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Duet playing in dementia care: a new therapeutic music technology

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ABSTRACT

Purpose: Supporting the relational worlds of people living with dementia, especially the spousal dyad, is a growing focus in dementia care as is advancing the therapeutic use of music in dementia care.

This paper describes a mixed-methods, multi-phase, iterative research study designed to develop the Music Memory Makers (MMM) Duet System, a novel therapeutic music technology, that allows non-musicians to play a personalized repertoire of songs arranged as duets.

Methods: Following a pilot phase to iteratively assess and refine the MMM Duet System for recreational and therapeutic purposes, multiple sources of data were used to investigate five older spousal dyads' experiences with the system, two couples living with dementia and three who were not. We assessed perceptions of task difficulty, joint agency, and enjoyment as well as therapeutic benefits associated with enhancing the spousal relationship and sense of couplehood.

Results: Findings suggest playing meaningful songs together is an enjoyable interactive activity that prompts musical reminiscence, involves joint agency, and supports relationship continuity within a relational, positive approach to dementia care. All couples mastered the task, none evaluated it as "very challenging," and positive couple interactions were evoked, commonly before and after playing the duets.

Conclusion: The MMM Duet System is recommended for further research and development as an innovative way to support couples living with dementia with commercial implications, and as a new music technology suitable for use as a research tool.

Key Words: music technology; dyad music-making; dementia care; caregiver support; relationship continuity; joint agency; musical reminiscence

IMPLICATIONS FOR REHABILITATION

- Music making is an engaging, rewarding activity promoting social bonding and wellbeing that with technology innovation, can be extended to non-musicians and people with differing skills, abilities, and preferences.

- The MMM Duet System is a promising new music technology that supports the relationship of people living with dementia and their spousal caregivers by encouraging relationship continuity and sense of couplehood. Supporting caregivers enables people with dementia to remain longer in their homes and communities.

- Practical suggestions are offered to develop music technology suitable for use by older adults and people living with dementia, e.g., involving participants who live with dementia, assembling interdisciplinary research teams, adopting iterative, participant-focused approach.

DUET PLAYING IN DEMENTIA CARE: A NEW THERAPEUTIC MUSIC TECHNOLOGY

Innovation in dementia care is needed urgently as dementia increases worldwide at dramatic rates (World Health Organization, 2022) and family members, especially spousal caregivers, find themselves providing the most care (Alzheimer Society of Canada, 2022; Hammond-Collins et al., 2014). To help sustain couples' wellbeing and quality of life, research recommends that spousal dyads strive to retain a sense of togetherness (Swall et al., 2020) and relationship continuity (Riley et al., 2017). Shared activities are one way to support relationship continuity (Carbonneau et al., 2010; Riley et al., 2017). Research also indicates that music can be an effective caring, non-pharmacological treatment for dementia (Hulme et al, 2010; Moreno-Morales, 2020), and that making music with others can promote social bonding and wellbeing (Lang, 2020; Tarr et al., 2014). Thus, the possibilities are rich for developing novel shared musical activities for therapeutic use in dementia care.

To this end, we assembled an interdisciplinary research team with expertise in music therapy, neuro-cognitive psychology, computer science, counselling psychology, music, and nursing, to create a novel shared musical activity that could be enjoyably used by older couples with and without dementia to support their relationships. We report here our development of the Music Memory Makers (MMM) Duet System, a novel therapeutic music technology that allows people with or without musical backgrounds to play a personalized repertoire of songs arranged as duets. We also provide initial evidence of its feasibility and enjoyability for use by people living with dementia and their spousal caregivers. For the latter, we used multiple sources of data to address three main research questions related to task mastery, task enjoyment, and potential therapeutic benefits: Can participants do the task? Is the task experienced as recreational? Are spousal relationships and sense of couplehood enhanced?

BACKGROUND

Dementia, Dementia Care, and Relationship Continuity

Dementia is one of the major causes of disability and dependency among older adults around the world (World Health Organization, 2017). The World Health Organization (2022) estimates that about 50 million people worldwide have dementia, with 10 million new cases every year and numbers anticipated to double by 2030 and triple by 2050. In Canada, an estimated 1.7 million Canadians will be living with dementia in 2050, triple the numbers of 2020 (Alzheimer Society of Canada, 2022).

The associated human and economic costs are substantial (Alzheimer Society of Canada, 2016) and supporting informal caregivers is a key component of both increasing quality of life for those with dementia and increasing cost-effectiveness (Rippon et al., 2020). Supporting caregivers reduces healthcare costs associated with formal care and pharmacological treatment and allows people with dementia to remain in their communities in their homes longer, a circumstance significantly impacted by the wellbeing and attitudes of family caregivers (Clare & Shakespeare, 2004; McGrath et al., 2021).

Although caring for those with dementia can be rewarding (Lloyd et al., 2016; Peacock et al., 2010), it is also challenging, complex, and stressful (Kales et al., 2015). People with dementia experience progressive neurodegeneration that impairs cognitive, memory, and social-emotional functioning (Alzheimer Society of Canada, 2012). Family and friends provide the bulk of caregiving support, and comparatively, spousal caregivers typically live with the person with dementia, give care for a longer time, and often have fewer resources (Hammond-Collins et al., 2014). Spouses spend more hours a week engaged in caregiving and report more burden, relationship strain, depression, and lower wellbeing compared to non-spousal caregivers (Chappell et al., 2014; Pinguart & Sörensen, 2011). Strains are placed on couple identity as the relationship becomes increasingly about caregiving, reciprocity weakens, and a power imbalance is introduced (Wadham et al., 2016). A continued sense of couplehood can help both members of the couple adjust to their changing situation (Conway et al.,

2018; Daley et al, 2017; Hellström et al., 2007; Wadham et al., 2016). Relationship-focused support preserves “a sense of togetherness” (p. 3) and being “us” (p. 4) that helps maintain wellbeing (Swall et al., 2020) and mitigate negative relational impacts associated with dementia (Bielsten & Hellström, 2019a). The links between appraisals of relationship continuity and positive and negative emotional impacts of caregiving are supported by both qualitative (e.g., Bielsten et al., 2018) and quantitative evidence (e.g., Riley et al., 2018).

