



What drives older adults' acceptance of virtual humans? A conjoint and latent class analysis on virtual exercise coach attributes for a community-based exercise program

Michael Joseph S. Dino^{a,b,d,h,*}, Kenneth W. Dion^{a,d}, Peter M. Abadir^e, Chakra Budhathoki^a, Chien-Ming Huang^f, William V. Padula^g, Irvin Ong^{a,b,d}, Cheryl R. Dennison Himmelfarb^{a,d}, Patricia M. Davidson^{a,c,d}, Ladda Thiamwong^{d,h}

^a School of Nursing, Johns Hopkins University, Baltimore, MD, 21205, USA

^b Our Lady of Fatima University, Valenzuela City, 1440, Philippines

^c The Vice-Chancellor's Unit, University of Wollongong, NSW, 2522, Australia

^d Sigma Theta Tau International Honor Society in Nursing, Indianapolis, IN, 46202, USA

^e School of Medicine, Johns Hopkins University, Baltimore, MD, 21205, USA

^f Department of Computer Science, Johns Hopkins University, Baltimore, MD, 21218, USA

^g Department of Pharmaceutical and Health Economics, University of Southern California, Los Angeles, CA, 90089, USA

^h College of Nursing, University of Central Florida, USA, Orlando, FL, USA

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ABSTRACT

As an example of health-enhancing physical activities (HEPA), structured physical exercise is valuable in promoting healthy lifestyles among community-dwelling older adults. Technology-driven virtual coaches have the potential to enhance and improve exercise programs, but the preferences of the aging population were not previously explored. This study examined and analyzed the attributes and levels related to the acceptance of virtual coaches among the aging cohort via experience-based conjoint and latent class analysis. Purposively selected respondents ($n = 232$) from two senior centers in the Philippines completed a conjoint activity followed by a computer-based survey focusing on attributes related to platform, appearance, gender, language, and music. Results revealed the subjects' inclination to a humanlike, feminine, local language-speaking virtual coach projected through a mixed reality platform with a contemporary music background. Additionally, latent class analysis outcomes produced three subgroups based on the pattern of preferences among the technology users. Study outcomes reinforce the importance of human-centered design and multidisciplinary approaches to health technology development.

1. Introduction

Population aging as a global phenomenon is generally associated with cognitive and physical decline. For instance, around 50 million people worldwide have a gradual loss of mental functioning (dementia) that causes disability, dependency, and death among the aging population (World Health Organization, 2020). New dementia cases are estimated at 10 million per year, with a financial burden of \$818 billion annually (World Health Organization, 2020). Also, with age, there is a gradual loss of lean muscle mass (sarcopenia), osteoarthritis, and decreased bone density, leading to frailty and a higher risk for falls, both

predominant among the older adult population (Canada, Stephan, Sutin, & Terracciano, 2020; Pilotto et al., 2020).

Forms of health-enhancing physical activity (HEPA) (Whiting et al., 2021), like structured physical exercise are essential for maintaining normal body function, healthy aging, and promoting a longer life span (Eckstrom, Neukam, Kalin, & Wright, 2020). Regular exercise can help reduce frailty, fall risk, and premature morbidity. Multinational campaigns and guidelines recommend the most beneficial multimodal exercise programs: aerobic, resistance training, flexibility, and balance components (Mora & Valencia, 2018). However, despite the tremendous benefits of exercise, studies show that older adults need to be more

* Corresponding author. School of Nursing, Johns Hopkins University, 525 N Wolfe St, Baltimore, MD, 21205, USA.

E-mail address: michaeljoseph.dino@ucf.edu (M.J.S. Dino).

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actively engaged in such health activities. In addition to lacking a structured and enticing program, scholars reported several socio-cognitive processes that impact exercise behavior, adoption, and maintenance (Arovah & Heesch, 2022). In support, scientists have long established the critical role of culture, society, and environment in the success of exercise programs (Watson et al., 2016). This outcome reinforces the development of location and culture-specific country programs and technologies based on cohort preferences and national policy to support older adults' exercise programs (Cunningham & O' Sullivan, 2020), which are currently few and still underdeveloped (Van Hoye et al., 2019).

Many emerging electronic health (eHealth) interventions have centered on behavioral change relating to physical activity. They have shown effectiveness in many instances (Hurmuz et al., 2022). The latest innovations in technology-driven exercise are the utilization of humanoid (human-resembling) technologies (HTs), like physical humanoid robot coaches (HRCs) (Sato et al., 2020; Tanioka et al., 2020). Due to the advent of virtual worlds and mixed-reality applications, virtual humans as embodied conversational agents (ECAs) are also emerging (Hurmuz et al., 2022). The emergence of virtual humans in studies related to health intervention is still a novice but a growing field with increasing acknowledgment of opportunities and challenges surrounding its implementation (Betriana, Tanioka, Gunawan, & Locsin, 2022; Dino, Davidson, Dion, Szanton, & Ong, 2022; Zhao, Lu, Zhou, Mao, & Fei, 2022).

One particular issue reported by scholars is the substantial divide among users and non-users of technologies (Neven, 2010). Furthermore, technology-led interventions have been previously reported to be potentially susceptible to disregard beyond technology availability due to usability issues. As a result, current studies are recommended to focus on developing and evaluating user-preferred technologies using human-centered approaches and innovative research designs (Fattal et al., 2020; Hurmuz et al., 2022). This approach is valuable for understanding how older adults interact with technology and leverage it to meet their needs (Sato et al., 2020) better. In response to the current grey spots and gaps found in a recently published literature review (see Dino et al., 2022), this paper envisions advancing the field of gero-technology interaction by assessing older adults' preferences for an ideal virtual human exercise coach based on several attributes and levels via conjoint analysis. It also aspires to determine natural segments in an older adult population based on their virtual coach preferences through latent class analysis. Conjoint and latent class approaches to healthcare research have been instrumental in discovering client preferences for treatment modalities, service delivery approaches, and provider-patient interactions (S. Chen et al., 2024; Larsen, Tele, & Kumar, 2021). It allows researchers to have better and more focused control of the intervention attributes to generate client predilections and prevent challenges of confounding factors and variations common in preference studies (Bridges et al., 2011).

