The Dynamics of Younger and Older Adult's Paired Behavior when Playing an Interactive Silhouette Game

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ABSTRACT

In this paper, we report on the findings of an acute trial in which we evaluate the design of a novel gesture-based game. 60 younger and older players, divided into three separate group-types: (i) Young-Young, (ii) Old-Old, and (iii) Young-Old, took part in the study. The primary aim of this work was to evaluate the communicative and cooperative behavior of same-age and mixed-age pairs, with secondary interests in their perceived ease-of-use of the game. A mixed-method approach was used, comprising of direct observations, a post-game questionnaire and paired interviews. Our results identified noticeable differences between the group-types, with the Young-Old showing more physical cooperation, as compared to the same-age groups. The work elaborates on how the young and old differ in expectations and perceived interaction, and concludes with some recommendations for future research.

Author Keywords

Intergenerational relations; older adults; silhouette interaction; cooperation; digital games.

INTRODUCTION

Over recent years, a number of studies have examined the efficacy of commercial video games as therapy tools for improving and maintaining well-being in later life. These include digital games for neuro-rehabilitation or cognitive training in older adults [e.g. 20]. However, the improvement and maintenance of well-being is not limited to one's physical or cognitive health, but can also be extended to the social domain.

Play is perceived to be an important channel for the development and maintenance of social attachments within the family [14]. As such, social interaction with grandchildren is foreseen to be a strong motivational factor for many older adults in the adoption of digital games [29], as games that involve intergenerational interaction have the potential to enhance communication, develop problem-solving and literacy skills, as well as foster relationships between different age cohorts [e.g. see 4]. In particular, Voida and Greenberg [30] report that digital games can be considered as a *social bridge* for cross-generational families who play them. Yet, despite a need to better understand how to design such games, there remains a lack of available research [1, 5, 29].

In this paper we describe the design and evaluation of pairs of younger and older adults when playing a novel gesture-based game, to understand how mixed-age and same-age players interact together over a single session. Building on our preliminary published work [23] we investigate aspects of partner preference, communication and cooperation within the context of intra- and intergenerational gameplay, as well as general ease-of-use. Specifically, in reporting on more detailed qualitative findings to our earlier results [23], a key aspect of this research is to understand how digital games can encourage social interaction between generations, shaped by differences in requirements, values and needs.

More specifically, the authors aim to address the following questions: (1) does the type of social interaction differ for different age pairs (i.e., Young-Young, Young-Old, Old-Old); (2) how do different age groups perceive their gameplay competency and experience; and (3) how do the findings from the current study inform us about the design of intergenerational games.

INTERGENERATIONAL GAMES

Previous studies have looked at fostering intergenerational relations through digital gameplay. These include understanding how intergenerational games can be supported through appropriate mental models and digital affordances [29], or be aided through live video chatting facilities for remote gameplay collaboration [5]. Attempts have also been made to differentiate the interaction for older adults by modifying the amount of gameplay challenge between age groups [10].

Studies indicate there is a preference towards designing cooperative compared to competitive intergenerational games. Al Mahmud et al. [1] reasoned that older adults tend to engage cooperatively, and seek more agreement and confirmation of actions from other players compared to children. This is supported by Gajadhar et al. [6] who identified that in co-located gameplay, older adults have a higher tendency to want to help, rather than compete against other players. They further suggest a lack of *social competitiveness* in older adults relates to generational differences in the perceptions associated with digital games and age-related lifestyles. In comparison, children will often become competitive if they perceive themselves to have a gameplay advantage [4]. Subsequently, the over-competitiveness of younger players has been reported to be a detracting factor in gameplay for some older adults [18].

In terms of player roles, Voida and Greenberg [30] have identified that younger players are more pro-active in deciding the types of games played. Likewise, they suggest some passivity in older adult's interaction in allocating more gameplay time to younger players [30]. Chiong [4] highlights this gameplay disparity, and attributes it to a lack of knowledge that many adults have in understanding digital games, leading children as more likely to be the 'authority' of the interaction. Chiong [4] further denotes that much of the interaction between children and their parents involves the learning of rules, as games played tend to be short and familiar to the dyad.

