Designing a Dementia-Informed, Accessible, Co-located Gaming Platform for Diverse Older Adults with Dementia, Family and Carers

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Abstract. The ABLE.family project deploys disability and crip approaches and universal design, to create a platform that engages diverse older adults with dementia (OAD) and their carers in social engagement and play. Our prototyped gaming platform, created with OAD stakeholders and carers aims to decrease loneliness and despair experienced by OAD and carers during the COVID-19 pandemic, by increasing opportunities for intergenerational family engagement. Pleasurable interactions are encouraged through real-time collaborative play (e.g. art and turn based games) and real-time video-calling embedded in the platform. Our human-centered design approach works with OAD and their carer networks to design the platform interface with features that can be used to effectively collaborate, interact and produce sustainable platforms for OAD and their carer community. This project is supported generously by funding from CABHI (Centre for Aging and Brain Health Innovation), the Alzheimer Society of Hamilton and Halton, and MIRA (the McMaster Institute for Research on Aging); resources and spaces supporting this work are provided by Pulse Lab (funded by the Asper Foundation) and McMaster University.

Keywords: Co-design · Gaming · Dementia

1 Introduction

Prior to the COVID-19 pandemic, growing research demonstrated the importance of engaging diverse older adult stakeholders in technology research to ensure it is usable, accessible, valued and effective for diverse populations. In pre-pandemic times, researchers seeking to enhance the engagement of older adults in research struggled to adhere to best practices for informed, sustained, and effective engagement of older adults; in dementia research, these challenges are yet amplified by the unique communication experiences and needs of diverse older adult populations.

Accelerated by the import of social movements for equity and inclusion, researchers are beginning to recognize, and funding bodies are beginning to demand, that researchers

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adjust their enhanced human centered approaches to center diverse older adults, particularly older adults with dementia (OAD) in health technology design. Engaging older adults also makes common sense: engaging diverse older adults in design increases the possibility that technologies created will be broadly accessible, desired, sustainable and effective for diverse users. Government agencies also increasingly recognize the value of focusing research on diverse older adults via human centered approaches. To wit, a key strategy of the Canadian Dementia Strategy [1] is to rigorously engage OAD and stakeholders to ensure that they inform the development of communication and assistive technologies based on lived experience. Contrary to popularly held beliefs, research shows that older adults are keen to engage with and participate in developing health and communication technologies. However, best practices for engaging older adults, particularly diverse OAD and their carers (now commonly referred to as carers) in research developing assistive and other health technologies, remains an under-researched area.

These realities were evident amongst researchers, funding and regulatory bodies, when the COVID-19 pandemic struck; at that moment, research teams and service provision groups working with OAD (such as the Alzheimer's Society) pivoted programming and research to remote communication platforms such as Zoom. Research and service teams immediately recognized a lack of proven practices for engaging older adults in research via remote technologies. While this research is slowly compiling, many human-focused research continues to under-represent diverse OAD, a problematic resulting from historic systems of inequity and access and cultural research practices that routinely marginalize BIPOC, remote and under resourced older adult participants in health systems and health and technology research.

This paper discusses our team's efforts to inform our critical, intersectional, human-centered approach to research. Our approach brings critical human-machine communication (HMC) theory, disability and "crip" research, and transdisciplinary, community-driven practices to normative human computer interaction (HCI) practices; in doing so we aim to create effective practices for research engaging older adults in meaningful ways via remote communication technologies[1]. The paper also discusses our efforts to employ that critical approach as we build ABLE.Family, as an accessible, interactive, intergenerational web-based gaming platform. The platform aims to offer opportunities for social engagement and play among diverse OAD, their families and carers, to combat loneliness and to produce an array of mood and health benefits. ABLE.Family is also

[1] Our team is currently working with stakeholders from organized community and university-supported dementia organizations and programs. We recognize that these programs struggle to serve diverse BIPOC, remote, under-resourced and indigenous folks, as well as diverse OAD experiencing varying levels of cognitive impairment. In this study, our stakeholders (primarily carers and service providers) offer their experiences with existing participants in this program, who are normally white, middle class, resourced, Canadians, but do reflect diverse spectrums of cognitive impairment. In this and other dementia research projects, we are working with organizations including Alzheimer Society of Hamilton and Halton, as well as the Hamilton Council on Aging and the Dementia-Friendly Communities, Hamilton, to investigate and redress the lack of engagement by diverse OAD, due to many factors including lack of security, lack of access to services and resources, and structural discrimination due to historic white supremacy and racial and ethnic bias; in future publications we will report on these efforts.

designed to relieve burdens on carers, who represent a significant population in need of support—a situation that has dramatically worsened since the pandemic.