Consequently, strategies designed for spousal dyads are garnering interest as the importance of the relational world of the person with dementia is recognized (Davies, 2011; McGovern, 2011) and person-centered approaches to dementia care are undertaken (Hampson & Morris, 2016; Lazar et al., 2017). A promising line of research to support relationship continuity is for couples to continue doing enjoyable shared activities as well as discover new ones (Riley et al., 2018). Engaging in activities together encourages reciprocity and companionship and helps sustain a sense of couplehood (Carbonneau et al., 2010). Furthermore, activities that encourage play and involve music are associated with increased wellbeing for people with dementia (Fauth et al., 2017; Treadaway et al., 2016). Two examples of evidence-based leisure activities described in the literature are circle dancing, to positively impact general wellbeing, communication, concentration, and mood (Hamill et al., 2011), and group singing, to relax and improve lucidity, mood, and focus (Davidson & Almeida, 2014). Other initiatives have incorporated technology and reminiscence activities to offset dementia-related communication challenges like initiating and maintaining conversation (Hoel et al., 2021). For example, Mullins et al. (2021) worked with a care recipient-carer couple living in the community to co-design a personalized digital story of holiday travel memories. Multi-sensory stimuli (e.g., drink, food, photos, soundscapes) were incorporated and used to prompt positive meaningful interactions between the couple.

Advancing Music in Dementia Care: Neuroscience and Technology

Music is another way to effectively stimulate reminiscence and facilitate social participation of people with dementia (Pigliautile et al., 2019). Although investigated as a promising intervention across a range of health conditions (Clift et al., 2010; Gick & Nicol, 2015; Nicol, 2010), music has become especially prominent in dementia care in the last few decades (McDermott et al., 2014), both for the person with dementia (McDermott et al., 2014) and the caregiver/care recipient dyad (Steiner-Brett, 2023). Music therapy—the use of music-by-music-therapists to “safely and ethically address human needs within cognitive, communicative, emotional, musical, physical, social, and spiritual domains” (Canadian Association of Music Therapists [CAMT], 2020, para. 1)—is recognized as a promising caring, non-pharmacologic intervention for dementia (Hulme et al., 2010; Kales et al., 2015; Patterson, 2018). Music’s unique ability to positively impact quality of life for individuals with dementia arises in part because the ability to engage with and enjoy music remains intact late into the disease (Baird & Samson, 2009; Maguire et al., 2015); musical memory can remain robust (Jacobsen, 2015); familiar music evokes positive feelings and memories (van der Steen et al., 2018); and making music with others promotes social bonding and wellbeing (Lang, 2020; Tarr et al., 2014). When joint music activities are perceived as valuable, supportive, and enjoyable, they can positively impact the caregiver/care recipient dyad and enhance caregivers’ psychosocial health (e.g., mood, relaxation, wellbeing, coping; Steiner-Brett, 2023).

Advances in the cognitive neuroscience of music and group music-making (Legge, 2015) are propelling further interest in music’s therapeutic value. Shared rhythms and the externalization of rhythms distinguish music from other activities, and across cultures and throughout history, humans have spontaneously synchronized with each other and entrained to a rhythmic beat (Tarr et al., 2014). As mentioned, people synchronizing involuntarily as they make music together is associated with subsequent positive social feelings and behaviour (Wiltermuth & Heath, 2009), which are pleasing and rewarding (Keller et al., 2015). Although it is unknown exactly how the relationship between music and

social bonding occurs, there is speculation that “performing movement simultaneously with someone else (synchronizing) causes some blurring of self and other via a neural pathway that codes for both action and perception as well as releases neurohormones” (Tarr et al., 2014, p. 1). The blurring of self and other is a form of ‘joint agency’ (Pacherie, 2012), and its occurrence during group music-like tasks is just beginning to be investigated as another focus of current neuroscientific inquiry (e.g., Loehr, 2022; Shiraishi & Shimada, 2021; Zhou et al., 2023). Stronger joint agency has been linked to verbal reports of lower task difficulty and increased task enjoyment (Zhou et al., 2022) as well as task enjoyment measured by physiological heart rate responses (Noy et al., 2015).

Innovation in music technology is also helping advance the use of music in dementia care. New music technology is increasing because of growing interest in inclusive music practices (Frid, 2019) and interdisciplinary collaborations across the fields of music, health, and technology (Agres et al., 2021). Frid (2019), for example, identified 85 different Customized Digital Musical Instruments (DMIs) incorporating ten different control interface types. Although many music therapists work in dementia care, the number of certified music therapists in Canada is limited (fewer than 1300, CAMT, 2022) and costs are not typically covered by medicare. New music technology promises to increase the numbers of people who can benefit from music, and because music can be personalized, opportunities for emotional regulation, social interaction, and motivation are increased (Agres et al., 2021). Examples illustrating innovative use of technology to increase access to music include SingFit, a tablet-based app to encourage singing (Reid et al., 2017); and AirSticks, a gestural musical instrument that enables musical improvisation with electronically generated music (Kenning et al., 2019). The MMM Duet System described in the current study uniquely allows non-musicians to play a personalized repertoire of songs arranged as duets.

Electronic Music Boxes

Electronic music (e-music) boxes provided a starting point for the MMM Duet System. First introduced by Novembre and colleagues in 2015 as an empirical tool for investigating interpersonal coordination and social bonding in group music-making, e-music boxes work in a fashion like mechanical music boxes and old player pianos, transforming cyclical rotation movements into pre-programmable digital musical output. Novembre et al. (2015) provided directions for building e-music boxes and evidence that young adult dyads could use them to play a MIDI version of the song “Somewhere Over the Rainbow” (Garland, 1940) together as synchronized melody lines (spaced 2 octaves apart). Each person turns the handle of their own e-music box and works to synchronize with their partner. The speed of rotation determines the tempo, and the movement produces a continuous data stream that can be recorded and analyzed. Critically, e-music boxes allow multiple individuals to create music together with no musical expertise required, and they can be programmed with people’s preferred songs.

In the current study, we brought together findings from these numerous lines of research with the two-fold purpose to: (a) develop a novel music technology enabling the enjoyable reproduction of commercial music recordings through duet music-making by non-musicians and (b) begin exploring the use of this interactive musical system for use in dementia care by people with dementia and their spousal caregivers.

METHODOLOGY

A mixed-methods, multi-phase, iterative research design that incorporated multiple sources of data was used, along with a participant-focused approach. This design enabled progressive modification of the MMM Duet System, and refinement of a teaching protocol. Ethics approval was granted by a University of Saskatchewan’s Behavioral Ethics Board (ID 1397) and a \$25.00 (CDN) per person/\$50.00

(CDN) per couple honorarium was approved. Additional ethical considerations related to the unique care needs and potential vulnerability of individuals with dementia were addressed with Shake's (2007) five-step guidelines: obtain permission/consent from appointed decision makers; share information; obtain assent; continually evaluate and re-establish assent; and seek feedback.

Pilot Phase

A pilot phase was undertaken to iteratively assess and refine the MMM Duet System to increase its suitability for recreational and therapeutic purposes. We considered functionality (e.g., operating the e-music boxes), aesthetic qualities (e.g., comparable sound to the original commercially released version), and therapeutic factors (e.g., features designed to facilitate/enhance feelings of agency in music-making with the MMM Duet System). Because isolation and loss of agency associated with dementia can accelerate physical and cognitive decline, decreasing feelings of isolation and amplifying feelings of control over the music were important considerations, as was improving the lives of caregivers and facilitating opportunities to interact with loved ones in a positive way.