Research on older adults' technology preferences is relevant because of the heterogeneity of the growing older adult population, which is characterized by varying levels of disability (Portz, 2017), intrinsic capacity (Kulzer, Hermanns, Gorges, Schwarz, & Haak, 2009), and motivation to exercise. Personalized healthcare via virtual coaches may be beneficial for persons experiencing average cognitive decline, such as older adults (Boumans, van de Sande, Thill, & Bosse, 2022). Now more than ever, the healthcare sector is increasingly recognizing the benefits of virtual coaches to aid patients such as older adults in attaining their health priorities while providing participatory and personalized content (Kocaballi et al., 2019) due to their automation and accessibility compared to physical coaches (Luo, Aguilera, Lyles, & Figueroa, 2021). Additionally, virtual coaches are envisioned to give options and alternative solutions to encourage older adults to adhere to self-management techniques (Bevilacqua et al., 2020).

2. Literature review

The literature review provides the groundwork and summary of relevant models and studies on technology-driven health interventions like virtual coaches among older adults. This section is structured as follows: First, the Model of Technology Preference is discussed as the study's theoretical underpinning and framework for the main objective and in determining the attributes of older adults' technology preferences. Second, the literature on the use of technology by older adults was reviewed and revisited to provide an overview of older adults as technology consumers. Third, HEPA among older adults was summarized to explain its value and relevance. Finally, the literature anchor of individual attributes of VH is provided.

2.1. Model of Technology Preference

This conjoint study is anchored on the Model of Technology Preference (MTP; Muthicharoen, Palvia, & Grover, 2011), an extension of the classic intention theories such as the Theory of Reasoned Action (TRA; Ajzen & Fishbein, 1977), Technology Acceptance Model (TAM; Davis, Bagozzi, & Warshaw, 1989), and Theory of Planned Behavior (TPB; Ajzen, 1991). This intention-based model is based on the concepts of attitude and attribute-based preferences. The model also underscores the importance of competing channels and the presentation of multiple and alternative versions of technologies to prospective beneficiaries. In the context of the current investigation, the choice of virtual coach among older adults must involve an explicit comparison of available alternatives to accurately predict their adoption and rejection of the proposed systems. Such activity can benefit studies in the emerging realm of mixed reality, where virtual humans like "exercise coaches" and digital objects can be projected in various ways. Since the model publication, it has been extensively used across multiple health (Cocosila, Farrelly, & Trabelsi, 2023), education (Williamson & Muckle, 2018), and social sciences (El-Gohary, 2012) disciplines, as well as consumer preferences for emerging technologies such as artificial intelligence (Lee, 2020), e-commerce (Wagner, Schramm-Klein, & Steinmann, 2020), e-government (Kumar, Sachan, & Mukherjee, 2017), and virtual communication (Jaafar, Darmawan, & Mohamed Ariffin, 2014)—the MTP theory supported including the multiple levels of attributes incorporated in the study.

2.2. Older adults as technology users

Older adults are emerging technology users. Research suggests that acceptance of technology among older adults is driven by satisfaction, actual use, effectiveness, efficiency, and user willingness (Or & Karsh, 2009). During the COVID-19 pandemic, a qualitative study involving Croatian adults communicated seniors' lack of competence and interest in using technology (Hošnjak & Pavlović, 2021). However, similar research showed positive experiences among Canadian older adults in technology engagement in subjects related to managing their health (Hall, Sattar, Ahmed, & Haase, 2021). There is a need to tailor-fit technology-based health interventions based on older adults' existing values, differing contexts, and environments (Sen, Prybutok, & Prybutok, 2022). In previous years, scholars have also examined older adults' phenomenon and lived experiences related to interventions for health and positive behavioral change using designs beyond post-positivist methodological approaches.

An excellent example is the Adherence for Exercise Rehabilitation (AERO) study conducted in the United Kingdom, (Room, Toye, Boulton, Dawes, & Barker, 2021), where ten purposively selected participants qualitatively described age-related challenges related to exercise compliance and the importance of encouragement. Another study (A. J. Moore, Holden, Foster, & Jinks, 2020) highlighted the relevance of a "therapeutic alliance" between the client and exercise providers as an essential bond for committing to HEPA programs. In a meta-synthesis

study on exercise uptake among South Asian older adults (Horne & Tierney, 2012), researchers have identified empowering and disempowering components of communication, relationships, beliefs, and environment that concretize the value of agents in behavioral change.

2.3. Health enhancing physical activities (HEPA) among older adults

Maintaining a healthy lifestyle encompasses a variety of activities and participation in health-enhancing behaviors. Literature is extant on the positive benefits of HEPA, such as exercise, to the overall well-being of individuals across their lifespan, more so for the older adult cohort. Despite the global pervasiveness of insufficiently active older adults, exacerbated by the COVID-19 pandemic (Cunningham & O' Sullivan, 2020; Guthold, Stevens, Riley, & Bull, 2018), health authorities continue to promote and recommend moderate to vigorous physical activity (Miko et al., 2020; Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010) for at least 150 min per week (Szabo-Reed et al., 2022; World Health Organization, 2021). Researchers consider this research area a classical concern and a “never-ending” story (Szabo-Reed et al., 2022; World Health Organization, 2021). Given the low participation rates, factors that serve as antecedents to exercise preferences, participation, and continuous engagement must receive substantial attention (Hooker, Masters, & Ranby, 2020).