2 The Challenge to Support Older Adults with Dementia and Their Carers

Canada is experiencing an epidemic of dementia. Over 1/2 million Canadians live with dementia, 90% of whom are cared for by spouses and adult children [2]. The COVID pandemic has created a crisis, where isolation due to public health measures has worsened the physiological, psychological, and quality of life of older adults with dementia (OAD) and their exhausted caregivers (hereto referred to as carers). Alongside the large proportion of OADs and CPs in remote areas, addressing the needs of those who are black, indigenous and people of colour (BIPOC) [3], of lower income, and other under-represented groups must be considered in the design of any initiatives aimed at this population. We contend that dementia-informed digital health technologies can offer highly accessible, affordable, effective, and pleasure-driven solutions when designed with engaged, diverse OAD and carer participants.

Older adults with dementia (OAD) suffer a range of debilitating health issues (physical, cognitive and affective), arising from isolation, immobility and loneliness. Social isolation can exacerbate certain dementia symptoms in older adults, resulting in sharp declines in physical and cognitive health, aggression, and worsening mood. Additionally, physical distancing can place increased demands on family and/ other carers, leading to greater amounts of burnout [4, 5]. Untreated symptoms lead to physical, cognitive and mood decline and often hospitalization and institutionalization which strain OAD and contribute to mounting government health costs exceeding $12 billion for this care [6]. Recent research assessing the impact of the pandemic on ageing research seeking to apply technology solutions for older adults. Sixsmith finds ongoing barriers include: structural impediments to large-scale implementation, the need to focus on service rather than crisis management, and to address the digital divide. The COVID-19 pandemic has created a heightened crisis reflecting these barriers, while social isolation yet worsens their impacts on physiological, psychological, and quality of life of OAD and their burdened carers.

3 The Promises of Digital Health, Activity and Gaming Technologies for OAD

While not a panacea, recent developments in dementia-friendly digital technologies offer approaches that can improve the quality of everyday life of those with OAD, their carers and families and aim to surmount some of the aforementioned barriers via enhanced digital service and supported access.

While the progression of disease cannot be reversed, regular physical activity and lifestyle choices for people with dementia can significantly slow disease progression and reduce depression. Research shows for example that telehealth and healthcare technologies designed *for* older adults (specifically, OAD) and their carers can significantly

impact the well-being and health of older adults and relieve carer burdens. Typical approaches to telehealth for persons with dementia however often render OAD as passive users who are not agentic and whole [4, 7]. Such styles can result in symptoms of agitation and aggression for OAD, placing a heavier burden for at-home carers, especially for those who are spouses of OAD or family members [5]. A critical, more inclusive approach to telehealth for OAD is possible when OAD and care networks are conceptualized as agentic stakeholders from the beginning.

Important research in telehealth lends advice regarding best practices for engaging OAD with communication technologies. For instance, [8] researchers suggest making brief, plain language how-to guides or videos to ease OAD through the telehealth process. Additionally, healthcare providers can embrace dementia-friendly approaches to care, such as rephrasing questions or giving OAD time to respond, can ease the digital communication between providers and OAD [9]. Telehealth providers find they may need to assess racial, cultural or linguistic barriers in care: emerging research emphasizes that working with culturally-safe practices can provide possibilities for comfort, trust, and agency for OAD from marginalized racial, cultural, or linguistic groups can ease the care process for older BIPOC and migrant groups who experience medical racism and discrimination [3, 10, 11]. By amplifying and designing telehealth and aging technology alongside OAD and care networks, OAD interdependence is enhanced, creating much-needed respite for at-home carers. As the COVID-19 pandemic continues, physical therapists, gerontologists, and other healthcare providers working with OAD may find it beneficial to adopt such practices into their telehealth conferencing [12].

Also important is research showing that creative activity, especially in regard to physical movement and sense of self can benefit physical, cognitive, and social wellness in OAD. Exercise programs can enhance emotional well-being, and social interaction; range of motion interventions reduce risks of falls and boost dual task ability [13, 14] and improve on global cognition for OAD [15]. Additionally, light physical activity, such as walking exercises, can improve balance and mobility [16, 17]. Other forms of gamified light activity, such as low-impact aerobics, walking activities, or tai-chi and meditation, can also relieve agitation and aggression, which may increase the possibility of falls for OAD [18–20]. Similarly, arts-based initiatives adding creativity and multisensorial engagement are shown to enhance mood and reduce loneliness and have become popular with those living with dementia. Dance programs can improve balance and offer culturally-safe practices for physical activity [21, 22]. As well, physical activity, combined with social interaction and art have synergistic effects, producing physical, cognitive and emotional benefits for older adults with dementia [23–25]. There are enormous possibilities to be gained in merging technology with these arts-based initiatives, but research must radically shift to ensure these platforms are designed in partnership with OADs and their families [26].