In the pilot phase, testing was carried out with team members (N=8) and three volunteer couples (age 50 or older; common-law or married) as participants. We used a *thinking-aloud* technique, a valuable and appropriate strategy for usability testing (Lewis, 1982). Pilot participants vocalized their thoughts, feelings and opinions while interacting with the MMM Duet System, which generated data that were immediately analyzed to determine which modifications were required. These modifications were then immediately integrated into the next design iteration. Pilot testing centred on five components of our interactive musical system: (1) the e-music boxes; (2) a visual interface; (3) temporal smoothing parameters; (4) a duet song database; and (5) a teaching protocol. We briefly describe each of these components next; we also report complete details of the technical implementation of the MMM Duet System in a separate report (Christensen et al., 2023) and provide open-source code and

instructions for hardware and software set-up online at

https://github.com/LoehrLab/MMM_Duet_System.

The E-Music Boxes. As described by Novembre and colleagues in a 2015 open access publication, e-music boxes are built using the following hardware and software: Max 6 or newer; Arduino 1.7 or newer; Laptop compatible with software mentioned above; 2 Serial ports for computer (RS-232); Numeric keypad; 2 DJ Hero devices; 4 Optical sensors; 2 Revolving Handles; 2 Arduinos; 2 RS232 shields for Arduino. We modified the construction by (a) adding new handles to the music box that turned independently for ease of use, and (b) adding changeable attachments for handles to allow comfort and/or grip assistance. Figure 1A shows the changeable attachments. Figure 1B shows the two e-music boxes and their arrangement during duet playing. and Figure 1C shows the Visual Interface, described next.

A Visual Interface. We developed a screen interface to help people to visually coordinate with one another (see Figure 1C). The interface showed each player their speed as an inverse exponential deviation from the correct speed. Both players' speeds were shown so they could also see their deviations from each other's speeds. This was implemented to challenge those who performed well and to improve the outlook of those who struggled.

Temporal Smoothing Parameters. Temporal smoothing parameters were developed to facilitate feelings of control over the music. To help performers spin at the correct speed, a cubic smoothing function was added. This speed smoothing could be increased for people less in control of their movements, so that they felt more in control of the task. Conversely, the speed smoothing could be decreased to increase the challenge of the task for those who were well in control of their movements. The smoothing function relies on a non-linear warping of the input by 7 variations of a basic cubic function $y=a(x-1)^3 + 1$ that is centred around (1,1), and thereby has a gentle slope (rise over run smaller than 1) of x in the region around the (1,1) inflection point. The exponential tails of the cubic functions

have also been modified to have their functions pass through the point (0,0) and to eliminate any possibility of large exponential changes that can occur when moving farther away from the central inflection point.

The speed of the song was also reflected in the speed of the spinning. To play at the correct speed, that is, to match the tempo of the familiar commercial version of the song, people spun faster for faster songs and slower for slower songs, so a slight tempo correction was added to match this. There were also continual slight adjustments to the amplitude of the audio output tied to speed of the spinning, that is, the faster the spinning, the louder the output. These adjustments were minimal, just enough to increase the feeling of control over production of the music and to not obstruct hearing a song like its original commercial version.

Last, there was an option for people to automatically be brought back together if they became too out of sync from one another. This option was implemented via a button controlled by the research assistant and was done in a seamless manner so that the players might not even notice that action was taken to bring them back together.

A.



B.



C.

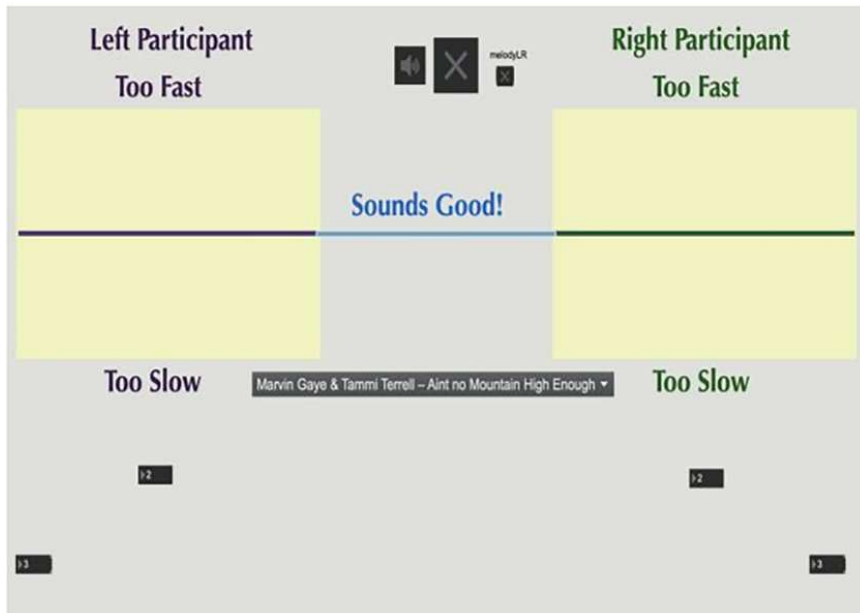


Figure 1. (A) One E-Music Box with Handles (B) MMM Duet System: Laptop with Visual Interface (C) Visual Interface to Assist with Synchronization

Duet Song Database. Song preparation required the expert re-working of original audio tracks to create a duet: two parts that when combined, reproduced the song in a form satisfyingly like its original commercially released version. Each person in the duo played one part, which included some of

the instruments and/or vocals of the original track. Playing a part that included familiar sounds from the original song encouraged feelings of individual control as well as feelings of success and competency when the two halves were successfully synchronized together to produce the original song. We strove to craft two equally appealing duet parts. Songs were prepared using open-source software and the six-step procedure outlined in Table 2.

Teaching Protocol. To structure the learning experience, we developed a teaching protocol that included a step-by-step procedure (see Table 3), presentation of different synchronization and adaptation strategies (see Table 4), as well as the following introductory statement to encourage a curious, fun, and collaborative atmosphere: “This is meant to be a fun, interactive experience. Feel free to laugh, sing along. It is expected that you will feel nervous and excited but the more you play with the e-music box, the more comfortable you will become.” To begin, two research assistants demonstrated how to play the duets together by performing the practice model song, “Ain’t No Mountain High” Enough by Marvin Gaye and Tammi Terrell (1967). Then the pilot participants were asked to follow the same steps themselves.

Table 1. Song playlist for each couple.