Developing exercise programs for older adults must consider a wealth of scientific literature, support from healthcare providers, and preference identification among its intended participants. Literature reported many incidences where exercise program planning consistently failed to consider the wishes and preferences of individuals, including older adults, in both institutional and community settings (Y.-M. Chen, 2010; Y.-M. Chen & Li, 2014; Dino, Dion, Abadir, Budhathoki, Huang, Padula, et al., 2024; L. J. Phillips & Flesner, 2013; Zubala et al., 2017).

Beyond self-determination theories and established factors relating to individual factors affecting exercise participation, there is an increasing discussion on specific factors influencing older adults' involvement with physical activity programs. The exercise program must possess characteristics that will make it stimulating and motivational to prospective beneficiaries. For instance, the quality and character (e.g., appearance, gender) of personal trainers, most especially during the adaption phase, are deemed to be an influential factor in maintaining their participation in the program (Tulloch et al., 2013). With the advent of Fourth Industrial Revolution Technologies, the emergence of on-demand “virtual human exercise coaches” from exercise systems and gadgets is receiving substantial attention (García-de-Villa, Casillas-Pérez, Jiménez-Martín, & García-Domínguez, 2022).

2.4. Attributes of virtual human exercise coach

This paper postulates that older adults' virtual human exercise coach preferences shall be based on literature-identified attributes (Table 1). Prior work exists that identified several characteristics that are relevant to exercise coach preferences. The gender of virtual human exercise coaches is believed to facilitate exercise activities and provide feedback and encouragement to clients (Kyriazakos et al., 2020). They can be deployed multi-platform through the web (Héroux, Watt, McGuire, & Berardi, 2017), computers, and personal devices (Ding et al., 2010). Virtual human exercise coaches can be displayed via video, virtual reality (VR), augmented reality (AR), and mixed reality (MR) (Dino, Dion, Abadir, Budhathoki, Huang, Ong, et al., 2024; Hülsmann, Göpfert, Hammer, Kopp, & Botsch, 2018), which are considered more cost-efficient than using physical robots (Dino, Dion, Abadir, Budhathoki, Huang, Ong, et al., 2024). The VR reality option utilizes a (closed) head-mounted display to immerse the user in a completely virtual environment without seeing the physical world. AR shows the virtual coach via device screen with the live physical environment as the camera feed background. MR displays the virtual coach via a

see-through head-mounted display, allowing the user to see the physical environment through transparent lenses. An emphasis on anthropomorphism is crucial (Bartneck, Kulić, Croft, & Zoghbi, 2009; E. Phillips, Zhao, Ullman, & Malle, 2018; Spatola & Agnieszka, 2021) for virtual coach development, considering that virtual humans are digital behavior influences (Li, Ham, & Eastin, 2024). In this study, human-like and humanoid virtual coaches were used. A human-like coach presents a virtual human with an Anthropomorphic Robot (ABOT) score (E. Phillips et al., 2018) of 85–95%, while the humanoid version presents a human display with an ABOT score of 25–35%. Participants of certain exercise studies also indicated language (local and global) and music (classic and current) incorporated in virtual human exercise coach programs as valuable factors influencing user preferences (Poveda-López, Montilla-Herrador, Gacto-Sánchez, Romero-Galisteo, & Lillo-Navarro, 2022; Fotakopoulos & Kotlia, 2018; Suwabe et al., 2021; P. Yang, Yang, Cao, Yang, & He, 2022).

Parsimoniously, no studies have been previously conducted that investigate the potential attributes of virtual human exercise coaches for community-based programs intended for older adult end users.

3. Methods

3.1. Research design

Understanding how older adults value and trade features of virtual human exercise coaches through the conjoint approach is crucial to human-centered technology design (Bridges et al., 2011). Conjoint analysis (CA) in the form of a discrete choice experiment involves measuring psychological judgment between choices and alternatives (Bahrampour et al., 2020). It is also influential in understanding and predicting the technology users' attribute tradeoffs, decisions, and preferences of features such as virtual human exercise coaches (Bagozzi, 1994). CA was initially introduced in psychology and marketing but has gained popularity in medicine and healthcare (Szeinbach et al., 2009). CA was deemed appropriate for the current study due to its straightforward, practical, and respondent-friendly features (Herrmann, Schmidt-Gallas, & Huber, 2003). As a challenging group, older adults will benefit more from attribute-focused and experience-based approaches over typical rating scale surveys for a better understanding of emerging technology features, leading to more accurate and reliable data collection. Latent class analysis (LCA) was also employed to identify subgroups of the older population based on their preferences.

3.2. Setting, subject, and sampling











The study was conducted in two senior centers in urban settings in the Philippines. The eligible participants were purposively selected from the study sites using the inclusion criteria: (a) ambulatory, (b) can follow simple instructions, (c) normal eyes functioning (or at most with corrective lenses), and (d) willingness to participate in the program with signed informed consent. Older adults with severe psychological conditions, safety issues, increased risk for arrhythmia, cardiovascular collapse, or respiratory distress, and bedridden will be excluded from participating. A total of 232 older adults were recruited via posters at community senior centers who underwent additional screening and health records review by a certified gerontologist to ensure safety and proper fit.

3.3. Technology and tools

This study followed the published standards for applying conjoint analysis methods in healthcare (Birlo et al., 2022). It included essential steps in the development of the conjoint survey, as follows: (a) defining virtual human exercise coach attributes and levels based on literature evidence, (b) designing and developing the technology options based on attributes and levels, and (c) developing the conjoint survey questionnaire.