Recently, digital approaches to serious gaming reveal the cognitive and social benefits of co-design with OAD and their care networks. Research shows that haptic matching games designed for older adults can have significant health and mood benefits, such as increases in memory and word recall for household or everyday objects [27, 28]. Serious gaming mobile applications can also present opportunities for intergenerational play and connection between OAD and young adults, creating new networks and possibilities for

social interaction and care as interfaces center the unique access needs of OAD, while providing nodes of contact and connection [29, 30]. Co-design approaches to serious gaming can promote physical therapy as a fun, engaging digital experience. Noting the popularity of exergame platforms in the early 2010s, many projects co-design serious gaming for OADs that position physical therapy and other forms of low-intensity activity with video game consoles such as Nintendo's Wii Fit [31] or Microsoft's Xbox Kinect systems [32, 33]. These efforts at gamification work to promote balance and cognition, in addition to providing a space for OAD to practice memory, word-recall, and specific types of physical movement (e.g.: raising arms). Recent studies reveal the important potential of serious gaming and/or social networking applications, for the physical, cognitive, and social health of older adults with dementia [34–36]. As the COVID-19 pandemic continues, halting the reopening of day programming for OAD, serious gaming or social media-based interventions can facilitate digital networks of interdependence and social interaction. While there is great promise in engaging digital technologies including gaming to gain multiple benefits for OAD, few technology solutions have been designed by and for OAD, and even fewer seek to deliver benefits to carers.

4 Incorporating OAD in Technology Design

Highly impactful digital health and communication technologies can be developed with approaches that recognize the unique physical, cognitive, and social health needs of People with Disabilities, in our case, OAD (older adults with dementia.) [34–36]. Participant-driven or deeply informed approaches are particularly effective, focusing on lateral knowledge sharing (across older adults, stakeholders and research team members), and engaging interdisciplinary teams focused on solution-driven methods; these enable agile and curious problem-solving, rather than addressing user needs via disciplinary approaches [37].

As noted, OAD tend to be positioned in research as individuals requiring care, rather than as offering lived expertise, skills, and abilities essential to advancing knowledge and treatment of dementia. Research on dementia disease and interventions has typically been developed focusing on a narrow white, upper middle-class population [38], leaving out knowledge from diverse OAD, that is crucial for ensuring solutions address the wide range of OAD and carer needs.

There are a multitude of reasons that older adults are absented or positioned as "users" and not as designers in technology design research. Older adults are stereotypically portrayed as technophobic and unable to engage with healthcare technologies and mobile communication devices. As a result, many age-related digital divides such as health and activity trackers, like media devices, such as smartphones, are incompatible with or fail to address older adults' unique needs, diverse cultural experiences, and fail to offer sustainable long-term assistance affordances [3, 39, 40] such as health monitoring or exercise incentives. A clear digital divide presents barriers to health technology adoption and use by individuals who are under-resourced and marginalized [41]. Many scholars [42] have warned that researchers tend to overlook diverse populations during health technology *implementation*, for example, failing to address how digital literacy and/or collective or nuclear family living impacts technology adoption.

While technology adoption is a serious barrier, our team focuses on the problematic absenting of diverse (e.g., BIPOC, cognitively diverse OAD, etc.) populations in technology *design research.* Developing technology with diverse older adults at the table allows for inclusive design of the interface and the interaction to fit into the lifestyle, flow and to anticipate trust and security needs of projected BIPOC users. It is not enough to include individuals from underserved and under-represented populations—rather, the structure of the research itself must seek to correct historic normative research practices that make BIPOC, differently abled and other marginalized folks reluctant, fearful and skeptical. Models are available to assist researchers in working with marginalized populations to create tools that are accessible, desired, and accommodate their lived realities of. Universal design is an approach that can design effectively across populations (of high to low digital 'literacy'. However, approaches must also take into account: participants' comfort with and access to digital health tools and remote health care provider services; reliable Internet access; and possessing an appropriate space to engage with these technologies, etc. [43]. It is essential that teams address issues of trust arising from historic marginalization and unethical treatment by medical communities; users won't consider using health devices (designed for low digital literacy) if they fear they are designed for privileged, white people but represent security and safety risks for themselves [3, 10, 44].

Finally, human technology development research driven by disciplinary and top-down approaches often alienate targeted user groups, in failing to explore fully the needs of diverse older adult participants and stakeholders, or sequentially distributing user problems to discreet team members [4, 7, 44]. Methods are available to help teams to enhance rigorous interdisciplinarity to support universal design and meet the needs of diverse OAD stakeholders.

5 Pivoting with COVID-19: Best Practices for Remote Research with Diverse Older Adults

The COVID-19 pandemic presents new challenges for health and technology research [42, 45] The rush to invent new health technologies or onboard individuals to new tools, for example, remote health monitoring, smartphone and web-based symptom tracking, virtual care via the "virtual hospital" (telemedicine practices, online prescriptions), raises concerns over risks to users. While digital tools can be effective in addressing mounting public health needs, they can be unethical (intrusive), unsafe (erode individual freedoms) and fail to reach at-risk and vulnerable populations [42]. Research to develop technologies for diverse OAD must ensure that such ethical concerns are embedded in their research questions and approaches.