1	Lady in Red Proud Mary Sweet Caroline Sounds of Silence	Chris de Burgh Creedence Clearwater Revival (CCR) Neil Diamond Simon & Garfunkel	1986 1969 1969 1964
2	You Are My Sunshine Edelweiss I Walk The Line	Anne Murray Christopher Plummer Johnny Cash	1965 1957 1965
3	Edelweiss The Old Rugged Cross Stayin’ Alive Sweet Caroline	Christopher Plummer Loretta Lynn Bee Gees Neil Diamond	1965 1968 1977 1969
4	Can’t Help Falling in Love Jump, Jive An’ Wail You Light Up My Life	Elvis Presley Brian Setzer Orchestra Debby Boone	1961 1998 1977
5	Sweet Caroline The Hockey Song I Walk the Line You Are My Sunshine	Neil Diamond Stompin’ Tom Connors Johnny Cash Anne Murray	1969 1973 1957 1977

Table 2. Steps for duet song preparation

Step	Action
1	Run Song through Open-Unmix, an open-source python code Recurrent Neural Network that separates a recording into instrument and voice stems. This code separates out the vocals, drums, bass, and other. This separating procedure is based on the ranges and timbres that the program, based its previous training, expects these instruments and voices to have.
2	Separate the chosen combinations of instruments and/or vocals into 2 monophonic parts.
3	Choose how to combine the vocal and instrumental parts to best divide up the important musical materials between two parts.
4	Cut 1 verse and 1 chorus out of a song, or the number of verses and choruses that best fits approximately 1 min of recorded audio from the song.
5	Normalize the two audio files so that the participants can feel that they are contributing to the combined audio output.
6	Add links in the Max patch to the new audio files and create a new menu item for the new song.

Table 3. Procedure for learning to play the MMM Duet System

Step	Instructions
1	Decide who will be Player 1 and Player 2.
2	Individual practice: Player 1, count yourself down saying “3-2-1 Spin” and on the word “spin”, start spinning to play the chorus of the model song. You will only hear one voice of the duet.
3	Individual practice: Player 2, count yourself down saying “3-2-1 Spin” and on the word “spin”, start spinning to play the chorus of the model song. You will only hear one voice of the duet.
4	Together: Count yourselves down together saying “3-2-1 Spin” and on the word “spin”, start spinning to play the chorus of the model song. You will hear both parts together. To play the song together, you will be synchronizing your playing.

Table 4. Suggestions for comfort and Synchronization

Purpose	Suggestion
Comfort	You can use a cushion as an arm rest if you like. You can stand or sit on a cushion to be higher up if you like. You can experiment with different handles.
Synchronization	Begin with your hand at “6 o’clock or where the handle is closest to your body. Move your hand is a smooth fluid motion. There are different ways to synchronize your playing with your partner’s playing <ul style="list-style-type: none"> • Look at the screen while turning the handle • Focus on you partner while turning the handle • Focus on your own hand while turning the handle If you feel like you are out of sync with the music or your partner, don’t panic. Adjust your speed by looking at the visual to see if you are too fast or too slow. The research team can also get you back on track.

Study Phase

Once these preparatory activities were completed, we proceeded to recruitment for the study phase, which was focused on addressing our three main research questions related to task mastery, task enjoyment, and potential therapeutic benefits of the MMM Duet System.

Participant recruitment and selection. Prospective participants were recruited by posting and distributing advertisements on the university campus and in community libraries, recreational centers, and health clinics. Two community organizations serving older adults and adults with dementia also distributed advertisements directly to their members at in-person gatherings and through newsletters. Once individuals contacted the research team directly, either by phone or by email, a research assistant followed up by phone to ensure they met the study's inclusion criteria: age 50 years or older; common-in-law or married; English speaking; living in the local vicinity; interested in learning to play a new electronic instrument with their partner, and willing to talk about their experience. We did a second round of recruitment with the additional criteria of being a couple living together in the community with one person diagnosed and in the early stages of dementia, who is able to communicate, to follow instructions, and live independently in their home with the support of a spouse. Our rationale for implementing two rounds of recruitment was that we wanted to first assess whether the MMM Duet System could be feasible and enjoyable for older couples, irrespective of dementia, and then introduce it to couples in which one spouse lived with dementia. We report findings from both recruitment rounds together to facilitate discussion of similarities and differences in the useability and enjoyability of the MMM Duet System between couples who were and were not living with dementia.

Those who met the inclusion criteria and were interested in participating were invited to meet at a preferred location and date for a single session of data collection. In preparation, participants were also asked to help compile a list of songs that they would enjoy playing together. We provided a list of

songs to choose from; we also prepared songs as requested. Email was used to exchange information about songs and send a reminder the day before the couple's data collection meeting.

The Participants. Five spousal dyads participated: male/female married couples, three unaffected by dementia and two in which one person was diagnosed and in the early stages of dementia. All participants were 54 years or older (women's age ranged from 54 to 78 years; \bar{X} = 63.4 years; men's age ranged from 55 to 78 years; \bar{X} = 64.8 years), married an average of 38.2 years (range of 26 to 54 years), and living in the community of a mid-size Canadian prairie city. The women were more likely to have musical experience/instruction than the men. Three of the women had more than 10-years instruction whereas only one man reported an equivalent amount. As couples, one couple had no previous musical experience; two couples had one member with musical background and one member without; and two couples had all members reporting past musical experience. These latter two couples (four participants) reported currently playing an instrument or singing 1-5 hrs per week. The other 3 couples (six participants) were not currently musically active.

Research setting and procedures. All but one couple chose to have the research assistants come to their home for data collection. One couple preferred to meet on the university campus. Two research assistants were present at data collection sessions: one attending to the technology and operating the taping equipment, and one leading interactions with participants. At the start of the meeting, one research assistant reviewed and completed consent forms with the couple while the second research assistant set up equipment.

Once consent was obtained and equipment set up, the couple observed the two research assistants demonstrate how to play the e-music boxes together. Then participants were invited to play. All couples started with the same first practice song, "Ain't No Mountain High Enough" by Marvin Gaye and Tammi Terrell (1967) and then three or four personal selections (see Table 1). Following each song, couples were asked questions of an open-ended nature to gain information about their experience.

Participants were also asked about the meaningfulness of the songs on their playlist. After the last song was played, additional questions were asked about strategies that helped them synchronize their playing as well as their thoughts on potentially using the MMM Duet System in dementia care. Each participant also completed a short, self-report inventory on the experience.

Measures and Analysis. In the study phase, data were generated from several sources to understand participants' experience of the task, and assess perceptions of task difficulty, joint agency, and enjoyment, which were important variables to determine the feasibility of MMM Duet System as a clinical tool with a special population. Analysis was multi-faceted, iterative, and informed by investigator and theory triangulation, and crystallization. Triangulation increases the integrity of inferences made by the research team by considering more than one vantage point (Patton, 1999) and crystallization suggests that rather than forcing data to converge on a single fixed point, findings have multi-dimensionalities and represent researchers' varied backgrounds (Janesick, 2000).