Table 1

Theoretical basis of attributes and levels' description.

| Theoretical Bases | Attribute | Levels | Description | Conjoint Image |
|--|------------|----------------|--|---|
| Object visualization can be projected via digital platforms (Chai, O'Sullivan, Gowen, Rooney, & Xu, 2022; Milgram & Kishino, 1994) | Platform | Virtual (VR) | Coach in complete virtual environment viewed at head-mounted (closed) display |  |
| | | Augmented (AR) | Coach overlaid in the actual scene on a display screen |  |
| | | Mixed (MR) | Coach overlaid in the actual scene viewed at a head-mounted (see-through) display |  |
| | | Video | The coach was captured on video and shown on TV |  |
| Levels of human appearance of virtual humans impact user behavior, motivation, cognition, and satisfaction (Spatola & Agnieszka, 2021) | Appearance | Humanlike | Human appearance with an ABOT score of 85–95† (E. Phillips et al., 2018) |  |
| | | Humanoid | Less human-like appearance, with an ABOT score of between 55 and 65 (E. Phillips et al., 2018) |  |
| Gender congruity is a driver of behavior and affinity (Pitardi, Bartikowski, Osburg, & Yoganathan, 2022) | Gender | Masculine | Coach with a masculine appearance |  |
| | | Feminine | Coach with a feminine appearance |  |
| Rhythmic music has a significant facilitatory effect on exercise tasks (Yang et al., 2022) | Music | Classic | Folk and classical music |  |
| | | Current | Modern music |  |

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Table 1 (continued)

| Theoretical Bases | Attribute | Levels | Description | Conjoint Image |
|---|-----------|------------------|-------------------|---|
| Language and location impact user preferences (Paul et al., 2021) | Language | English | English language |  |
| | | Filipino (local) | Filipino language |  |

Initially, a literature review was conducted to identify the levels and attributes of virtual human exercise coaches (Table 1). This step was followed by developing several virtual human exercise coach versions based on the identified levels and attributes. A multidisciplinary team of nurses, physical therapists, medical doctors (sports, gerontologists), software engineers, and programmers worked together to accomplish the technology. The primary software used is the Mixed Reality Toolkit version 2, Unity 2018.4.x, and Unreal Engine. The development team utilized models for motion capture and remix music from GarageBand®. Microsoft Visual Studio was used to debug and deploy the programming code from the development software to the OST-HMD device (Rahaman, Champion, & Bekele, 2019) to address potential issues related to vengeance-accommodation conflict (Arabadzhiyska, Tursun, Seidel, & Didyk, 2022). Finally, the conjoint survey was developed via Sawtooth software. Images, text, and icons referring to several attributes and levels of the virtual human exercise coach (Table 1) were used to enhance understanding of the design attributes and facilitate judgment (Vriens, Loosschilder, Rosbergen, & Wittink, 1998). Pilot testing of the virtual human versions and conjoint survey was deployed under the guidance of a health team.

3.4. Data gathering procedure

Consenting participants were given orientation sessions and the

opportunity to try several versions and features of the virtual human exercise coach. Three (3) experience stations were developed (Fig. 1). Station 1 allows the subjects to visualize the virtual human exercise coach in various platforms, namely video, virtual reality (VR), augmented reality (AR), and mixed reality (MR). Station 2 showcases the icons and images representing the appearance and gender of the virtual humans. Station 3 permits the participants to be exposed to the music and languages integrated into the virtual human exercise coach. After the experience trials, a computer-based conjoint survey (Fig. 2) was deployed to the participants. Participants completed the same flow of immersion to the experience stations and data-gathering activity between 30 and 40 min. Trained research personnel were available to assist the participants in both experience and survey sessions. Protocols were strictly followed to maintain intervention fidelity (Dino et al., 2024) . The older adults conveyed no reports of fatigue and anxiety.

3.5. Measurement and data analysis

A participant demographic questionnaire and computer-based conjoint survey served as study measurements. Descriptive statistics was used to describe the respondent demographics. In the conjoint method, regression analysis is adopted to relate the probability of choosing several profiles simultaneously. The regression model assumes that “the probability of choosing one profile is a linear function of the



Fig. 1. Virtual human experience and data collection stations.