The potential benefits of intergenerational games can be far-reaching, as grandchildren who perceive having a close relationship to their grandparents favorably report more positive attitudes about them [3]. Strong intergenerational bonds can also reduce segregation and prevent ageism [13], as grandparents can provide strong emotional support to older grandchildren [24]. Despite this, relatively little is known about what motivates the young and old to play digital games together, the types of *triggers* that might stimulate interaction, or how digital games could accommodate for different skill-sets, without biasing the interaction towards one age group.

A growing number of studies have explored ageing and gameplay within areas of rehabilitation and physical therapy; however these studies do not necessarily translate into effective intergenerational game design. For example, Gerling et al. [7] provide recommendations for institutionalized older adults with physical impairments using a small set of gesture movements, while Alankus et al. [2] have explored digital games to improve the physical coordination in stroke patients. While interesting, these specialized groups present a very different set of requirements to designing for healthy older adults, and the purpose of looking at gameplay as a form of social bonding across generations.

In this paper, the focus on adolescent players is supported by studies that have identified less favorable perceptions by young adults towards old age. For example, Sanders et al. [25] identified that amongst undergraduate college students, increasing the age of older adults' significantly reduced positive perceptions towards them. Similarly, McCann et al. [15] reports that discomfort and uncertainty by younger adults in interacting with elders can lead to a stronger obligation to be respectful. On the other hand, a reduction in familial interaction due to lifestyle changes and household re-structuring has called for new synergies of intergenerational exchange across non-family age groups [28]. In particular, *generational re-engagement* across a wider platform of community involved projects [28]. As such, the author's focus on evaluating with *strangers* (as opposed to family members) is driven by interests in understanding how the attributes of digital games can be utilized within community practices to encourage collaboration, friendship and learning.

THE GAME ENVIRONMENT

The notion of communicating using a digitalized shadow or silhouette has been investigated in areas ranging from computer graphics, HCI and the performing arts. Much of this current literature is pre-dated by the work of Krueger et al. [12] and the proposal of utilizing graphical imagery to manipulate two-dimensional objects within an augmented environment.

More recently, this concept has been used to engage interaction between actors and their associated audience, using thermal cameras to detect body regions, which are then image-processed and projected on a two-way theatrical slit screen [17]. Other approaches allow the user to transform their silhouette size by altering their position to a relative light source [26]. In terms of applications, Tang and Minneman [27] developed a remote drawing tool, capturing the shadows of body gestures as a means of reducing the sense of distance between two remote collaborators. Alternatively, Okamoto et al. [19] used shadow detection to create a sense of social presence between multiple users. Thus, in summarizing [17, 19, 26, 27], the characteristics of 'shadow interactivity' can be described as 1) providing direct and clear visual feedback with graphical objects over distance; 2) providing a sense of personal embodiment and a virtual 'extension of oneself', and 3) alerting the presence of others within a sharable, interactive space.

System Architecture

Consisting of a projector, large-screen projection screen and a laptop with an integrated web-camera, the goal of the system is to track the silhouette of the player and represent them virtually on-screen. To do this, the system uses two established computer vision techniques known as *frame differencing* and *blob detection*. Frame differencing first captures an image of the play area, and then subtracts that image from subsequent camera images. When a foreign entity enters this area (e.g. a player), the frame differencing technique detects their presence in the form of differentiated pixels. Blob detection then clusters the differentiated pixels in close proximity to form 'blobs'. These blobs form the virtual silhouette, which acts as a form of feedback and mode of interaction for virtual objects. Advantageously, our system's approach does not require the use of depth information to detect players, such as Kinect-driven applications. Comparatively, the system is able to detect non-human objects to complement players as controllers (e.g. walking stick, umbrella, or over-sized gloves, etc.). Within an approximate distance of 1.5 meters or greater to the camera, full body detection can be robustly captured.