Sixsmith's [6] review of the Canadian Ageing and Technology research network identifies key areas to target to support appropriate technology solutions for older adults via remote communication technologies. Technology, for example, should not be a "bandage" but should support long term care interventions. It is essential that we address systemic inequities in care provision and avoid enhancing the digital divide. In so doing, more OAD can remain at home, which both abides their wishes, and prevents decline and the risks associated with congregate living in long term care facilities. We must

create policy change to foreground digital citizenship, and to the right affordable Internet access. In the immediate, however, our team seeks to create technology suitable for immediate and longer-term care provision, and to create an accessible and free platform with a low barrier to entry. In working with NGOs invested in providing cheap digital technologies to OA (such as digital tablets), we hope to intervene effectively at this moment of the pandemic, offering a gaming platform that will sustain OAD's family and social engagement, and that over time, policy changes will produce greater access to digital technologies and Internet access to support the use of such digital health and activity platforms.

6 ABLE.Family: Intergenerational Gaming for Older Adults with Dementia and Carers

The ABLE.Family project seeks to engage diverse OAD and stakeholders in rigorous co-design to create a gaming platform for families participating via remote technology. Our research approach centres OAD and carers in the development of the interface and game interaction to meet diverse needs and interests, and to ensure sustained use and benefits.

The goals of ABLE.Family platform are to: reduce loneliness and isolation; increase socialization & pleasurable interactions, particularly intergenerational play; reduce carer stress and depression; investigate how the interactions might aid memory, cognitive and mood enhancement; to restore a sense of self, identity and family role for OAD, and to restore close relations among OAD and family members. Our interface and interaction design strategies reflect emerging research on dementia, and the needs and experiences of those living with dementia and their carers, as outlined earlier.

Our design process has the following objectives, further explained below:

1 Diverse OAD and stakeholders will offer rich personal experiences to inform the interface and gaming elements of the ABLE.Family gaming platform
2 The online game platform will be highly accessible to diverse OAD and intergenerational family members; it should, for example, offer opportunities for non-verbal interaction and other dementia-informed approaches to enhance the accessibility and effectiveness of the platform for OAD
3 The game platform should provide activity and playful interactions that enhance the well-being and increase the cognitive engagement of OAD.
4 The platform games should engage OAD in motor learning, supporting consistent game play using the platform.
5 The online game platform will aim to increase interaction to reduce dementia symptoms in OAD, provide stress relief to carers, and enhance family and friendship bonds among players.

7 Fortifying an OAD-Friendly Human-Centered Design Approach

In pursuit of these diverse objectives, our team draws on our multiple experts, and engages in interdisciplinary practice. We bring distinct skill sets in aging (reflecting diverse

needs of older adults with frailty and dementia and their carers); platform and sensor design, code design, and data analytics; occupational therapy and rehabilitation with older adults; and frailty-informed co-design, user interaction design and disability theory. Our interdisciplinarity practice is informed by research and experience. Four years of team-based work has taught us to embrace the following key practices: comprehensive engagement with and sharing of data acquired in co-design with stakeholders; blending our diverse disciplinary methods; critical approaches to remote research collaboration across the team and with stakeholders; community engagement, knowledge sharing and translation; and a ongoing reflexive review of our mission and objectives. To support remote collaboration, our team employs new digital tools including an iterative design map to track planning, documentation and timelines (as these change, routinely) and to facilitate the persistent transfer of learnings and knowledge among all team members.

8 Pivoting from ABLE Music to ABLE.Family's Web-based Platform

Iterative design is key to our development; over the past four years we have developed ABLE platform versions with distinct interactions (using gesture and wearable technologies) to meet different needs (e.g. movement, mood enhancement) all of which draw on arts and game-based interaction. With the pandemic, we pivoted to designing a web-based gaming platform, to meet the needs of OAD, carers and multigenerational family members isolated at home. To date we have produced a beta version of ABLE.Family as a co-located, interactive platform to combat the extended isolation, loss of cognitive and activity and socialization. Research shows that loss of socialization produces loneliness, loss of identity, and depressed mood. The platform is designed with approaches drawn from dementia therapy, disability studies, and successful technology and game research for OAD. The Able.Family platform aims to create opportunities for family play and cognitive engagement.

In response to the COVID-19 crisis, we have adapted our design process to work with stakeholders (e.g. physical and occupational therapists, Gerontologists, recreation therapists, and carers), rather than OAD. Engage in research that is ethical, accessible and rewarding with stakeholders, prior to engaging OAD them in remote participation. Our team-based work and testing has leaned more toward participatory (or human centered) design, as we are unable to maintain consistent rigorous co-design approaches via remote communication tools [46]. However, we maintain a commitment to ensuring that the games and interface are dementia-friendly and fully accessible for a diverse population, taking into account potential technology, physical, emotional and cognitive barriers.