Demographics and personal music history. Each participant completed a paper and pencil inventory collecting demographic information (age, gender, years together as a couple, dominant hand, first language) as well as previous musical experience (instrument(s), years of experience and lessons) and time currently spent playing an instrument and if with other musicians.

Videotape. All sessions were videotaped using a Noldus Technologies portable observation lab, which included three video cameras to videotape from different locations during data collection. The first three spousal dyads involved descriptive/observational analysis based on repeated viewing and discussion amongst team members. More detailed behavioral analysis using the software tool, ObserverXT, was completed for the last 2 spousal dyads, the couples living with dementia. Frequency and duration of individual (smiling, laughing, singing, moving to the music) and interactive behaviors (talking, touching, looking to the other) between the married couples were analyzed before, during, and

after playing the MMM Duet System together. On-task behavior (playing the duets) was similarly analyzed.

Interviews. During the data collection meeting, each couple started with the practice song and then had three or four more music-making opportunities to play personal song selections. After each song, participants were asked open-ended questions about their experience. For example, “How are you feeling?”, “How did you know if you were successful or not?”, “What was successful?”, “What was challenging?”, and “How did this time differ from the previous time?”. There was also discussion about the meaning of the personal song selections. At the end, there was a summary discussion that started with a question about “What strategies did you find easier to work with while playing?” and ended with open-ended questions about the couple’s thoughts on incorporating the MMM Duet System into dementia care. For example, “How might this device be successful in dementia care?”, “How might it be challenging?”, “What would make it enjoyable and/or therapeutic?”, “What would make it unenjoyable or non-therapeutic?”. Interview data were analyzed using content analysis. We coded to classify and categorize data in order to understand participants’ experience of the task.

Post-Playing Self-Report Inventory. After the music-making opportunities ended and the last set of interview questions were discussed, each participant completed a self-report inventory designed for the study. A 7-point Likert scale was used to answer two questions about how enjoyable and how challenging playing the duets together was (“not at all” to “very much”). Participants were also asked to report their perceptions of joint agency during the task, by rating how much they shared control over the music with their partner (“completely shared control” to “did not share control at all”) and how integrated they felt with their partner while playing the duets together. The latter rating was made by choosing one of seven diagrams involving two separate circles that are presented as successively more overlapping and integrated (a modified version of the Inclusion of Other in the Self scale; Aron et al., 1992; see Figure 2). Both joint agency scales were coded so that higher scores reflect stronger joint

agency (i.e., “did not share control at all” and non-overlapping circles were coded as 1; “completely shared control” and nearly completely overlapping circles were coded as 7).

Field notes. Immediately after leaving the data collection meeting, the two research assistants independently completed field notes. These notes were descriptive (a summary of activities/events) and reflective (e.g., thoughts, feelings, questions, impressions, connection to other experiences and theory, and/or actions for next time), analyzed for content related to design modifications and teaching protocol refinements as well as insight into participants’ experiences with the technology.

FINDINGS

MMM Duet System as a Promising Therapeutic Music Technology

Holistic and detailed analyses of qualitative and quantitative data from the study phase, across and within five spousal dyads, were used to explore the MMM Duet System as a therapeutic tool for dementia care. We organize our findings in relation to our three main research questions regarding task mastery (Can participants do the task?), task enjoyment (Is the task experienced as recreational?), and potential therapeutic benefits (Are spousal relationships and sense of couplehood enhanced?).

Task Mastery

Descriptive analyses of raw self-report Likert data showed that although couples with a partner with dementia reported more challenge than the couples unaffected by dementia ($\bar{X} = 3.5$, range of 1-5 versus $\bar{X} = 2.2$, range of 1-3), all couples were able to master the task, and no one evaluated the challenge as a 7 (very challenging) or a 6. Nobody gave up and stopped playing. Everybody stayed on task, spinning their handle throughout the duration of song. Whether practicing alone or playing together and whether they were well synchronized or not, players persevered and kept playing.

First attempts to play together prompted comments like: “It’s easier on your own than when playing with someone, that’s for sure,” “it’s a little finicky,” or more to the point “we kind of suck!”

(laughter followed). However, participants quickly gained comfort and familiarity with the system, and decided upon personal preferences: “I like the handle with the ball better... more space for (my) hand to rest”; “I think it might be easier if you’re standing above it. Ya know what I mean...sorta kinda feel like I would have more control (than sitting).”

They evaluated their individual performance – e.g., “a little jerky to begin with but I smoothed out a bit later;” “I sometimes felt I was a little ahead of the music or vocal line;” “The problem for me is I forgot which is my part and so when I heard one was fast and one was slower, I wasn’t sure it was me or not!” – and explained their strategies. For example, one person really focused on the visual interface at first: “I just had my eyes on that (points to the screen) and trying to keep it in the middle” whereas another person focused on the music: “I was coordinating my moving with the beat of the music.”

Couples had to strategize together as well if they were to produce a pleasing duet. A variety of strategies were described:

I was really watching ya know....getting the feel for his motion. It took me a while but eventually....yeah

I actually spent most of my time looking at her hand....really paying attention to her hand
(using) my listening skills in addition to my eyesight

I’m following her, trying to match up our hands

It was good because I think we got in sync very early

Couples recognized success because they could hear and see their synchronized playing. They noted improvement with comments like “it was much better that time” and “that was generally good I thought.” They also knew when the duet went well as illustrated in these exclamations:

Pretty good!

Yeah! We nailed that!

That was so wonderful.

In addition to revealing progress and increased competency and task mastery, participant statements also conveyed enjoyment and pleasure, as described next.

Task Enjoyment

According to the self-report data collected on a 7-point Likert scale, participants enjoyed playing the MMM Duet System with their spouse. Answers ranged from 4 to 7, with a mode of 7 (enjoyed very much) and average of 6.4. Enjoyment as a couple or as an individual did not vary systematically by musical background and instruction or by years together, nor by a dementia diagnosis. Average enjoyment across couples was slightly higher for the two couples living with dementia ($\bar{X} = 6$) versus those couples not impacted by dementia ($\bar{X} = 5.8$).