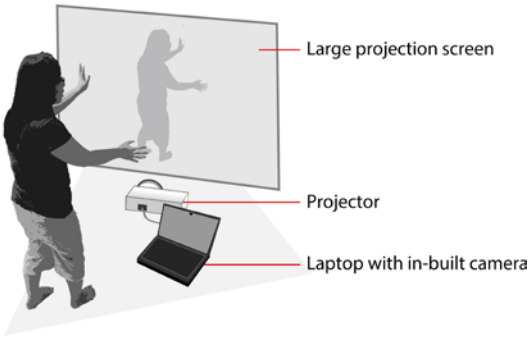

Figure 1. The game setup.

The game - Xtreme Gardener

This work is originally built on the design and evaluation of a small set of gesture-based games with 36 older adults, to identify player's acceptance to full body interaction using a silhouette metaphor [21]. Entitled *Xtreme Gardener*, the objective of this game is to assist in the nurturing and growth of a small set of garden plants through the manipulation and control of various weather elements. In total, there are 5 progressive levels, which are designed as separate days. Players are able to interact with on-screen graphical objects using their two-dimensional silhouette, which utilizes features like 'power-up buttons', requiring a player to hover their hand over a graphical object for 3 seconds. This is designed to ensure buttons are not accidently triggered by a player's silhouette. An on-screen tutorial is provided, while for rewards, players win virtual money for the number of plants they successfully keep alive. This money can then be used to customize plant features.

A range of mainly upper body movements is integrated into the game (i.e. stretching of arms, bending or light twisting), as well as quicker swiping and punching actions to interact with faster moving on-screen objects. Players are also able to enlarge or reduce the size of their silhouette, relative to the distance to screen, as well as merge silhouettes together for more coupled actions (Figure 2.c).

Designed to encourage collaboration, the game consists of the following features:

Weather conditions. Players have to maintain the optimum amount of sunlight and water fed to plants by guiding the direction of rain droplets, or shielding them from too many sunrays (Figure 2.a). These are indicated by associated water, sun and health bars. In harsher weather conditions, they must also prevent destructive lightning strikes and eliminate attacking birds (Figure 2.b). As players progress between levels, more coordinated actions are required to control multiple conditions (e.g. attacking birds with heavier rainfall).

Weather forecast. Foretells the different weather conditions for each day. Displayed before the start of each level, this feature is designed to encourage players to jointly plan ahead. During the gameplay a graphical timeline is used at the top of the screen to indicate a change in the weather condition.

Screen configuration. This includes re-positioning plants or equipping them with modifiers to alter their resilience to harsher weather (e.g. a change of soil-type to affect the rate of water loss, or sun block to reduce the rate of intake of sunlight). Players can also buy new seedlings to replace those that have wilted and died. The configuration screen is automatically re-visited at the end of each level.

METHOD

Using a between-subjects design, the aim of the study was to compare the gameplay interaction and general perceptions of engagement across three groups of younger and older players. Two separate pilot studies were conducted with 12 participants to test out the balance of levels, visual design and gestures that would be suitable for both age groups in the prototype game. Appropriate amendments were subsequently made.

Participants

As stated in [23], 60 participants (16 males and 44 females) took part in the study. The mean age of the younger adults was 18.0 years (*SD* = 1.87) with an age range of 15 to 20 years, while for the older participants it was 61.3 years (*SD* = 5.08) with an age range of 55 to 74 years. Participants were matched together based on their age and gender, and divided into one of three groups: Young-Young (Y-Y), Young-Old (Y-O) or Old-Old (O-O). Each group consisted of 20 participants, separated into 10 pairs. Each session was conducted with one pair of participants and completed over approximately 90 minutes. For consistency, participants did not know each other prior to the start of the study.