9 A Disability and Crip-Informed Research Approach

The ABLE.Family platform is informed by crip theory (a branch of critical disability studies) and disability justice activism, aiming to subvert ableism, or the oppressive practice of assuming all disabled people should be made able. Crip theory rejects cure,

rehabilitation, and assimilation [47–51] and understands disability as a cultural experience and a political category. Crip approaches call for interdependence among disabled people and for coalition building among different disability groups; it foregrounds intersectionality [52], mapping how disability and race are shaped by systems of ableism and white supremacy in cultural institutions, such as education and healthcare [53, 54]. Crip approaches to OAD do not seek to 'cure' or rehabilitate but invite OAD to define their own goals and definitions of wellness. This aligns with the demands made by disability rights movements for self-leadership by those living with multiple tiers of 'disability' (e.g. neurodivergent people, older adults, and BIPOC and queer/trans disabled people) [55, 56]; the mission to eradicate ableism thus shares aims with movements to disrupt white supremacy, settler-colonialism, and the medical industrial complex [57].

Recent projects in human-computer interaction, science and technology studies, and media studies have used crip and disability justice-informed critiques, illustrating the important applied and theoretical contributions of these frameworks. Crip approaches to technoscience reveal the benefits of design teams working with disabled stakeholders to meet diverse needs and goals [44], to provide access rather than recovery, and to challenge positioning OAD as cognitively deficient [7], instead prioritizing the wholeness of OAD [4, 9, 57]. These approaches inform our co-design processes for ABLE.Family, which complement our ongoing efforts to embed elements of speculative and emotional design in our human centered design approaches [46, 58] to ensure participants drive research goals and practices, project the future they wish to see for themselves, and achieve benefits from the research experience.

10 Dementia, Crip and Accessibility-Informed, Intergenerational Game Design

In this section, we will discuss the key conceptual ideas that drive our interaction and interface designs, always filtered via dementia and crip-informed and participatory, community-based research [7]. We position OAD and their carers as experienced thinkers, tinkerers, creators, and makers [44] whose design expertise is crucial to team success. In our co-design approach, we rework the platform goals in iterative design to re-center OAD goals, preferences and crucially, their diverse interests, while focusing on objectives to meet diverse needs, and not to cure disability [26].

The game choices rely on OAD's (often strong) long term memory [25, 29, 59] to increase pleasure and reduce discomfort. We aim for games to be familiar and colours to be bright, reflecting reminiscence (memory) theory, and language/colour recognition approaches [27, 60]. We reference familiar interface and game options, reflecting principles of accessible and universal design. We endeavour to offer opportunities for OAD to recall memories of music, and to reminisce, or create personal stories, known to be comforting to OAD. [30, 61, 62]. The platform allows users to save a drawn picture as a.png file, to be printed as memento or used as a screensaver, which is beneficial for recall [63] and re-instills a sense of identity for family members, such as grandparenting.

We implement accessibility design principles to maximize usability, and support the diverse needs and abilities of users. Following a responsive design approach, we aim for ease of navigation, offering simple and intuitive interaction. The platform aims to

respond and adapt to multiple devices, allowing users to access the platform in their preferred format. The design platform includes text and icons that are easy to read and understand by diverse users. The interface calls upon Zoom and tablet interaction skills that OAD already possess. To increase accessibility, we added roll-over text that appears when a user places their mouse or finger over a button or symbol, to explain in plain language the feature's purpose. We offer text below buttons and other features to increase redundancy, and ease of use for people with sight disabilities or colour blindness. Certain buttons have an activation colour, denoting a mode or setting, e.g. selecting draw mode, using the pencil or eraser, etc. These features reference mechanical systems that may be recognizable to OAD users, such as a latching button or switch used to turn on a household device.

Dementia-friendly principles drive us to design with clear and concrete instructions. To wit: we have created the platform as a sparsely populated space; use navigational colours and symbols (drawing on long term memory); offer short duration game options; level play difficulty; and offer multiple options befitting different levels of cognitive impairment engagement (e.g. observing, responding, guessing, making/active playing). Larger buttons are used to focus OAD's attention on the most important features for play. As well, the platform (and our instruction manual) invites trusted carers to choose and even customize game interactions that will be most pleasurable and least frustrating for their OAD. One key challenge given Canada's diversity is to offer games that reflect diverse cultural, ethnic and regional experiences. To this end, we have designed open-ended games (such as group drawings) which allow for cultural expression, and have planned customized features allowing families for example to upload a familiar pictures to "paint" or favourite songs to sing with. In this way, families can "curate" their game experience to reflect their family's traditions and OAD needs.

The following images demonstrate how these principles (clarity, clean interface, color coding, game options, etc.) are instituted in our present prototype. Note that as testing and iterative design occurs, we are yet minimizing button options on the interface and plan a highly minimal view (1 play pad, 2 buttons) for OAD players in future iterations. Each frame will be discussed following the images (Fig. 1 and 2).

