Exploring the Technological Mediation of a Pickleball Launching Machine on Social Reconnection Among Seniors

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

The U.S. population is currently older than it has ever been, and for the first time in human history, there are more people in the world over the age of 65 than there are under the age of five (Levy, 2022). By 2030, one in six people in the world will be aged 60 or older (WHO, 2022) and 20% of the U.S. population will be 65 and older (America Counts Staff, 2019). This unprecedented aging of the U.S. is largely dictated by the aging of the Baby Boomer generation (North, 2023), and as this trend progresses, the nation is forced to face a moral imperative to ensure that older adults maintain a high quality of life. Yet, seniors are currently living increasingly lonely lives (Stepler, 2016) and being dismissed as expensive to care for (Landau, 2017).

Loneliness is a significant public health concern among seniors, and it has grown to become a prominent threat to their well-being (de Jong-Gierveld et al., 2006, p. 491; Gerst-Emerson & Jayawardhana, 2015, p. 1013). Seniors are found to face social rejection and have increasingly limited opportunities to engage in meaningful socialization (Shiovitz-Ezra et al., 2018, p. 369). This gives rise to numerous physical and mental health problems, such as depression, Alzheimer's disease, and even premature mortality (Beller & Wagner, 2018, p. 8; Liu et al., 2016, pp. 750-751; Wilson et al., 2007, pp. 236-237).

To encourage activity among seniors, my technical project aims to improve both their physical and mental health by focusing on pickleball, which has gained immense popularity within the senior community (Burns, 2022). We accomplished this by designing and prototyping a pickleball machine that feeds pickleballs towards the user from across the court at varying speeds and angles. The primary goal of our project was to make solo training more accessible by offering users a cheaper feeding machine with customizations comparable to those of existing,

more expensive, automatic pickleball launchers. By doing so, this machine would ideally serve as a resource to keep seniors engaged with their community through sport, aiming to reduce strong feelings of loneliness by increasing the breadth of their social activity.

The design of this machine invites reflection surrounding how effective the incorporation of an automatic feeding machine is when used to help seniors curb loneliness through a social sport. There is currently limited literature on how the design of such machines influence seniors' interaction with society. My goal is to understand the technological needs of seniors by studying other health technologies designed for them, which could be applied to the development of pickleball machines.

It's essential to incorporate design elements in technology tailored to fulfill seniors' preferences to successfully reintegrate them into their community. This is because technology is not merely a tool that we engage with, but it actively shapes and influences our perceptions and interactions of the world. Technological artifacts can evoke certain human behavior (Verbeek, 2006, p. 362). A well-designed feeding machine should not only be functional but should also inspire the user to engage with pickleball and reap the social benefits inherent to the sport. In this paper, I use the theory of technological mediation to analyze the efficacy of resolving senior loneliness via the use of a pickleball training machine. I will also illustrate the influence of technological mediation on the design process of such a machine.

The Epidemic of Loneliness Among Seniors

Loneliness is manifested as an individual’s perceived discrepancy between desired and actual levels of social involvement (Russell et al., 2012, p. 7). These feelings of loneliness are growing to be increasingly prevalent among older adults (Valtorta & Hanratty, 2012, p. 519). According to the University of Michigan National Poll on Healthy Aging (2023), 30% of a

national sample of adults between the ages of 50 and 80 reported feeling lonely and isolated from others within the year of 2022. Those who suffer from loneliness are additionally associated with higher rates of clinically significant depression and anxiety (Beutel et al., 2017, p. 2), which further contribute to the accumulation of extreme psychological stress (Friedler et al., 2015, p. 495). Beyond psychiatric illness, lonelier seniors are also susceptible to numerous physical issues, such as cardiovascular disease and sleep dysfunction (Hawkley et al., 2010, p. 2). As briefly mentioned, they may even be faced with early mortality (Rico-Uribe et al., 2018, p. 21), with the reported risk of cardiovascular death increasing by 90%, and the risk of death from attempted suicide doubling in frequency (CDC, 2022).

A recent study conducted by the Pew Research Center (2020) illustrates that older adults are more likely to live alone in the U.S. than anywhere else in the world. Within the U.S., 27% of adults aged 60 and older live alone, compared to many other countries in the Asia-Pacific and Middle East-North Africa regions, where fewer than 5% of seniors live alone (Ausubel, 2020). The study also reveals that in the U.S., an average senior beyond the age of 60 lives in a household size averaging 2.1 people, compared to a worldwide average of 3.4 people per household (Ausubel, 2020). The significantly smaller household frequent within the U.S. may contribute to the loneliness experienced by seniors, as the environment fails to support meaningful relationships or relationships of adequate quality (Cacioppo & Hawkley, 2009, pp. 451-452; Gierveld & Havens, 2004, pp. 110-111).