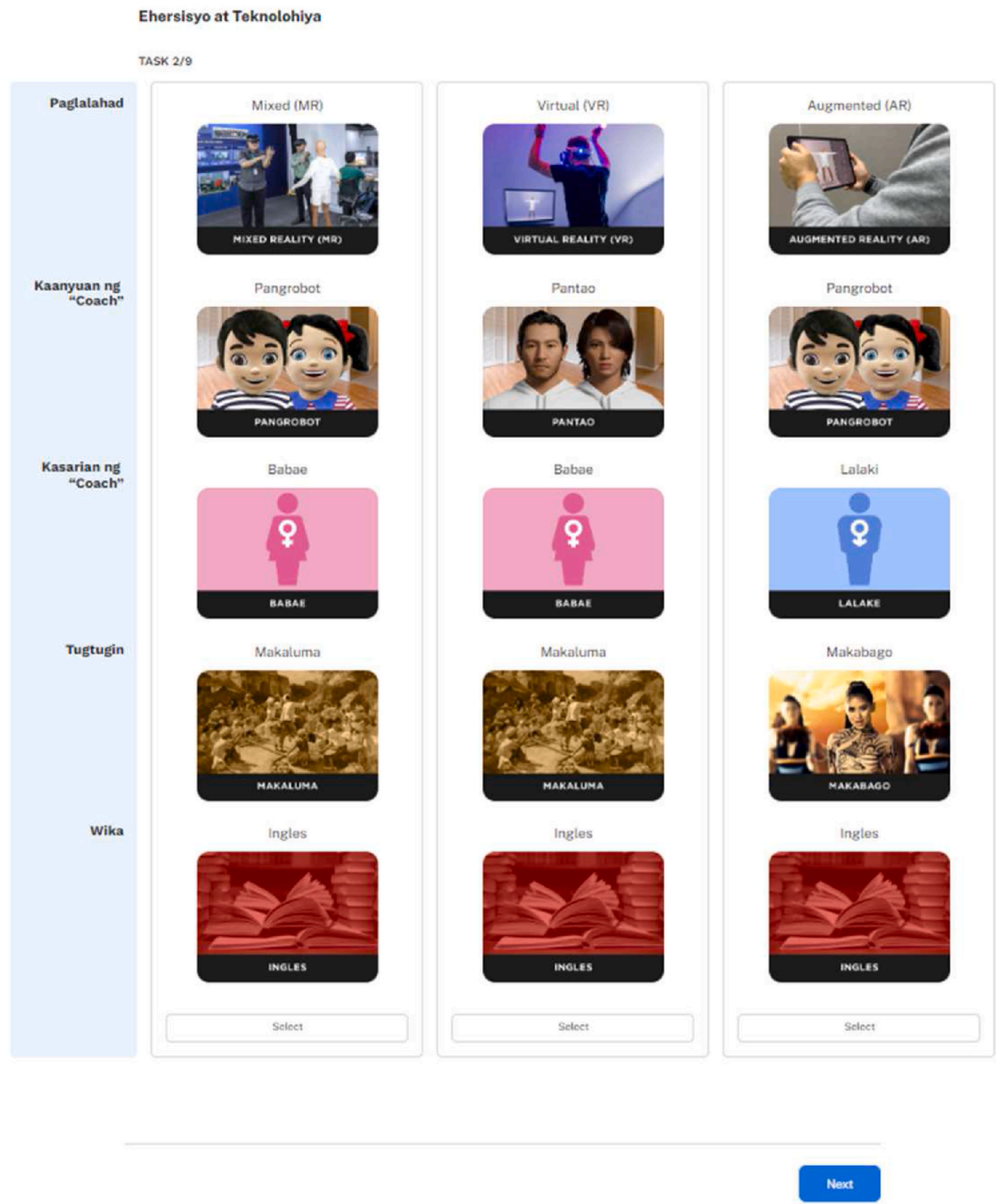


Fig. 2. Sample screenshot of the computer-based conjoint survey via Sawtooth software.

attribute levels in the profile." Sawtooth Software Lighthouse Studio version 9.11 statistical package was employed to calculate individual preference coefficients (utilities) in each attribute level and attribute importance scores (Fazeli et al., 2022). In addition, the primary and joint effects of the preference attributes, average importance, and utility values were also generated (Tasdemir Yigitoglu et al., 2021). The ESTIMATE checklist (Hauber et al., 2016) developed by the ISPOR Conjoint Analysis Good Research Practices Task Force was used to report and interpret the study outcomes. Outputs from the Sawtooth Latent Class standalone program were reported based on published guidelines (Schreiber, 2017).

3.6. Ethics and protection of human subjects

The JHM IRBand OLFU IRBgranted ethical clearances for the study under reference numbers IRB00347131 and 2022-IERC1-20299V2-01, respectively.

4. Results

4.1. Participant characteristics

A total of 232 responses were captured from community-dwelling

older adults. Their demographic, technology, and health characteristics are summarized in Table 2. Most respondents were female (89.22%), aged 60–65 (45.26%), married (57.33%). Approximately a third of the subjects completed a bachelor's degree and above (30.17%), and most have self-rated their technology competency and literacy as good (51.27% and 56.90%, respectively). More than half of the respondents perceived their health as good (67.67%).

4.2. Virtual coach attributes and levels

As Table 3 demonstrates, the most influential factor affecting older adults' virtual coach preference for community-based exercise programs was platform (35.53%), followed by appearance (18.61%), language (18.25%), and gender (15.29%). Interestingly, music was the most minor preferred attribute (12.33%).

Mixed reality (37.28) and video (20.09) were most favored over virtual reality (−19.76) and augmented reality (−19.76) among the levels of the attribute 'platform.' Respondents had specific preferences for humanlike (39.20) female (19.30) coach that speaks the local language (31.48) with contemporary melody (11.15) in terms of 'gender,' 'language,' and 'music' attributes, respectively. These findings are illustrated in Fig. 3.

4.3. Latent class analysis

A maximum run of five clusters was performed since no theoretical number of clusters is expected. Table 4 shows the five potential models with corresponding segment and model fit values. Given the lack of consensus in selecting the number of segments, the decision followed the general recommendations (Sawtooth Software, 2021), which were: (a) smaller CAIC, (b) larger relative chi-square, and (c) lower AIC, BIC, and ABIC. After examining the patterns and inflections (Schreiber, 2017), the three-group model demonstrated a balance of good fit as a solution and acceptable number of segments due to its moderate relative chi-square (14.19), CAIC (4460.34), and AIC (4307.53), lower BIC (4437.34) and lowest ABIC (4364.27). Its theoretical interpretability was the most logical, with a maximum membership value of 81% compared to other generated clusters.

Table 2
Participants' demographic, technology, and health characteristics (n = 232).

| Characteristics | n | % |
|---------------------------------|-----|-------|
| Gender | | |
| Female | 207 | 89.22 |
| Male | 25 | 10.78 |
| Age | | |
| 60-65 | 105 | 45.26 |
| 66-70 | 75 | 32.33 |
| 71-75 | 52 | 22.41 |
| Marital Status | | |
| Single | 21 | 9.05 |
| Married | 133 | 57.33 |
| Separated | 78 | 33.62 |
| Education | | |
| Less than high school | 80 | 34.48 |
| Highschool | 82 | 35.34 |
| Bachelor's degree and above | 70 | 30.17 |
| Technology competency | | |
| Poor | 80 | 34.48 |
| Good | 119 | 51.29 |
| Excellent | 33 | 14.22 |
| Technology literacy | | |
| Poor | 75 | 32.33 |
| Good | 132 | 56.90 |
| Excellent | 25 | 10.78 |
| Perceived General Health Status | | |
| Poor | 20 | 8.62 |
| Good | 157 | 67.67 |
| Excellent | 55 | 23.71 |

Table 3

Utility estimates and relative importance of virtual coach attributes and levels.

