technology in the context of the music classroom, and their behaviors while using either the iPad only or the KAiKU Music Glove. Concepts such as concentration, experience, and play while learning music through technology in childhood music education were discussed. Overall, we found in the current study that the student group who used the iPad with the Keyboard Touch Instrument app improved more in their learning performance compared with the student group who used the KAiKU Music Glove with the iPad and Keyboard Touch Instrument app (for sound output). In addition, the study found that students using both technologies rated higher perceived ease of use before they engaged the devices and lower ratings after 6 weeks of use. Furthermore, the study found that both devices were rated similarly in perceived ease of use toward the end of the study period. We observed concentration-related behavior to be respectively high in both groups of students using their devices. Specifically, concentration-related behavior was found to be higher in the two students using the KAiKU Music Glove compared with the students who used the iPad only. When the concentration data is associated with perceived ease of use (from the TAM; Davis, 1985), it explains that both technologies were anticipated strongly in their ease of use to play music, yet the iPad required less effort during play compared with the KAiKU Music Glove. Specifically, less effort may have been exerted by the students using the iPad only as compared with the KAiKU Music Glove, primarily because of their familiarity with the iPad in their music education. As IT is a widely integrated aspect of teaching and learning in today's Nordic childhood music classes (Christophersen & Gullberg, 2017), the current study provides practical insights into the creative use of music technology in the childhood music classroom.

IMPLICATIONS FOR RESEARCH, APPLICATION, OR POLICY

As technologies, particularly tablet devices, are becoming more prevalent in childhood education, and particularly in music learning, this research provides a foundation for future research as well as application considerations. Our finding that unfamiliarity with a technology may impede learning will help future researchers and teachers think through their introductions of new technologies and take the necessary steps needed to avoid any negative impact of the actual device on their evaluations of technology-enhanced learning. The same is true in regard to perceived ease of use and its impact on successful use of a learning technology. Finally, although our results are somewhat preliminary, our research contributes important considerations regarding what constitutes on-task task and off-task behaviors during the introduction of unfamiliar technologies.

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Appendix: Likert-type Scale for Student Self-Report on User Experience

(BEFORE THE LESSON)

Student Name: ______________________________ Date: ____________________

Assigned Student Number: ____________

1. I am very excited to use the iPad/Glove today. — not at all · no · maybe · yes · very much

2. I think the iPad/Glove will be easy to use today. — not at all · no · maybe · yes · very much

3. I view the iPad/Glove as a musical instrument. just like the recorder and piano. — not at all · no · maybe · yes · very much

(AFTER THE LESSON)

Student Name: ______________________________ Date: ____________________

Assigned Student Number: ____________

1. Today, I found the iPad/Glove easy to use. — not at all · no · maybe · yes · very much

2. Making music on the iPad/Glove today was easy. — not at all · no · maybe · yes · very much

3. Today I viewed the iPad/Glove as a musical instrument Just like the recorder and piano. — not at all · no · maybe · yes · very much

4. I think I could teach my friends to play the iPad/Glove. — not at all · no · maybe · yes · very much