Connecting Seniors to Their Community Through Sport

The increasing prevalence of loneliness among an aging population, coupled with its detrimental effects on their health, emphasizes the need for effective intervention. Lonelier individuals tend to be less physically active, which further compounds the negative effects of

loneliness on their wellbeing (Ahn et al., 2024, pp. 1-2). According to the CDC (2023), regular physical activity is one of the most important things an older adult can do for their health. In addition to the maintenance of physical health, regular exercise can also introduce opportunities for positive social interactions (Basterfield et al., 2021, p. 5). Generally, physical activity is shown to improve psychological health and the quality of social friendships (Pels & Kleinert, 2016, pp. 18-20; Umberson & Montez, 2010, p. S55).

Encouraging seniors to consistently participate in physical activity is an effective way to reduce loneliness (Ahn et al., 2024, pp. 9-10). Researchers have found that working out in a group lowers stress by 26% while significantly improving quality of life (American Osteopathic Association, 2017; Sebastião & Mirda, 2021, pp. 2-3). A study assessed the effects of group exercise among a community of 382 participants averaging an age of 76.8 years (Mays et al., 2021, pp. 2-3). Results of the study reported decreased loneliness and improved social connection after six months of group activity when compared to their baseline scores.

Beyond acknowledging the benefits of physical activity, it's also important to recognize the type of exercise that is most suitable and favorable for the senior community. A study conducted by the National Institutes of Health (2022) reports that older adults who consistently engage in racket sports had the lowest all-cause mortality risk when compared to other activities, such as swimming or cycling. The positive effects of racket sports may be associated with the specific physiological demands and adaptations characteristic of the sport (Watts et al., 2022, pp. 5-7). Racket sports require hand-eye coordination as well as intermittent bursts of high intensity (Gavelin et al., 2021, pp. 11-12) which additionally improves physical functioning (Ito, 2019, p. 181). These actions also fall in line with the Physical Activity Guidelines for Americans (2018),

recommending older adults engage in physical activity involving both balance-training and aerobic activities.

Among all racket sports, pickleball has been growing with immense popularity among seniors (Buzzelli & Draper, 2019, p. 180; Heo et al., 2018, p. 69). The Sports and Fitness Industry Association reported that 60% of the 1.4 million core players of pickleball, defined by those who play at least eight times a year, were 55 and older (Fields, 2022). Additionally, more than 33.7% of these core players were 65 and older, further illustrating pickleball's appeal to the older demographic.

The popularity of pickleball is largely fueled by the social environment inherent to the sport. For example, a common open-play format used in recreational settings, known as mixer play (Buzzelli & Draper, 2019, p. 180), accommodates players of varying skill levels by allowing winning players to advance up a court and losing players to move down a court, eventually pairing players of similar ability. This setting further allows different players to mingle among themselves, providing participants with a more enjoyable social experience (Casper & Jeon, 2019, p. 29). The psychosocial benefits of pickleball, along with the quality of exercise that it provides to the senior community (Ryu et al., 2018, pp. 133-135), frames it as a viable intervention to help curb loneliness among seniors.

Technological Interventions Among Seniors

Traditional methods of playing pickleball with a partner may not always be feasible for seniors who are already suffering from loneliness. Extended periods of loneliness could lead to deficits in social skills, making it difficult to quickly re-establish social connections (Cohen-Mansfield & Eisner, 2019, pp. 567-568; Cohen-Mansfield & Parpura-Gill, 2006, p. 289). Lonelier individuals are also more likely to feel threatened and mistrustful of others (NIH, n.d.).

Technology can be used to reconcile this problem (Chauhan & Pal, 2022, pp. 175-176), allowing them to independently reap the benefits of the sport while easing back into the social environment of their community.

Technology has the potential to assist with physical activity interventions (Araullo, 2016, p. 7). New technologies ranging from wearable technology to training machines all aim to promote a healthier lifestyle (Chaddha et al., 2017, pp. 149-150; Sullivan & Lachman, 2017, pp. 5-6), however, design choices surrounding these technologies have not necessarily been catered towards seniors (Pirhonen et al., 2020, pp. 7-8). The adoption of new technology within senior communities is dictated by several factors, such as affordability, reliability, and compatibility (Lee, 2014, pp. 14-15). A key barrier to adoption is the inability for older adults to easily visualize the contributions of a technology to their lives (Walsh & Callan, 2010, pp. 114-116).

Current pickleball training machines that are found on the market are expensive. Popular and highly rated pickleball machines such as the Erne and Pickleball Tutor Plus retail for $1899 and $1050, respectively (*Meet ERNE*, n.d.; *Pickleball Tutor Plus*, n.d.). The steep price tag of these products is justified by its expansive array of features. These machines can serve a variety of pickleball strokes including serves, groundstrokes, dinks, and lobs. They also offer different timing configurations and shot location customizations. However, more doesn't always equal better, especially for an older target audience.