A few design issues that interrupted enjoyment were identified early in the study phase. For example, in the first spousal dyad, the couple reported being distracted by “bumpy” spinning, that is – “when you start to spin, it’s almost like a hole and you feel it” or “it really feels rough, when you’re trying to get precise and I feel like it’s riding on a bumping road.” There was also a noise associated with the handle – “The spinner has a noise to it, you move forward and you can hear the noise.” Quality of the produced sound was also key to enjoying the music-making experience. Couples expected their efforts to produce the sound of the original commercially released version. Volume, for example, was immediately identified as an essential component of the experience by the male partner in the first spousal dyad. After playing a reasonably well synchronized version of “Sweet Caroline” by Neil Diamond (1969) with his wife, he said, “I like the song but I have never ever heard it like, that quiet...the music is

way too quiet...I really want to hear the music.” One couple was surprised and palatably disappointed when one of their requested songs was not performed by the artist they expected. Another surprising insight occurred with when a couple found themselves happenstance assigned incongruent male and female vocal parts: “It is really weird to have her doing Marvin Gaye and me doing Tammi Terrell hahaha (laugh).” We made additional refinements to the MMM Duet System in response to these early comments to increase alignment of expectations, satisfaction with the “feel” of the playing mechanisms, and enjoyment of both the process and outcome for subsequent couples.

An assortment of participant statements confirmed pleasure that related to (a) the activity’s creative unique element (“It’s pretty neat, I like it” and “Can we buy one?”), (b) successful synchronizing (“It felt good”), even if there were some challenges (“She’s worried...but doesn’t matter as we had a good time”), (c) being rewarded with a positive experience (“It’s great fun. I fully enjoy it.”), and (d) playing an aesthetically pleasing (“that’s not bad, hey? Yeah, I like it.”) and familiar song (“Because the music is familiar, it’s enjoyable to listen to”).

Non-verbal behavior like smiles, laughter, singing, and moving with the music offered further evidence of enjoyment. The behavioral analyses of the couples living with dementia showed that for one dyad, the frequency of all such behaviors increased after playing their MMM Duet System together. In the other dyad, the individual practice task prompted smiles from the spouse with dementia while the spousal caregiver moved and sung along with the music during both his individual practice and when they played together.

Also specific to the context of dementia was the importance of a possible new recreational opportunity:

Spousal caregiver: He’s lost his abilities to play cards or do any games that we used to play together, or anything. So this is something that, yeah, you could do

together again, you know. Like even our kids would have fun with it too I think.

Spouse with dementia I would think that, just to do that kind of stuff, it keeps you motivated – like to do something different.

Spousal caregiver It's something that he can actually do. He's lost a lot of everything that he can do, like the reading, writing and the stuff (Spouse - Yeah) so this is something he can actually do.

Spouse with dementia Do like it. Like the music by myself, I could probably get that too.

As conveyed in this exchange, having an activity to do together as a couple, with other family members, or even alone was significant. Although designed for the purposes of duet playing by two people, the solo practice time where each person played alone turned out to be an enjoyable activity, especially if one was playing the melody or able to sing the melody over the harmony part.

Therapeutic Benefits Related to Spousal Relationships and Sense of Couplehood

The task evoked many positive couple interactions. Notably, most of these occurred before and after playing the duets, whereas during playing, the spouses focused on the task. The detailed behavioral data analysis of couples living with dementia indicated that the task required focused attention and effort: when playing together, spouses sometimes look at each other's hands to synchronize, but otherwise, verbal and non-verbal interactions occurred before- and after-task rather than during. To figure out how to master the task, couples had to support and encourage each other. This elicited spontaneous comments providing helpful advice (e.g., "You can focus on your hand") and encouragement (e.g., "wonderful job, M__;" "It was much better that time!"). Spouses conferred on their performance: "I sometimes felt I was a little ahead of the music or something. (Maybe a hair's

difference, but it sounded pretty good.) I was pretty close". One couple teased each other: "How did that feel for you? (Good) Show off! (laughing)". Another couple had a brief, touching exchange:

I'm going to follow you.

Me?

Yes.

I'm not good enough

You are good.

To synchronize their playing and create a good sound, couples had to tune in and attune. They had to be attentive and responsive to each other: "We need to be in sync to create good music. I was trying to be sensitive." The joint nature of the task created a "we" mentality:

Hey we did that pretty good! High five!

We're not going to screw this one up! (laughter)

This "we" mentality was also reflected in participants' ratings of joint agency. Couples unaffected by dementia reported a strong sense of joint agency (shared control: $\bar{X} = 6.5$, range 6-7; integration: $\bar{X} = 6.2$, range = 4-7). Couples with a partner with dementia reported somewhat less strong, and more variable, experiences of joint agency (shared control: $\bar{X} = 4.3$, range = 2-7; integration: $\bar{X} = 4.0$, range = 3-7), aligning with their perceptions of the task as somewhat more challenging. Interestingly, in both couples living with dementia, the spouse with dementia reported stronger shared control (ratings of 4 and 7) than the spousal caregiver (ratings of 2 and 4, respectively).

The musical nature of the task provided further therapeutic benefits. Different configurations of harmony, melody, instrumentation, and tempo generated different energies and feelings. A song like

“Edelweiss” by Christopher Plummer (1965) produced a quiet intimacy, or as one participant said:

“Edelweiss... is..a ... ya know it’s ait’s more of a tender thing...” Conversely, a disco tune like the Bee Gees (1977) “Stayin’ Alive” introduced vitality and “Fun! It was a fun song!”

The songs held further personal meanings and associations that were unique to the couples’ shared history. Some music connected to special stories of a couple’s romance. One man recalled the moment he first found the courage to ask his wife to dance:

We met in university, and I always thought she was way out of my league. Then I dared to ask her to dance, and the rest is history. Her first project when we started dating, was to teach me how to dance.... And I like jiving. So when you hear a song like Jump, Jive An’ Wail....it’s great fun and it’s great exercise....we enjoyed a lot of dancing over the years, once she got me straightened out (laughter from the couple)

Another man talked about how the song, “Lady In Red,” by Chris de Burgh (1986) evoked a single strong image of his wedding day, the vision of his bride in a beautiful Japanese jacket.

“Lady In Red” is actually about when we got married. She has a really wonderful, really beautiful Japanese style dress, right? What is it called? (Japanese jacket) Japanese jacket, right? Magnificent! The most beautiful in the world! When you play the song, you actually go back to the place associated with it, so that, the “Lady In Red” is one for me.

A playful exchange occurred between one couple living with dementia as the husband described a 40th wedding anniversary where he felt tricked into karaoke singing. The song was “Can’t Help Falling In Love With You” (Presley, 1961).

It was a 40th wedding anniversary with the surprise gathering of our children. (We) went to Royal Canadian legion karaoke night and she told me she’d sing if I did. So I sang this song. And

she never did sing anything! Despite having six triple binder things (puts hand near wife's neck pretending to choke her and she rocks gently as if being choked), she reneged on her promise! (laughter from the couple)

The second couple also living with dementia chose two songs – “The Hockey Song” by Stompin’ Tom Connors (1973) and “You Are My Sunshine” (1977/2002) sung by Anne Murray – that prompted recollections of raising their children, the couple’s shared history as parents. The latter song was “sung to the girls all the time” to lull them to sleep at night; the other song was associated with life at the ice rink where both children skated and played hockey. “The Hockey Song” also evoked memories of summer holidays at the lake: “some of the kids play guitar, and they play this song around the fire at the lake.” A third song they requested, “Sweet Caroline” by Neil Diamond (1969), was linked with larger extended family gatherings because “... when the family get together, we play it and have fun with it.”