Fig. 1. Mockup images of the ABLE.Family platform in its desktop computer version used in a web browser.

Fig. 2. Mockup images of the ABLE.Family platform in its iPad or Tablet device version used in a web browser.

11 Detailed Interface Review

The above images depict each screen or mode that can be used in the current iteration of the ABLE.Family platform. From screen one (viewing left to right and then row by row), screens/modes consist of:

- Login – The login screen is the first thing a user sees after going to the ABLE.Family platform URL on their web browser. A user is asked to enter a room name and their name, which will be used to identify each user while using the app. The room name connects all users that entered the same room. This allows people connected to the Internet, either in the same room or somewhere else in the world, to interact in real-time with each other in their own private virtual room.
- Draw – The draw mode allows users to use their mouse, stylus or press their finger on a touchscreen in order to draw pictures on the canvas at the same time. The user can select a pencil or the eraser and select a wide array of colours by pressing the pencil, eraser and choose colour buttons (in the upper right of the page in the desktop layout and bottom left of the iPad layout). Live video feeds can be seen to the right or bottom of the screen, displaying video from other people in the current room. Using the camera on the user's device, e.g. iPad camera or laptop webcam, everyone in the room can be seen and heard in real-time. Several types of turn based games or collaborative drawing can be done to encourage intergenerational play. The drawn picture can be downloaded to be shared or viewed later.
- Pictionary – This mode is based on the popular game where a person draws out a secret word while their teammates try to guess what it is before the timer runs out. On the ABLE.Family platform, a user can select a category from the dropdown menu and

then start drawing out the word it supplies. In the image above, the word pineapple has been given in the "Your Word" box. None of the other users can see the word in the "Your Word" box until the person drawing selects the green check mark of red "X" to signal to players if they have guessed correctly or incorrectly. Connecting red and green colours to buttons can help an OAD to understand the actions initiated by the button. The game is reset by selecting another category and receiving a new word.

- Charades – This mode is based on the popular game similar to Pictionary; instead of drawing, the user acts out the word while the rest of the players try to guess what it is. In this mode, the drawing canvas is turned into a larger video screen enabling everyone to see the player acting out the word. Other buttons allow players to take a screenshot of the live video or start a recording of everyone playing to share or watch later.
- Tic-Tac-Toe – In this mode, two or more users can play the game Tic-Tac-Toe. In this turn-based game, one player draws an X in a box while another player places an O. In order to win, players need to draw three of their own symbols in a row in any direction. This game encourages intergenerational play through its familiarity and enables OAD to teach strategy to child or younger players.
- Paint by Numbers – This mode is based on the popular painting trend in 1950's and 1960's North America, where players could paint a white canvas with faint outlines, by following the numbers found in each segment and selecting the corresponding colour. In our app, the outlines can be seen, though no numbers are present. The user can paint on the canvas to virtually apply paint to the image and the colour is chosen automatically. This is both a beneficial sensory (eg tactile) engagement for OAD, and reduces anxiety associated with painting within the lines and allows for cooperative game play to reveal the image. The game offers various images to choose from and will add a feature where users can upload images familiar and comforting to OAD (eg. family cottages, favourite events, pets, etc.). This mode can stimulate reminiscence and storytelling known to be beneficial and comforting to OAD. As well, as images appear, participants can invite OAD to narrate what they see for cognitive enhancement. This practice also offers opportunities to restore grandparents as roles as teachers and family historians while it builds family bonds.

12 Planning Future Iterations: Music, Matching and Dementia-Informed Movement Games

Future iterations plan music games including "Name that Tune" (where players guess recognizable songs) and "Sing Alongs", a popular experience in long term care facilities, where OAD sing along and motion to old tunes such as "The Itsy Bitsy Spider", and "The Wheels on the Bus".[2]) Research is well-established noting that music referencing long term memory is cognitively and affectively beneficial for OAD.

Notably, the simple games we have included are chosen because they are pleasurable for OAD, recognizable to older adults children and fun for smaller children (and grandchildren.) We anticipate that the "Sing Alongs", group drawing, "Pictionary" (drawing

[2] Our team has past music intervention experiences for OAD; these new ideas come from conversations with IM Hope (Hamilton, Ontario), who advise the project.

guessing game) and Charades games will be engaging for young children, who might in fact drive the play, allowing OAD to observe, cheer, and congratulate them, and in so doing, restore a sense of identity and family roles, which is a goal of dementia-friendly research. Future iterations will test the interest and enjoyment for OAD and small children in playing interactive puzzle, matching and guessing games.

We are currently exploring the integration of movement into this interface. As discussed in past publications [58], the Able Music project intended to exploit the synergistic effects that come from platforms offering movement, art and social interaction, which are shown to beneficially impact older adults physiologically, cognitively and to improve mood. We are engaging an expert in dance and movement therapy, with experience teaching dance to older adults via remote platform during the pandemic to create options for low level and intensity movement, such as Tai Chi, with proven benefits [19, 64]. The movement will not replicate physical therapy but in some cases will seek to simulate some of the movements of physical therapy exercises while feeling like play.