| Attribute | Relative Importance | Utility Estimate | SE |
|-------------------|---------------------|------------------|------|
| Platform | 35.53% | | |
| Virtual Reality | | −19.76 | 4.47 |
| Augmented Reality | | −37.61 | 3.41 |
| Mixed Reality | | 37.28 | 5.24 |
| Video | | 20.09 | 5.02 |
| Appearance | 18.61% | | |
| Humanlike | | 39.20 | 2.62 |
| Humanoid | | −39.20 | 2.62 |
| Music | 12.33% | | |
| Classic | | −11.15 | 2.47 |
| Current | | 11.15 | 2.47 |
| Language | 18.25% | | |
| English | | −31.48 | 3.11 |
| Filipino | | 31.48 | 3.11 |
| Gender | 15.29% | | |
| Masculine | | −19.30 | 2.71 |
| Feminine | | 19.30 | 2.71 |

Table 5 shows the distinguishable patterns of virtual coach preferences for the three-class LCA model based on rescaled segment utilities and attribute importance. Cluster 1 included 17.6% (41/232) of the respondents described as the "Explorers". Older adults in this cluster considered the attribute "platform" to be the most important. They highly preferred a humanlike English-speaking virtual coach projected through mixed reality with accompanying modern music. Most older adult participants (47.7%; 111/232) were the "Listeners" cluster members. They considered language use the most important attribute, with a high preference for employing local dialects for the virtual coach. They want humanlike virtual coaches projected through virtual reality and mixed reality. Cluster 3 participants (34.7%; 80/232) are tagged as the "Viewers" due to their prioritization of the "platform" attribute, particularly video-based virtual coaches. They want humanlike coaches with classic music accompaniment.

5. Discussion

A novel experience-based approach in the conjoint and latent class study was implemented to capture older adults' preferences for a mixed-reality virtual coach. The cohorts from two senior centers have attractive virtual coach preferences in specific areas of the mixed reality program's platform, appearance, language, gender, and music. This study also revealed three specific sub-groups of technology program users based on their characteristics and inclinations.

5.1. Participant characteristics

There is a robust research base concerning the role of participants' characteristics in their choices and preferences in technology (Gell, Rosenberg, Demiris, LaCroix, & Patel, 2015). These factors may provide clarity and understanding of the patterns of technology inclinations among end users. This section provides an overview of the respondents' characteristics that may limit the generalizability of the results. As the Model of Technology Preference (MTP) advances, technology studies must consider the unique features of the target end users in multiple contexts and settings (Muthitharoen et al., 2011).

Study results indicate that most respondents are married, educated females from the younger-old older adult group. This outcome is due to the nature of the voluntary study participation, and similar programs in the study site have been commonly participated in by older female adults in previous years. In the Philippines, females have higher life expectancies than men (World Bank, 2023a). Advances in health technology and services in the Philippines have eradicated many diseases that previously resulted in increased mortality and yielded improvements in life expectancy (Flores-Coscolluela & Faustino, 2014).

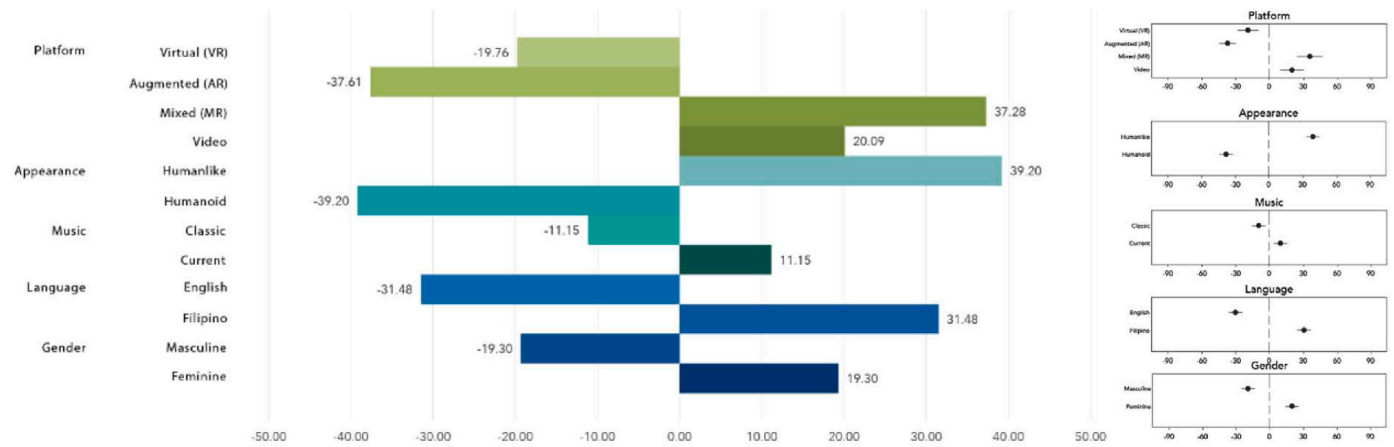


Fig. 3. Utility estimates of virtual coach levels.

Table 4
Segments and model fit statistics.

| Cluster | LL | PC | AIC | CAIC | BIC | ABIC | χ^2 | Relative χ^2 | AMM |
|---------|----------|------|---------|---------|---------|---------|----------|-------------------|------|
| 1 | -2195.81 | 4.28 | 4405.63 | 4452.13 | 4445.13 | 4422.89 | 196.18 | 28.03 | 100 |
| 2 | -2156.73 | 5.98 | 4343.47 | 4443.13 | 4428.13 | 4380.47 | 274.34 | 18.29 | 0.93 |
| 3 | -2130.77 | 7.11 | 4307.53 | 4460.34 | 4437.34 | 4364.27 | 326.27 | 14.19 | 0.81 |
| 4 | -2113.37 | 7.87 | 4288.75 | 4494.71 | 4463.71 | 4365.22 | 361.06 | 11.65 | 0.80 |
| 5 | -2097.91 | 8.54 | 4273.81 | 4532.92 | 4493.92 | 4370.02 | 391.99 | 10.05 | 0.78 |

Note. LL = log-likelihood, PC = Percent Certainty, AIC = Akaike Information Criterion, CAIC = consistent AIC, BIC = Bayesian information criterion, ABIC = Adjusted BIC, χ^2 = Chi-Square, AMM = Average Maximum Membership.