Parenting across generations was evoked for one woman who recalled that “Edelweiss” from the film, *Sound of Music* (1965) was played at the moment “...when he (Captain von Trapp) starts to blubber and so Julie Andrews comes in and saves the day” (laughter from the couple). She further elaborated that “It’s favorite music ya know. My parents took me to see it as a kid and (now) we’ve watched it (as a couple, as a family)”

Another couple requested the “Old Rugged Cross” (Lynn, 1968). When asked about its meaning, they simply said: “It’s a hymn, we are believers, we believe the doctrine of it.” This music affirmed their individual and mutual faith identity, further shared in a faith community of other believers.

And for one song, the significance lay in its title. When asked about the meaning of “You Light Up My Life” (Boone, 1977), the husband replied “Well, just seemed very appropriate to what she does for me (both spouses smile as he nudges his wife gently with his elbow)... very meaningful for us.... Sometimes the light comes from a spark.”

DISCUSSION

Within the context of a person-centered approach to dementia care that focused on the relational world of people with dementia, we undertook a study to develop an innovative therapeutic music technology. Intended for independent use in dementia care as a shared activity for people with dementia and their spousal caregivers, the MMM Duet System provides a means for couples to play songs together, and experience feelings of togetherness and relationship continuity. Findings demonstrated the usability and feasibility of the system and represent a neuro-music-relational approach to dementia care supported by creative research strategies with implications for further development and research.

The Practical: Personnel, Research Design and Guiding Principles

In keeping with recommendations for developing new music technology (Agres et al., 2021) and Accessible Digital Musical Instruments (Frid, 2019), assembling an interdisciplinary development research team was critical. Our team had 8 members: 4 research faculty, 1 post-doctoral researcher, and 3 graduate research assistants who cumulatively represented the fields of music therapy, neuro-cognitive psychology, computer science, counselling psychology, music, and nursing. Interdisciplinary work is challenging given differences in terminology, measures, and approaches. We also realized, given the complexity of the project, that it is not possible for one person to fully understand each element of the project as it progressed moment-by-moment in a dynamic iterative fashion. Regular team meetings and designated responsibilities helped, as did having a strong conceptual framework to anchor and sustain us. It was also helpful that two members had interdisciplinary backgrounds (music therapy/counselling psychology; computer science/music/psychology) and thus were familiar with the challenges and rewards of interdisciplinary work.

Further characteristics associated with a successful prototyping process were also incorporated: being user-focused, employing an iterative research design and/or participatory research methods, and

incorporating technology adaptability and customization (Frid, 2019). Participants were valued partners in the study, an idea introduced in the script for the screening phone call and then again in the introductory statement welcome and instructions provided at the start of data collection sessions. Participants provided feedback and comments that successively and iteratively fed back into the technology development. Co-design elements were also utilized. In the pilot phase, after each session, field notes and design notes were discussed by the team and a list of prioritized design improvement tasks developed with as many as possible ready for the next session. As well, we used a thinking-aloud protocol through both phases, asking participants to vocalize design choices that they liked. Versatility was realized through technology customization that included changeable attachments for the handles and a personalized repertoire of songs as well as adaptability of standing, sitting, using a cushion or not to play the MMM Duet System, and multiple learning strategies (e.g., relying on auditory or visual cues). The aesthetic nature of the experience was important (quality of sound) as was congruence of expectations (singers, song arrangements) and ability to customize volume and balance of parts and choose from a wide array of genres, tempos, and mood.

Closely aligned with these characteristics was the recommendation from Agres and colleagues (2021) that new and novel music technology be developed for person-centered care. This principle infused all aspects of the study. Beyond the practical elements of adopting a participatory iterative design and striving for versatility in keeping with user needs and preferences, the sensibility of the team was person-centered. We focused on strengths and personhood of all participants rather than the disease (Hampson & Morris, 2016), and were motivated to design a technology not for doctors or therapists, but for couples to use independently in their own homes. Person-centered technology focuses on engaging people, rather than solving problems (Lazar et al., 2017). Person-centered dementia care is often described as empowering (Lazar et al., 2017), which in this study was realized in the

opportunity to master the rewarding cooperative task of playing familiar and personally meaningful songs, arranged as duets, together.

Deconstructing the Duet Activity

The MMM Duet System integrates diverse threads of empirical, theoretical, and clinical knowledge in a multi-layered conceptualization drawn from the fields of nursing (activities support couplehood and relationship continuity in dementia), music therapy (music as a rich therapeutic medium), and cognitive neuroscience (group music-making involves synchronicity that prompts brain activity associated with joint agency). To elaborate, evidence suggests that activities done together support couplehood and relationship continuity for couples with dementia (Riley et al., 2018). Further evidence establishes music as a multi-faceted medium with established therapeutic properties (Nicol, 2010) including musical reminiscence (Jacobsen et al., 2015), social bonding (Tarr et al., 2014), and wellbeing (Lang, 2020). Music prompts involuntary synchronizing or attunement to a common rhythm or pulse, which is pleasing and rewarding (Keller et al., 2014). Additionally, people can synchronize physical movements, for example, a military band marching together or in the case of the MMM Duet System, both individuals rotating their handles in a repetitive circular movement. The associated perceptions of closeness and bonding make any music activity involving synchronicity a highly rewarding experience, further enhanced by being a task that incorporates music that is familiar, personal to the couple's history. Last, growing evidence from neurocognitive studies suggests that synchronization may activate brain activity associated with feelings of connection and closeness (Wiltermuth & Heath, 2009). Synchronization is a key aspect of joint agency, which refers to the blurring of self and other that occurs when people "act together," for example, during a group music task (Loehr, 2022; Pacherie, 2012), and is another focus of current neuroscientific inquiry (e.g., Shiraishi & Shimada, 2021). We further note that in the context of dementia and spousal caregiver/care recipient dyads, an activity that involves "acting together" and evokes joint agency emphasizes reciprocity rather than the power imbalance more typical

of caregiver/care recipient dyads. Findings provide evidence consistent with this conceptualization and in some instances, add to previous research, as described next.