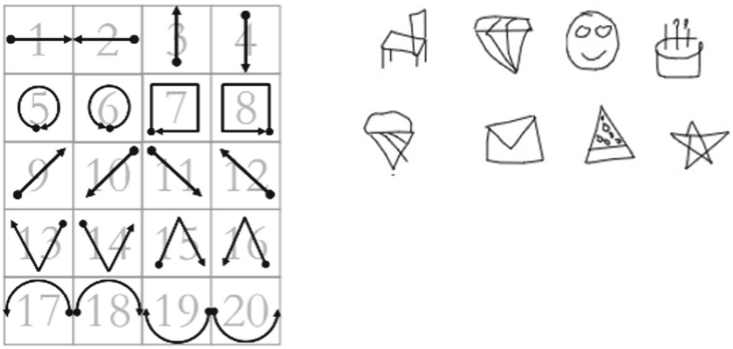
An additional key approach of the platform, which we will further implement in the future, is engaging motor learning to allow OAD to return each time to the platform and know (from experience) how to engage and play. From a motor learning perspective, OAD learn and re-learn best through procedural or implicit learning where they "learn by doing" in contrast to declarative or explicit learning which requires conscious awareness and knowledge [65–67]. Implicit learning means the OAD learn through repetition and skill practice without deliberate cognitive oversight (e.g., awareness, reflection, attention). In the ABLE.Family platform, OAD can engage in familiar tasks that allow them to learn and re-learn motor tasks which do not require explicit cognitive oversight.

13 Future Machine Learning Approaches to Gesture and Game Design

As noted [46], the previous ABLE Music platform sought to transform movement into play and art creation; we were employing wearable sensors to capture and translate user movement data to create artful and gaming interactions. Though we pivoted to a web-based platform with Able.Family, we plan to offer gesture-capture as a platform add-on tool that allows for non-verbal interaction (gesture rather than hand tools such as touchpads, mice, and tablet pens) in advanced future iterations. To this end, we have ideated a gesture-based interaction in Pictionary where players would draw a shape (in the air); images drawn would be captured by a wearable sensor and then revealed in computer renderings visible on the computer screen. This ideation is in the early stages of development and of course requires that we further pursue our efforts to train the sensor via machine learning techniques. We have begun this research, as described below.

Free painting in the air with a wrist-worn sensor is a non-trivial task if no limits are imposed. Research on Google Quick Draw shows that 86% of Americans draw circles counterclockwise while 80% of Japanese draw them clockwise [68]. To address the problem of drawing from different directions, we have formulated the problem as a 2-step pattern matching. In the first step, a machine learning model will help recognize a sequence of pre-defined meta-gestures painted by the user. Then a simple matching step will compare the predicted sequence with predefined templates and output the

corresponding ID of the sketched object. The predefined meta-gestures and objects to be recognized are shown in Fig. 3.

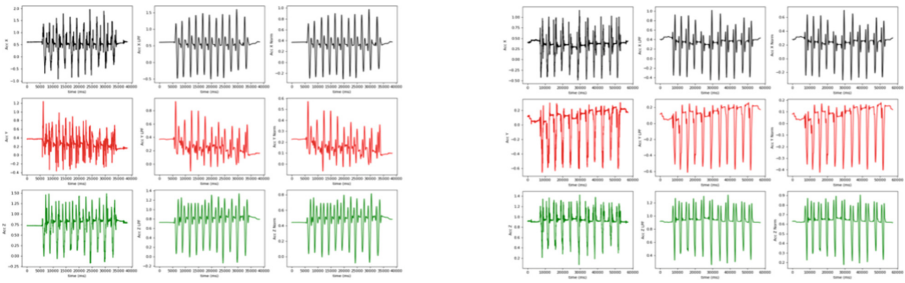


(a) meta-patterns (b) pre-defined painting objects

Fig. 3. To limit the scope of painting, we define (b) sketched objects to be recognized by the machine learning model and further decompose them into (a) basic meta-patterns. To allow users to paint from any direction and paint in any order, the template is defined as a set that includes all possible meta-patterns. E.g., a template of a smiling face is defined as {5, 6, 19, 20}.

To recognize meta-patterns in a free painting, it is necessary to segment data into one-stroke pieces. As an IMU sensor records data continuously, it is difficult to implement data segmentation by post-processing. Thus, we simplify the problem by asking the user to make a 1 s stop when they finish each stroke of paint. Then with a 1 s length sliding window, the neural network can predict the corresponding meta-patterns contained in it.

Another issue to be considered is that the target users may have different dominant arms and thus wear IMU at either wrist. Such using habits divergence will lead to dramatically different sensor signal patterns. The painting habit matters more than simply rotating the sensor or augmenting the recorded data; a straightforward example is given in Fig. 4.