Many older adults feel intimidated when faced with new technology, and such intimidation effectively lowers perceived benefits, satisfaction, and likelihood of consistent engagement with the technology (Meuter et al., 2003, p. 900; Piper et al., 2010, pp. 907-909). The high cost of these machines is another common grievance among seniors, who may see an imbalance between tangible costs and potential benefits (Mitzner et al., 2010, pp. 1719-1720).

The user experience of a pickleball machine heavily dictates how well it will be received by seniors. A negative experience not only hinders the integration of seniors into the community but can also trigger technology-related anxiety, further diminishing seniors' confidence.

The Technological Mediation of a Pickleball Machine

The design of technology and the degree of which older adults choose to engage with it can be described using the theory of technological mediation. The central idea of this theory describes how relations between human beings and the world around them are shaped through the use of technology (Verbeek, 2016). Technology is constantly guiding our behavior: a speed bump invites us to slow down by threatening damage to the vehicle, and a car could demand all doors be securely locked by refusing to start otherwise. Within the context of addressing senior loneliness, it's examining to what extent the design of the pickleball machine inspires or limits engagement from senior users.

Principles of user-centered design among engineering are crucial for making technology more engaging. Designing technology with the explicit purpose of influencing human actions can easily raise moral questions, so technological mediation charges both users and designers with the responsibility to be actively engaged in shaping the impact of technologies on social practices. At the very least, technology should be designed with nonmaleficence.

Technology that has a purpose usually withdraws from the user's attention (Verbeek, 2006, p. 364). For example, when writing a letter, the user's attention is on the contents of the letter rather than the pen itself. Similarly, when users engage with an automatic pickleball feeding machine, their attention should be placed on the ball and the strokes they take to hit it, rather than on the machine. It is only when the piece of technology breaks down that attention is

drawn to it. It is also at this point where the artifact loses the ability to foster the relationship between the user and the world.

In this way, technology transforms the way we perceive by mediating our sensory relationship with reality (Verbeek, 2006, p. 365). A well-designed pickleball machine warrants senior engagement, and frequent interactions would allow them to develop a deeper understanding of the game. The iterative process of experimenting with different launching configurations also encourages seniors to improve their skills at their own pace. The control and autonomy that the machine provides could resultingly boost their confidence and motivate them to participate in community pickleball events and activities.

Because technology helps to determine how people interpret reality, the question then becomes how engineers can incorporate the awareness of technology's mediating influence into the design. A possible method of addressing this is to involve the intentional users into the design process. Technology could be equipped with novel features and state-of-the-art customizations, but poor reception from a user standpoint eliminates all its value.

Methodology

When developing technology for older adults, direct feedback pertaining to needs and expectations would ideally be collected to design a machine which confidently integrates consumer necessities. This stems from the idea that technological advancement frequently depends on preconceived notions about the needs and expectations of older adults, rather than on their genuine preferences and requirements (Lee, 2014, p. 16). However, due to time constraints, my team neglected to survey seniors before designing our pickleball machine. Nevertheless, we recognize the importance of this step and intend to incorporate it into future engineering projects. As an alternative method of gauging senior needs, I opted to conduct a systematic literature

review which examines studies to identify the nature of older users' involvement within the design process and how it impacts their utilization of technology.

The review of this literature had been narrowed down using the key words of "user involvement," "design process," "technology," "health," and "older adults." Searches were conducted primarily within bibliographic databases such as ScienceDirect and Oxford Academic. The type of technical intervention wasn't limited within my search, so topics within relevant papers ranged from wearable technology to fitness apps. In doing so, I was able to find common ground among the core values that seniors prioritize across various types of technology. Two specific cases will be explored to demonstrate the importance of user-centered design in mediating the relationship between technology and seniors. While there is limited literature specifically addressing the user experience of ball feeding machines, takeaways from the review can be expanded to explore how the design of a pickleball machine could either effectively or ineffectively reintegrate seniors into their community.

Case 1: Reception of Fitbit Among Seniors

Wearable devices have become widely available and are growing increasingly popular among young users. Devices such as Fitbit allow users to track and monitor their levels of physical activity, nutrition, and even sleeping habits. Numerous studies have cited the success of enhancing users' physical activity through wearable devices (Mercer et al., 2016, p. 7), yet this appeal doesn't extend to the senior community, as only 3.3% of its users are 65 years or older (Wurmser, 2019). An important factor that impacts seniors' intention to use wearable devices is perceived complexity.

Perceived complexity is defined as the degree to which an innovation is perceived as difficult to use and understand. Findings of this study had concluded that input and output

complexity of wearable devices had significant impacts on their use of the technology (Farivar et al., 2020, pp. 2-3). For example, some seniors reported to have doubts of their own ability when being explained how to input their personal data and sync the Fitbit to their smartphone. Others were reluctant to use the device due to the laborious process of configuring initial settings. Concerns of interpreting the various data metrics were also voiced, with many facing difficulties when understanding the meaning of lesser-known measurements.