Joint Agency. Our findings align with previous theoretical and empirical work that suggests a potential role of joint agency in eliciting positive therapeutic benefits from joint music-making. Specifically, most participants reported experiencing a “we” mentality, a sense that they shared control over producing the music, and a sense of feeling integrated with their spouse while playing the MMM Duet System together. This “we” mentality has been identified as an important factor in helping couples preserve a sense of togetherness following a dementia diagnosis, and is linked with increased resilience and improved quality of life (Conway et al., 2018; Hellström et al., 2007; Stedje et al., 2023). Adopting a “we” mentality can also promote increased participation individuals living with dementia by emphasising shared accountability rather than individual responsibility, lowering the likelihood of them experiencing embarrassment from their contributions to the group activity (Nilsson, 2018). Our findings also align with a hypothesized link between joint agency and positive outcomes such as increased social bonding, whereby the positive emotions that accompany joint agency might transfer to subsequent interactions (see, e.g., Rabinowitch & Gill, 2021; Zapparoli et al., 2022).

Findings also align with previous work showing that ebbs and flows in joint agency are accompanied by positive and negative emotional responses, respectively (Stephens, 2020), and that stronger joint agency is linked to verbal reports of lower task difficulty and increased task enjoyment (Zhou et al., 2022) as well as task enjoyment as measured by physiological heart rate responses (Noy et al., 2015).

Interpersonal Coordination. With respect to Task Mastery, the findings shed light on the cues couples used to coordinate their duet playing together. Particularly noteworthy were differences between the participants in terms of which information modalities (auditory versus visual) they relied on to support their coordination performance. Specifically, whereas some participants reported relying

exclusively on auditory information (sounds), others relied on visual information (looking at their partner's hand and the visual interface) or both. Thus, musical devices that allow people to use multiple modalities to coordinate their performances could be preferable as they allow people to focus on whichever modalities are best suited to their personal skills and preferences. These findings align with studies of coordination among expert musicians, who likewise rely on both auditory and visual information (e.g., coordination of eye gaze; tracking of others' movements) to synchronize their performances (Bishop et al., 2019; Williamon & Davidson, 2002).

Also of note were the smoothing features to assist mastery as needed and support joint agency. The smoothing features were needed both to produce pleasing renditions of songs, and to ensure that participants experienced control over their own part of the duet, by reinforcing links between the participant's movements and the perceptual outcomes of those movements (i.e., the speed and volume of the music that was produced). The implementation of these features was inspired by previous research indicating that musicians need to maintain a degree of distinction between themselves and other performers when performing in ensembles (Keller et al., 2016), as evident, for example, in findings that singers' vocal control suffers if they are unable to hear their own voice while performing in a choir (Ternström, 1999). Future research is needed to examine links between players' experiences of individual control over their own part of the duet and their experiences of joint agency, or shared control between partners, in this population and others (see Loehr, 2022).

Togetherness in Music. Findings supported using the MMM Duet System as a feasible activity to encourage togetherness and relationship continuity. Participants reported and demonstrated enjoyment as they worked together to master the task of synchronizing their duet playing. They practiced together; succeeded and failed together; laughed and smiled together; conversed together; reminisced; connected.

In large part, we would suggest these interactions were due to the musical nature of the task. As described in phenomenological studies of music, humans have involuntary embodied responses to music that are also relational, temporal, and spatial (Nicol, 2010). There is immediacy when people engage in music together, and share time-ordered, embodied experiences synchronizing to a common beat. Such music experiences are recommended to help anchor people with dementia in the moment and help them connect with their partners (Dowlen et al., 2022). Staying engaged rather than becoming passive recipients of care impacts wellbeing and sense of identity (Treadaway et al., 2018)

Music can also evoke memories and reminiscences. Familiar songs become “musical hooks” (p. 359) that bring the past into the present, helping people recollect and remember who they are, especially valuable in the context of aging and illness (Nicol, 2010). In the current study, because participants shared long histories as a married couple, the songs they requested confirmed shared identities over time, from courting couple and dance partners to husband/wife, parents, and for one spousal dyad, people of faith.

Another benefit for dementia care is the non-verbal yet communicative nature of music. A recent scoping review (Elliot & Gardner, 2018) on the role of music in dementia identified two key benefits: 1) music enhances communication and offers an alternate way to communicate; and 2) music gives family members a way to interact and be together. A subsequent study (Elliot et al., 2020) concluded that music allowed people with dementia to connect with their partner and gave them a way to spend time together. In our study, one couple talked about the loss of activities and were excited by the possibilities offered by the MMM Duet System. They also envisioned the possibilities of using the MMM Duet System with family members.

Study Limitations and Opportunities for Further Research

Five spousal dyads’ experiences with the MMM Duet System provide promising support for its feasibility as a promising technology for older married dyads and older married dyads living with

dementia. The sample size however is small, and findings are limited to these spousal dyads. Although the sample was diverse in participants' music background, all volunteered for the study and may have been more receptive to the new technology than other couples. Further research with more couples is recommended, as is continued development of the MMM Duet System. We developed a usable research prototype for the current study, but further development is needed to create a stand-alone system that does not require specialized expertise to set up or operate. We have since undertaken some further development to address some of the limitations of our research prototype. Specifically, as described in Christensen et al. (2023), we developed 3D printed cases and incorporated Bluetooth technology to eliminate the many wires that were required for the current set up. We also developed a more user-friendly graphical user interface that adopts imagery for communicating "faster" and "slower" that is familiar to people and maps onto their previous experiences. We provide software for controlling the devices, instructions for how to build the hardware, and instructions for how to split commercial recordings into duets online at https://github.com/LoehrLab/MMM_Duet_System. We estimate that the supplies needed to build the hardware for two devices would cost less than \$200CAD). The software comes pre-loaded with one song that was originally recorded in 1914 and is therefore in the public domain and can be used freely without violating copyright law. That said, some technical expertise is still needed to build the system and create a library of duets customized for specific users. Thus, further work is needed before the MMM Duet System is ready for easy use by all members of the general public.

The need to advance music-based person-centered care strategies that support the spousal care recipient/caregiver dyad is urgent. More strategies are needed to support couples, ideally reducing some strain and burden associated with caregiving and improving couples' ability to age in place. Strategies involving other art forms may also be valuable (e.g., art, dance, pottery). All efforts in this

area should incorporate inter-disciplinary, inter-professional collaborations that involve iterative, participatory methods and place users at the heart of the research.

Last, music therapy and music education are advanced by the possibility of using a dyad music-making activity that requires no musical skills and ability; and cognitive neuroscience is advanced by applying the e-music boxes to a new population and offering a way to investigate the brain basis of joint agency in group music-making in this population. There is very limited work on how dementia might affect people's ability to synchronize with others. The feasibility of carrying out this work is increased with development of the MMM Duet System.

Conclusion

The MMM Duet System enables people, with or without musical backgrounds, to play music together, sharing and making memories as a couple, and with the potential to extend to family members. Introducing this activity early in the disease may help support relationship continuity over the disease course, and positively impact couples' emotional adjustment to dementia. We believe the MMM Duet System is a promising powerful therapeutic music technology as well as a valuable tool to advance research.

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