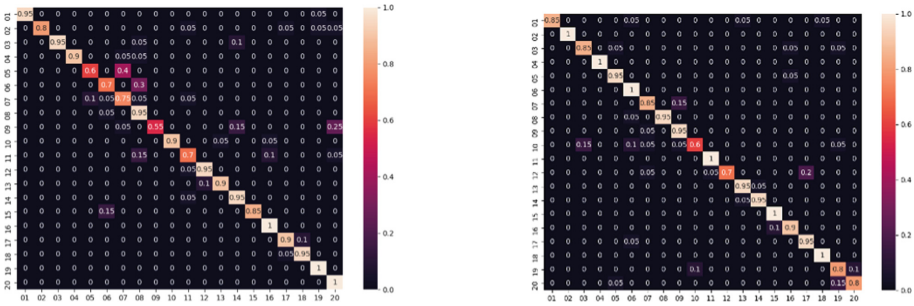
(a) draw with left arm (b) draw with right arm

Fig. 4. A comparison of 3-axis accelerometer data captured when drawing a circle clockwise with different arms. Each data trial includes 10 repetitions.

From Fig. 4, it is clear that exchanging the sign of x and y-axis in (a) respectively, though they share similarities, will not make the signal pattern match with that in (b). This procedure simulates the rotation of the sensor around the z-axis for 180 degrees and aligns the coordinates of the two sensors. The observation indicates a meta-pattern painted by different hands should be treated separately. Transfer learning techniques [69] can be utilized to help a machine learning model extract the shared feature for a given pattern painted by both hands.

The proposed pipeline of training the machine learning model has 3 steps. First, pre-train a neural network on large-scale right-handed sensor-based gesture recognition dataset; second, keep the feature extractor of the pre-trained model and update it with right-handed data from the target dataset; last, take advantage of adversarial training proposed in [70], force the features extracted from lefthanded data to be inseparable to that of the right-handed ones. Note: the adversarial adaptation step here only helps the left-handed model to take advantage of the large-scale right-handed data; we still have two separate models for inference on each hand.

We implemented this pipeline and evaluated it on a small in-house dataset. Data was collected from 2 subjects painting each meta-pattern for 10 times with both hands. Then it was randomly split 80% for model adaptation and 20% for test. The confusion matrix for the test on each hand shows in Fig. 5.



(a) test with left hand (b) test with right hand

Fig. 5. Confusion matrix of the meta-pattern recognition test.

The test accuracy for meta-pattern painting is >80%, and the confused meta-patterns for each hand are different. We also collected another data trial on 1 subject painting each predefined object 3 times with both hands then evaluated the accuracy of predicting sketch paintings with it. Despite the simplicity of predefined objects and their distinctive pattern from each other, the overall test accuracy is merely around 60%. As future work we plan to revise the design of the machine learning pipeline and further improve its performance by enriching supported objects and collecting more sensory data for model training.

14 Conclusion and the ABLE.Family Future

In this paper, we have reviewed key outcomes and plans for future development of the ABLE.Family gaming platform designed for OAD and their carers, which firmly centers diverse OAD and the carers as experts in their experiences of the world and how they wish to navigate it via technology. To ensure diverse input into the platform, our team is working with regional dementia-engaged organizations to broaden the diversity OAD who participate in this research. Many of these organizations also work to enhance access to digital technologies and Internet access for diverse OAD. For our work to succeed, we recognize the need for policy changes to redress systemic discrimination, bias against and neglect of marginalized populations, due to historic racial and ethnic biases and white supremacy. Canadian health care providers and researchers must amplify calls for policy changes that will improve access to telehealth, digital healthcare technologies, and Internet service for diverse populations, particularly the many and growing numbers of OAD and their carers.

As researchers, it is also our responsibility to integrate theory and methods (such as disability and crip theory, and universal and co-design methods) to ensure that we are designing *with* OAD and carers, to create technology with universal accessibility and to produce tools that are desired, inviting, sustainable and innovative, affordable and meet the health and wellness goals of diverse OAD. In these efforts, interdisciplinary teams and approaches are key. Our team's diverse expertise in gerontology, computer science and machine learning, art and design, and disability and "crip" methods has allowed us to address challenges posed by COVID-19, to create a gaming platform that combats long-term isolation and loneliness of OAD. We are inspired by and grateful for the creative ideas and engagements offered by participating OAD carers and stakeholders. Their ongoing insights and challenges have productively 'broken' the ABLE.Family platform many times over, offering us the opportunity to create a truly accessible platform to combat loneliness and despair, and to enhance opportunities for play and pleasure among intergenerational family members. We look forward to continuing to update and modify the platform, and in the spirit of universal design, and dementia- and crip-informed approaches, to continue to improve and add features to the platform. As well, we look forward to launching this as a free, accessible, and *living* platform (that will be continually updated and evolved) in the near future.

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