This case highlights perceived complexity as a major deterrent for the use of wearable technology among seniors. Despite the intention of Fitbit in facilitating a more active lifestyle, complexities in the design were not suitable in attracting seniors. The mediating role of a Fitbit is dependent on both the ways in which the technology is used and on the ways in which the technology allows unforeseen mediations to emerge, even when used as the designer intended. Health tracking technologies should disburden the user and serve as a bridge to cultivate healthier habits, but the complexity of interpreting the device's collected data provides the opposite experience. The Fitbit demands a certain level of technological proficiency, which shifts seniors' attention away from the intended goals it aims to achieve to focus on the device itself. The technology embodies a consequentially large cost associated with living a healthier lifestyle. Well-designed technology should evoke a bond with their users, and a Fitbit should invite senior interaction without being so demanding that few are prepared to use it. Limiting features within the design could still provide seniors with a sense of autonomy over what health statistics they would like to see while not overwhelming them with options.

Case 2: Senior Co-Design of mHealth Applications

mHealth applications are aimed at addressing health deficits among older adults, with a subset of them intended to be used to improve physical activity levels. Over 100,000 mHealth

applications exist across the Apple App Store and Google Play Store, offering services ranging from customized training plans to daily activity tracking. However, despite the ubiquity of these apps, usage among seniors were found to be exceptionally low (Pew Research Center, 2024). Consensus survey data had also shown abandonment of these applications within the first three months of downloading (Harrington et al., 2018, p. 1).

Many existing guidelines of fitness applications are developed under the assumption that users adopt these technologies to improve physical fitness and weight, or to be more aware of the state of their health. However, these guidelines don't necessarily apply to older adults, who are more motivated by factors such as positive reinforcement and social influence (Harrington et al., 2018, p. 2). Even with the knowledge of what motivates older adults, it may still be difficult to incorporate these strategies into the design without direct feedback from seniors themselves. This study focused on understanding older adults' experiences with existing mHealth applications and how co-design would be effective in promoting sustained use among this age demographic.

This case illustrates the importance of incorporating relevant actors into the design process to understand technological needs. Co-design allows a practical connection to be established between the context of design and the context of use, which allows an informed prediction about the mediating role of a technology. This method involves all relevant social actors of designers, users, regulators, and so forth into the design process with the goal of reaching a consensus around the most suitable design of a technology.

However, co-design has certain limitations from the perspective of technological mediation. The process shifts focus away from the actively mediating role of the core technology by analyzing the dynamics of its development. Understanding how technologies emerge from their design context comes with a cost, which is understanding the role of the technology within

its use context. Beyond only focusing on user needs in product specifications, relevant social actors could be encouraged to anticipate possible mediating roles of the technology being designed. Explicitly incorporating this step into the co-design process is beneficial in defining the designers' responsibility to promote a desirable influence of technology.

Results

Takeaways from these two case studies can be applied to our pickleball machine to ensure that we are designing a more meaningful piece of technology. Because the pickleball machine is not a static piece of technology that works without interaction, I have the responsibility to ensure that the machine I design invites engagement and is an active facilitator of community. The point that technology inevitably plays a mediating role in the behavior of its users makes my work as a designer an inherently moral activity.

I have the responsibility of anticipating these mediating roles, but there are tradeoffs which come with this anticipation. For instance, my team and I programmed in a delay of around 10 seconds between the user pressing ‘Start’ to load a pre-designed drill on the machine and the first ball being fed out of the machine. The intention of the delay is to allow the user enough time to travel back to the other side of the court before beginning the drill, which is especially necessary when the user starts the drill solo. However, in doing so takes away a certain amount of freedom in deciding how long the user wishes to wait between starting the drill and receiving the first ball, which could be undesirable to fast-paced players. As my pickleball machine is designed for seniors with naturally slower reaction times than younger adults, it circles back to my responsibility in ensuring that these seniors aren't disadvantaged by the machine's design, even if it means compromising convenience for younger players.

Analysis of the first case study also reveals seniors' desire to have a degree of customization across the technology they engage with while avoiding complexity. Customization is crucial for enhancing the feeling of closeness and comfort with the machine, allowing users to make intentional choices about how they wish to engage in pickleball. We incorporated the ability to toggle the speed of the launched ball, as well as the net clearance or court placement of the ball. Each of these customizations is intuitively simple and straightforward on its own, but when combined, they can produce hundreds of unique feeding patterns. In this way, the pickleball machine communicates the versatility of the sport, and seniors can feel empowered by the autonomy and control they have over their practice environment. By experimenting with the combinations of different configurations, seniors learn how to optimize the machine's performance to suit their needs and preferences. This could enrich their experience by inspiring a sense of mastery and accomplishment, encouraging them to further interact with others who share a similar passion for the sport.