Table 5
Rescaled segment utilities and attribute importance (n = 232).

| Attributes and Levels | Explorers (n = 41) | Listeners (n = 111) | Viewers (n = 80) |
|-----------------------|--------------------|---------------------|--------------------|
| Platform | 59.60 ^a | 11.99 | 55.46 ^a |
| Virtual Reality | -96.45 | 26.24 | -44.93 |
| Augmented Reality | -61.10 | -14.44 | -95.78 |
| Mixed Reality | 201.54 | 21.92 | -40.79 |
| Video | -43.99 | -33.72 | 181.51 |
| Appearance | 17.09 | 23.89 | 18.31 |
| Humanlike | 42.73 | 59.72 | 45.77 |
| Humanoid | -42.73 | -59.72 | -45.77 |
| Gender | 7.34 | 23.28 | 7.71 |
| Masculine | -18.34 | -58.20 | 19.27 |
| Feminine | 18.34 | 58.20 | -19.27 |
| Music | 9.77 | 0.85 | 15.65 |
| Classic | -24.42 | 2.13 | -39.13 |
| Current | 24.42 | -2.13 | 39.13 |
| Language | 6.21 | 39.99 ^a | 2.87 |
| English | 15.53 | -99.97 | 7.19 |
| Filipino | -15.53 | 99.97 | -7.19 |

Note. Attributes are reported as relative importance and respective levels as utility estimates.

^a Highest relative importance.

Consistent in both genders, the country is gradually transitioning to an aging society due to the declining share of the younger cohort (World Bank, 2023b).

Consistent with expectations, Filipino older adults from cities and municipalities rate themselves as having good health status, although they reported several illnesses and functional abilities (de Leon, 2014; Reyes, Arboneda, & Asis, 2019). Although they acknowledge the physical challenges associated with aging, Filipino seniors generally have a positive outlook regarding senescence as a period of productivity, creativity, fulfillment, and extraordinary experiences (Esteban, 2015; Valdez, Angeles, Pareja-Corpuz, & Hernandez, 2013). This perception is

attributed to self-actualization, dignity, and respect from their affiliations and society (Badana & Andel, 2018), essential in achieving multidimensional health.

The older adult participants rated themselves as technology literate and competent in their technology assessment. Globally, it has been reported that older adults are already transitioning from being technology-defiant to digitally connected, owning and using technologies at the same rate as their younger counterparts (Anderson & Perrin, 2017). Since most of the study respondents are young and educated to some degree. Results in this area concur with studies that show the congruence of technology use with age and educational attainment (Anderson & Perrin, 2017). The development of the digital society also encourages even the older adult cohort to utilize technology in their daily life (Yasuoka, 2023), which the COVID-19 pandemic has further intensified (Melchiorre, Cerea, Socci, & Lamura, 2023). The “grey digital divide” (Millward, 2003) in technology is narrowing (Tirado-Morueta, Rodríguez-Martín, Álvarez-Arregui, Ortíz-Sobrinho, & Aguaded-Gómez, 2023), and technology adoption among seniors is inevitable. Study results on participants’ characteristics communicate the knowledge-translation potential of the study to older adult groups from similar contexts, such as the Philippines.

5.2. Relative importance of virtual coach attributes

This section showcases the degree of importance and preferences of older adult users on selected attributes of the virtual coach. Based on MTP (Muthitharoen et al., 2011), identifying the relative significance of technology attributes is essential in prioritizing technology components and developing strategies for technology adoption. It was discovered that the platform in which the virtual coach was projected to the older adult users is the most essential attribute among others. This finding is similar to an earlier study suggesting that the platform utilized for technology activities can help sustain user engagement (Mohammad, Yusof, Puaad, Jamal, & Wee, 2023). This outcome indicates that the technology used in projecting the virtual human coach matters to older

adults. A stream of classic and contemporary studies (Fazio & Zanna, 1978; Hattula, Herzog, & Dhar, 2023; Rucker, Tormala, Petty, & Briñol, 2014) suggests that user experience with the product is among the most valuable antecedents of choice confidence. Notably, studies also showed that the perceived experience with the technology ultimately drives confidence level compared with experience (Rucker et al., 2014). This understanding is advantageous in mixed reality technologies since virtual objects mimic natural objects in the real world and further reinforce the application of human-centered technology design (Beres et al., 2019; Dino et al., 2022; Gualtieri, Revolti, & Dallasega, 2023; Ward, Skubic, Rantz, & Vorderstrasse, 2020).

It was also uncovered that gender is the least essential attribute in virtual coach preference. In the healthcare field, there is a well-established theory on the choice of same-sex healthcare providers, most especially in situations where patients need to share confidential gender-related health concerns (Furnham, Petrides, & Temple, 2006). In coaching, female mentors are preferred (Furnham, Grover, & McClelland, 2023; Rojon, Bode, & McDowall, 2020). Additionally, previous studies showed that clients shared a greater preference for practitioners from their ethnicity (Ahmad, 2002). Results in this area may be influenced by the physical attributes of the developed virtual coach, which are based on the physical features of the local individuals in communities where the older adults reside. Hence, the gender of the virtual human may not be an essential determinant of coach choice among older adults since exercise coaching is typically a one-way health promotion activity. This understanding reinforces a more gender-inclusive choice of virtual humans among the senior cohort.