Insights from the two case studies guide my approach to designing a more meaningful pickleball machine. Through thoughtful design, my goal is to cultivate an enjoyable pickleball experience among seniors that can resultingly strengthen their engagement with the sport and each other.

Conclusion

Technological mediation creates a specific responsibility for engineers because the goal of designing behavior-influencing technologies can raise moral questions itself. It's important to recognize that all design choices will effectively illicit certain changes in behavior, and large responsibility falls on the designer to ensure that these influences are positive. In the case of my team's pickleball machine, anticipating how the design of our machine will support the age and

behavior of seniors is important in positively mediating the relationship between them and society. However, I also recognize the difficulty in doing so because there's no definite one-to-one relationship between the decisions made by designers and the mediating role of the technology being designed, despite the intention. Many external factors influence the mediating role, including the user demographic to which the technology is introduced and the unpredictable way the technology may be used. Regardless, shifting focus towards anticipating the mediating role of technology and ensuring that the design of technology inherently disburdens the user are important steps to take in responsible engineering.

References

Ahn, J., Falk, E. B., & Kang, Y. (2024). Relationships Between Physical Activity and Loneliness: A Systematic Review of Intervention Studies. *Current Research in Behavioral Sciences*, *6*, 1–16. https://doi.org/10.1016/j.crbeha.2023.100141

America Counts Staff. (2019, December 10). *2020 Census Will Help Policymakers Prepare for the Incoming Wave of Aging Boomers*. Census.Gov. https://www.census.gov/library/stories/2019/12/by-2030-all-baby-boomers-will-be-age-65-or-older.html

American Osteopathic Association. (2017, October 30). *Group Exercise Improves Quality of Life, Reduces Stress Far More Than Individual Work Outs*. ScienceDaily. https://www.sciencedaily.com/releases/2017/10/171030092917.htm

Araullo, J. (2016). Increasing Physical Activity In Seniors Using Emerging Technology: Identifying Adoption Barriers and Enablers. *Proceedings of the 2016 ACM SIGMIS Conference on Computers and People Research*, 7–8. https://doi.org/10.1145/2890602.2906185

Ausubel, J. (2020, March 10). Older People Are More Likely to Live Alone in the U.S. Than Elsewhere in the World. *Pew Research Center*. https://www.pewresearch.org/short-reads/2020/03/10/older-people-are-more-likely-to-live-alone-in-the-u-s-than-elsewhere-in-the-world/

Basterfield, L., Burn, N. L., Galna, B., Karoblyte, G., & Weston, K. L. (2021). The Association Between Physical Fitness, Sports Club Participation and Body Mass Index on Health-Related Quality of Life in Primary School Children From a Socioeconomically Deprived Area of England. *Preventive Medicine Reports*, *24*, 1–7. https://doi.org/10.1016/j.pmedr.2021.101557

Beller, J., & Wagner, A. (2018). Loneliness, Social Isolation, Their Synergistic Interaction, and Mortality. *Health Psychology*, *37*(9), 808. https://doi.org/10.1037/hea0000605

Beutel, M. E., Klein, E. M., Brähler, E., Reiner, I., Jünger, C., Michal, M., Wiltink, J., Wild, P. S., Münzel, T., Lackner, K. J., & Tibubos, A. N. (2017). Loneliness in the General Population: Prevalence, Determinants and Relations to Mental Health. *BMC Psychiatry*, *17*(1), 97. https://doi.org/10.1186/s12888-017-1262-x

Burns, H. (2022, August 30). *Why Older People Love Pickleball So Much*. Time. https://time.com/6209400/is-pickleball-good-exercise-seniors/

Buzzelli, A. A., & Draper, J. A. (2019). Examining the Motivation and Perceived Benefits of Pickleball Participation in Older Adults. *Journal of Aging and Physical Activity*, *28*(2), 180–186. https://doi.org/10.1123/japa.2018-0413

Cacioppo, J. T., & Hawkley, L. C. (2009). Perceived Social Isolation and Cognition. *Trends in Cognitive Sciences*, *13*(10), 447–454. https://doi.org/10.1016/j.tics.2009.06.005

Cacioppo, J. T., Hughes, M. E., Waite, L. J., Hawkley, L. C., & Thisted, R. A. (2006). Loneliness as a Specific Risk Factor for Depressive Symptoms: Cross-Sectional and Longitudinal Analyses. *Psychology and Aging*, *21*(1), 140. https://doi.org/10.1037/0882-7974.21.1.140

Casper, J. M., & Jeon, J.-H. (2019). Psychological Connection to Pickleball: Assessing Motives and Participation in Older Adults. *Journal of Aging and Physical Activity*, *27*(1), 28–33. https://doi.org/10.1123/japa.2017-0381

CDC. (2022, December 8). *Loneliness and Social Isolation Linked to Serious Health Conditions*. https://www.cdc.gov/aging/publications/features/lonely-older-adults.html

CDC. (2023, July 6). *Physical Activity for Healthy Aging*. Centers for Disease Control and Prevention. https://www.cdc.gov/physicalactivity/basics/older_adults/index.htm

Chaddha, A., Jackson, E. A., Richardson, C. R., & Franklin, B. A. (2017). Technology to Help Promote Physical Activity. *The American Journal of Cardiology*, *119*(1), 149–152. https://doi.org/10.1016/j.amjcard.2016.09.025

Chauhan, Y. S., & Pal, U. S. (2022). Innovative Evolution of Technology Used Among Racket Sports: An Overview. *Journal of Sports Science and Nutrition*, *3*(2), 175–179. https://doi.org/10.33545/27077012.2022.v3.i2c.117

Cohen-Mansfield, J., & Eisner, R. (2019). The Meanings of Loneliness for Older Persons. *Aging & Mental Health*, *24*(4), 564–574. https://doi.org/10.1080/13607863.2019.1571019

Cohen-Mansfield, J., & Parpura-Gill, A. (2006). Loneliness in Older Persons: A Theoretical Model and Empirical Findings. *International Psychogeriatrics*, *19*(2), 279–294. https://doi.org/10.1017/S1041610206004200

de Jong-Gierveld, J., Van Tilburg, T. G., & Dykstra, P. A. (2006). Loneliness and Social Isolation. In *The Cambridge Handbook of Personal Relationships* (pp. 485–500). Cambridge University Press. https://www.researchgate.net/publication/227944437_Loneliness_and_Social_Isolation

Farivar, S., Abouzahra, M., & Ghasemaghaei, M. (2020). Wearable Device Adoption Among Older Adults: A Mixed-Methods Study. *International Journal of Information Management*, *55*, 1–14. https://doi.org/10.1016/j.ijinfomgt.2020.102209

Fields, L. (2022, June 3). *5 Hidden Health Benefits of Pickleball*. SilverSneakers. https://www.silversneakers.com/blog/pickleball-health-benefits/

Friedler, B., Crapser, J., & McCullough, L. (2014). One Is the Deadliest Number: The Detrimental Effects of Social Isolation on Cerebrovascular Diseases and Cognition. *Acta Neuropathologica*, *129*, 493–509. https://doi.org/10.1007/s00401-014-1377-9

Gavelin, H. M., Dong, C., Minkov, R., Bahar-Fuchs, A., Ellis, K. A., Lautenschlager, N. T., Mellow, M. L., Wade, A. T., Smith, A. E., Finke, C., Krohn, S., & Lampit, A. (2021). Combined Physical and Cognitive Training for Older Adults With and Without Cognitive Impairment: A Systematic Review and Network Meta-Analysis of Randomized Controlled Trials. *Ageing Research Reviews*, *66*, 1–15. https://doi.org/10.1016/j.arr.2020.101232

Gerst-Emerson, K., & Jayawardhana, J. (2015). Loneliness as a Public Health Issue: The Impact of Loneliness on Health Care Utilization Among Older Adults. *American Journal of Public Health*, *105*(5), 1013–1019. https://doi.org/10.2105/AJPH.2014.302427

Gierveld, J. de J., & Havens, B. (2004). Cross-National Comparisons of Social Isolation and Loneliness: Introduction and Overview. *Canadian Journal on Aging*, *23*(2), 109–113. https://doi.org/10.1353/cja.2004.0021

Harrington, C. N., Wilcox, L., Connelly, K., Rogers, W., & Sanford, J. (2018). Designing Health and Fitness Apps with Older Adults: Examining the Value of Experience-Based Co-Design. *Proceedings of the 12th EAI International Conference on Pervasive Computing Technologies for Healthcare*, 15–24. https://doi.org/10.1145/3240925.3240929

Hawkley, L. C., Cacioppo, J. T., & Thisted, R. A. (2010). Perceived Social Isolation Makes Me Sad: 5-Year Cross-Lagged Analyses of Loneliness and Depressive Symptomatology in the Chicago Health, Aging, and Social Relations Study. *Psychology and Aging*, *25*(2), 453. https://doi.org/10.1037/a0017216

Heo, J., Ryu, J., Yang, H., Kim, A. C. H., & Rhee, Y. (2018). Importance of Playing Pickleball for Older Adults' Subjective Well-Being: A Serious Leisure Perspective. *The Journal of Positive Psychology*, *13*(1), 67–77. https://doi.org/10.1080/17439760.2017.1374438

Ito, S. (2019). High-Intensity Interval Training for Health Benefits and Care of Cardiac Diseases—The Key to an Efficient Exercise Protocol. *World Journal of Cardiology*, *11*(7), 171–188. https://doi.org/10.4330/wjc.v11.i7.171

Landau, J. (2017, October 3). *Health-Care Dilemma: 10,000 Boomers Retiring Each Day.* https://www.cnbc.com/2017/10/03/health-care-dilemma-10000-boomers-retiring-each-day.html