5.3. Utility estimates of virtual coach attributes' levels

Specific preferences on virtual attributes' levels were identified as MTP underscores the relevance of evaluating several complementary and competing options in developing technology features (Muthithcharoen et al., 2011). It was found that mixed reality (MR), where older adult users wear head-mounted see-through devices to see the virtual coach, is the most preferred technology platform. This outcome challenges previous claims that headsets are difficult to set up and uncomfortable for the aging cohort (Bermúdez I Badia et al., 2023). In this study, the digital 3D virtual coach was overlaid in the natural environment through a spatial mapping strategy, and older adults can see the virtual human strategically positioned in front of them. Seeing through the transparent lens, the participants can also see the natural environment, hence eliminating the incidence of imbalance and "cybersickness" (or negative symptoms related to proprioceptive sensory mismatch), which is expected to fully immersive platforms such as virtual reality (VR) (Drazich et al., 2023). This study revealed that video-based virtual coaches are more preferred than augmented reality (AR) and virtual reality (VR). This outcome might be explained by the older adults' previous experiences with non-immersive audio-video and avoidance of cybersickness-related symptoms. In augmented reality projected through a tablet device, the screen is smaller, and following the exercise instructions from the virtual human from a limited screen space may be difficult for older adult users.

Older adult users prefer virtual humanlike (less appearing human) to humanoid virtual coaches. This outcome reinforces the phenomenon where humans elicit negative responses or "eerie" feelings towards robotic objects that seem "almost human." Known as the Uncanny Valley hypothesis (Mori, MacDorman, & Kageki, 2012), this assumption has been proven and applied in numerous studies and projects concerning the development of physical anthropomorphic robots and virtual humans (Minh Trieu & Truong Thanh, 2023).

Virtual coaches speaking the local language (Filipino) were chosen over the international language (English). Though English is one of the official languages in the Philippines and Filipinos are proficient in it (Santos, Fernandez, & Ilustre, 2022), older adults wish to privilege using the native dialect in exercise coaching. It coincides with the previous

finding on gender as the minor preferred attribute since the Filipino language is also gender-neutral (Yoon & Pratt, 2023). Nevertheless, utility estimates revealed that female coaches are more favored.

Contemporary music is preferred over classical music for the virtual coach program. This result may be attributed to the indispensable role of media in the society. Contemporary local music dominates social, internet, and mainstream media. With the advent of digital social media, foreign influences on song preferences are highly evident (Rojo, Flores, Bunagan, Dela Cruz, & Dionisio, 2022). Classic folk songs are only heard nowadays if accessed through in-demand sources.

Findings in this area echo the importance of human-like, client gender, local language, and contemporary music features as necessary components of developing virtual coaches for older adults.

5.4. Latent class analysis

Subclasses of older adults based on their pattern of inclinations were also examined. The analysis generated three distinct groups of respondents as characterized by their cohort's high preferences for immersive mixed reality (the "Explorers"), language use (the "Listeners"), and conventional video-based virtual coach (the "Viewers"). These outcomes revealed the importance of vernacular, as well as the presence of early adopters and laggards in technology. A large-scale field study (R. C. Moore, Hancock, & Bailenson, 2023) revealed a substantial variation among older adults based on how they use technology. This outcome is due to the documented differences in health and social attributes that shape their preferences and emotional experiences in the innovation (Carstensen, 1998; Jaul & Barron, 2017). For the aging cohort, it is necessary to adopt participatory design approaches to tailor health technologies to be helpful for the target end-users (Turner, Flood, & LaMonica, 2023). However, identifying the preferences of subgroups within the older adult clusters will make technology appropriate and the perfect fit. Results in this section convey the possibility of developing three different modes, versions, or selections in a virtual coach mixed reality program to ensure applicability to target end-users. MTP highlights the importance of providing users with various service channels and options to deliver consistent service value (Muthithcharoen et al., 2011).

6. Study limitations

This work considers the broad field of mixed reality research and has provided an initial groundwork for upcoming, similar studies on gero-technology. Similar to other research work, this paper has inherent limitations related to the variables involved, study respondents, and target location. The researchers limited the focus of the study to the Philippines and core variables and attributes identified from the literature, which may be different in other contexts of technology adoption. As a developing nation with unique demographic features, the Philippines may have a different approach to technology development based on its population and culture. Although study findings may apply to countries with similar characteristics, future scholars may include additional interesting and equally valuable attributes of virtual humans (e.g., speaking voice, colors) in their work in other locations with advanced or inferior technology and fields of experience and expertise. Using artificial intelligence to make the virtual agent a conversational coach may also provide additional advantages. The present study also involved a majority of female end users, and future studies may provide more insights into the preferences of the male cohort for gender-inclusive technology development. Investigating the technology controls and user interfaces in mixed reality technology may also offer extended understanding in advancing human-computer and human-humanoid interaction in this promising area of inquiry.

7. Conclusion

This study uses a robust experience-based approach in conjoint research to explore older adults' preferences for a virtual human coach for a community-based exercise program. It is the first of its kind to introduce a practical experience component to a conjoint study involving a promising mixed-reality virtual coach technology for older adults. Platform emerged as the most essential attribute, and gender was the least important. The subjects desired a humanlike, feminine, local language-speaking virtual coach projected through a mixed reality platform with a contemporary music background. Latent class analysis outcomes revealed three subgroups based on their pattern of preferences. Findings supported and challenged the outcomes of previous studies but have strengthened the importance of human-centered design in developing technologies in the virtual world. Researchers and technology developers may benefit from these results by acknowledging the older adult cohort's unique but practical needs and preferences. It is expected that studies involving the technologies for the greying population will increase as older adults become equally active in the virtual space. A multidisciplinary approach to respond to these challenges is imperative to advance the development of user-preferred and relevant technologies and improve the quality of life of older adult human beings with the help of virtual humans.

CRedit authorship contribution statement

Michael Joseph S. Dino: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Kenneth W. Dion:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Peter M. Abadir:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Chakra Budhathoki:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Chien-Ming Huang:** Writing – review & editing, Supervision, Methodology, Conceptualization. **William V. Padula:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Irvin Ong:** Writing – review & editing, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Cheryl R. Dennison Himmelfarb:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Conceptualization. **Patricia M. Davidson:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ladda Thiamwong:** Funding acquisition, Methodology, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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