Lee, C. (2014). Adoption of Smart Technology Among Older Adults: Challenges and Issues. *Public Policy & Aging Report*, *24*(1), 14–17. https://doi.org/10.1093/ppar/prt005

Lee, C. C., Czaja, S. J., Moxley, J. H., Sharit, J., Boot, W. R., Charness, N., & Rogers, W. A. (2019). Attitudes Toward Computers Across Adulthood From 1994 to 2013. *The Gerontologist*, *59*(1), 22–33. https://doi.org/10.1093/geront/gny081

Levy, B. (2022). *Breaking the Age Code: How Your Beliefs About Aging Determine How Long and Well You Live* (1st ed.). William Morrow.

Liu, L., Gou, Z., & Zuo, J. (2016). Social Support Mediates Loneliness and Depression in Elderly People. *Journal of Health Psychology*, *21*(5), 750–758. https://doi.org/10.1177/1359105314536941

Mays, A. M., Kim, S., Rosales, K., Au, T., & Rosen, S. (2021). The Leveraging Exercise to Age in Place (LEAP) Study: Engaging Older Adults in Community-Based Exercise Classes to Impact Loneliness and Social Isolation. *The American Journal of Geriatric Psychiatry*, *29*(8), 1–12. https://doi.org/10.1016/j.jagp.2020.10.006

Meet ERNE. (n.d.). Victory Sports Technologies. Retrieved April 1, 2024, from https://www.ernepickleballmachine.com

Mercer, K., Li, M., Giangregorio, L., Burns, C., & Grindrod, K. (2016). Behavior Change Techniques Present in Wearable Activity Trackers: A Critical Analysis. *JMIR mHealth and uHealth*, *4*(2), 1–9. https://doi.org/10.2196/mhealth.4461

Meuter, M. L., Ostrom, A. L., Bitner, M. J., & Roundtree, R. (2003). The Influence of Technology Anxiety on Consumer Use and Experiences With Self-Service Technologies. *Journal of Business Research*, *56*(11), 899–906. https://doi.org/10.1016/S0148-2963(01)00276-4

Mitzner, T. L., Boron, J. B., Fausset, C. B., Adams, A. E., Charness, N., Czaja, S. J., Dijkstra, K., Fisk, A. D., Rogers, W. A., & Sharit, J. (2010). Older Adults Talk Technology: Technology Usage and Attitudes. *Computers in Human Behavior*, *26*(6), 1710–1721. https://doi.org/10.1016/j.chb.2010.06.020

NIH. (n.d.). *Loneliness and Social Isolation—Tips for Staying Connected*. National Institute on Aging. Retrieved March 31, 2024, from https://www.nia.nih.gov/health/loneliness-and-social-isolation/loneliness-and-social-isolation-tips-staying-connected

North, A. (2023, September 11). *Baby Boomers Are Aging. Their Kids Aren't Ready.* Vox. https://www.vox.com/the-highlight/23850582/millennials-aging-parents-boomers-seniors-family-care-taker

Pels, F., & Kleinert, J. (2016). Loneliness and Physical Activity: A Systematic Review. *International Review of Sport and Exercise Psychology*, *9*(1), 231–260. https://doi.org/10.1080/1750984X.2016.1177849

Pew Research Center. (2024, January 31). Mobile Fact Sheet. *Pew Research Center: Internet, Science & Tech*. https://www.pewresearch.org/internet/fact-sheet/mobile/

Pickleball Tutor Plus. (n.d.). Retrieved April 1, 2024, from https://pickleballtutor.com/pickleball-tutor-plus/

Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., George, S. M., & Olson, R. D. (2018). The Physical Activity Guidelines for Americans. *JAMA*, *320*(19), 2020–2028. https://doi.org/10.1001/jama.2018.14854

Piper, A. M., Campbell, R., & Hollan, J. D. (2010). Exploring the Accessibility and Appeal of Surface Computing for Older Adult Health Care Support. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 907–916. https://doi.org/10.1145/1753326.1753461

Pirhonen, J., Lolich, L., Tuominen, K., Jolanki, O., & Timonen, V. (2020). "These Devices Have Not Been Made for Older People's Needs" – Older Adults' Perceptions of Digital Technologies in Finland and Ireland. *Technology in Society*, *62*, 1–9. https://doi.org/10.1016/j.techsoc.2020.101287

Rico-Uribe, L. A., Caballero, F. F., Martín-María, N., Cabello, M., Ayuso-Mateos, J. L., & Miret, M. (2018). Association of Loneliness With All-Cause Mortality: A Meta-Analysis. *PLOS ONE*, *13*(1), 1–21. https://doi.org/10.1371/journal.pone.0190033

Rietveld, R., van Dolen, W., Mazloom, M., & Worring, M. (2020). What You Feel, Is What You Like Influence of Message Appeals on Customer Engagement on Instagram. *Journal of Interactive Marketing*, *49*, 20–53. https://doi.org/10.1016/j.intmar.2019.06.003

Russell, D. W., Cutrona, C. E., McRae, C., & Gomez, M. (2012). Is Loneliness the Same as Being Alone? *The Journal of Psychology*, *146*(1–2), 7–22. https://doi.org/10.1080/00223980.2011.589414

Ryu, J., Yang, H., Kim, A. C. H., Kim, K. M., & Heo, J. (2018). Understanding Pickleball as a New Leisure Pursuit Among Older Adults. *Educational Gerontology*, *44*(2–3), 128–138. https://doi.org/10.1080/03601277.2018.1424507

Sebastião, E., & Mirda, D. (2021). Group-Based Physical Activity as a Means to Reduce Social Isolation and Loneliness Among Older Adults. *Aging Clinical and Experimental Research*, *33*(7), 2003–2006. https://doi.org/10.1007/s40520-020-01722-w

Shiovitz-Ezra, S., Shemesh, J., & McDonnell/Naughton, M. (2018). Pathways from Ageism to Loneliness. In L. Ayalon & C. Tesch-Römer (Eds.), *Contemporary Perspectives on Ageism* (pp. 369–382). Springer International Publishing. https://doi.org/10.1007/978-3-319-73820-8_9

Steele, R., Lo, A., Secombe, C., & Wong, Y. K. (2009). Elderly Persons' Perception and Acceptance of Using Wireless Sensor Networks to Assist Healthcare. *International Journal of Medical Informatics*, *78*(12), 788–801. https://doi.org/10.1016/j.ijmedinf.2009.08.001

Stepler, R. (2016, February 18). Smaller Share of Women Ages 65 and Older Are Living Alone. *Pew Research Center's Social & Demographic Trends Project*. https://www.pewresearch.org/social-trends/2016/02/18/smaller-share-of-women-ages-65-and-older-are-living-alone/

Sullivan, A. N., & Lachman, M. E. (2017). Behavior Change with Fitness Technology in Sedentary Adults: A Review of the Evidence for Increasing Physical Activity. *Frontiers in Public Health*, *4*, 1–16. https://doi.org/10.3389/fpubh.2016.00289

Trends in Loneliness Among Older Adults from 2018-2023 | National Poll on Healthy Aging. (2023, March 13). https://www.healthyagingpoll.org/reports-more/report/trends-loneliness-among-older-adults-2018-2023

Umberson, D., & Montez, J. K. (2010). Social Relationships and Health: A Flashpoint for Health Policy. *Journal of Health and Social Behavior*, *51*(1_suppl), S54–S66. https://doi.org/10.1177/0022146510383501

Valtorta, N., & Hanratty, B. (2012). Loneliness, Isolation and the Health of Older Adults: Do We Need a New Research Agenda? *Journal of the Royal Society of Medicine*, *105*(12), 518–522. https://doi.org/10.1258/jrsm.2012.120128

Verbeek, P.-P. (2006). *Materializing Morality: Design Ethics and Technological Mediation—Peter-Paul Verbeek, 2006*. *31*(3), 361–380. https://doi.org/10.1177/0162243905285847

Verbeek, P.-P. (2016). Toward a Theory of Technological Mediation: A Program for Postphenomenological Research. In J. K. B. O. Friis & R. P. Crease (Eds.), *Technoscience and Postphenomenology* (p. 189). Lexington Books.

Walsh, K., & Callan, A. (2010). Perceptions, Preferences, and Acceptance of Information and Communication Technologies in Older-Adult Community Care Settings in Ireland: A

Case-Study and Ranked-Care Program Analysis. *Ageing International*, *36*, 102–122. https://doi.org/10.1007/s12126-010-9075-y

Watts, E. L., Matthews, C. E., Freeman, J. R., Gorzelitz, J. S., Hong, H. G., Liao, L. M., McClain, K. M., Saint-Maurice, P. F., Shiroma, E. J., & Moore, S. C. (2022). Association of Leisure Time Physical Activity Types and Risks of All-Cause, Cardiovascular, and Cancer Mortality Among Older Adults. *JAMA Network Open*, *5*(8), 1–14. https://doi.org/10.1001/jamanetworkopen.2022.28510

WHO. (2022, October 1). *Ageing and Health*. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

Wilson, R. S., Krueger, K. R., Arnold, S. E., Schneider, J. A., Kelly, J. F., Barnes, L. L., Tang, Y., & Bennett, D. A. (2007). Loneliness and Risk of Alzheimer Disease. *Archives of General Psychiatry*, *64*(2), 234–240. https://doi.org/10.1001/archpsyc.64.2.234

Wurmser, Y. (2019, January 3). *Wearables 2019*. EMARKETER. https://www.emarketer.com/content/wearables-2019