Procedure

Participants were first introduced to each other and briefed on the purpose of the research. Upon consent, a background questionnaire was given that contained questions regarding socio-demographic data and general technology experience (including prior gameplay experience). Participants were then introduced to the game concept through a short interactive tutorial to guide them through the associated features, and become accustomed with using the shadow interaction. Once familiar, the pair was given 30 minutes to complete up to five levels of the game. On completion, participants answered a post-game questionnaire, followed by a semi-structured interview conducted by two facilitators, which typically lasted between 20-25 minutes. This was designed to review participants' perceptions and preferences to the prototype game, and included questions that focused on their interactive experience during the

Figure 2: Screenshots of the Xtreme Gardener game with study participants.

gameplay, and the suitability of the game for different age groups (e.g. *how well did you interact together? - Did you find the game suitable for your age group?*). Participants were also probed to provide rationales for their responses. Finally participants were debriefed.

Measures

For the post-game questionnaire, 22 items were designed to assess 5 constructs. Three of these constructs reported on the social interaction of the gameplay: *Co-operation* (COOP), *Communication* (COMM) and *Partner Preference* (PAR PREF). In addition, a further two constructs were used to assess the appropriateness and usability of the game: *Ease of Use* (EOU) and *Competence* (COMP) (see Table 1). Designed by the authors, questions 18 and 19 drew influence from the Game Experience Questionnaire [9], while question 8 is cited from [8]. All items in the questionnaire were rated on a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree) and included both positive and negative statements that were randomly ordered in the questionnaire. After reverse coding for the negative statements, a score was obtained for each construct by averaging the item scores within the constructs.

Data analysis

Observational data from the video recordings were reviewed to quantify differences in user behavior. To assist in this analysis, related video segments were time-stamped. A coding scheme was developed based on Yoder and Symons [32] methodology for measuring cooperative behavior. The observers analyzing the videos agreed on the coding scheme, and divided the coding for cooperation into *Verbal Cooperative*, *Physical Cooperative*, and *Non-compliance*. These cooperative behaviors were defined as an action (physical or verbal) performed by a player to assist their partner in the game without prior instruction; specifically:

- **Verbal Cooperative:** Cooperative behavior shown by a partner that utilizes spoken words (e.g. warning of a prevailing danger).
- **Physical Cooperative**: Cooperative behavior shown by a partner that utilizes a physical action or gesture (e.g. nudging a partner, or shielding a partner's plants without their request).
- **Non-compliance**: Intention given by one partner, but failed to be complied by the other.

Two raters independently scored the above behaviors. After an initial round of scoring, both raters compared the scores. In the case of any disagreement, conflicts were resolved by reviewing the video data together. The reviewed scores were then used for the final analysis.

Table 1: Post-game questionnaire. Cronbach's Alpha scores reported in parentheses.

Constructs	Questions
COOP (α =.780)	1. My partner and I worked well together 2. The game was easier when I cooperated with my partner 3. My partner and I played individually 4. My partner and I shared tips with each other when playing the game
COMM (α =.765)	5. I communicated well with my partner during the game 6. My partner was responsive 7. I understood what my partner was trying to tell me 8. It was difficult to communicate with my partner
PAR PREF (α =.809)	9. Playing alone would be more effective than playing as a pair 10. The age of my partner made the gameplay interesting 11. I didn't enjoy playing with my partner 12. I would feel more comfortable playing without a partner
EOU (α =.803)	13. I quickly understood how to play the game 14. I found the game simple to use 15. It was easy for me to interact with the game 16. The game was user friendly 17. I was slow at understanding the game
COMP (α =.789)	18. I felt competent in playing the game 19. I was good at playing the game 20. It was difficult to reach the game goal 21. I was poor at playing the game 22. I could have completed more levels if I was given more time

FINDINGS

The results are separated into three sections. First we report on the questionnaire findings, followed by the paired interaction from the video analysis. We then go on to summarize the feedback from the post-game interviews.

Questionnaire results

In terms of prior gameplay experience, with one exception, all of the younger participants reported playing video

games. In contrast, 43% of the older participants reported no digital game experience. Nobody from the younger cohort reported playing games with grandparents, while two of the older participants indicated they played with one or more grandchildren.

Reviewing the post-game questionnaire, Pearson's correlation coefficient identified positive correlations between all of the constructs (see below).

Table 2. Correlation results.

	COMM	COOP	PAR PREF	EOU	COMP
COMM	-				
COOP	.798**	-			
PAR PREF	.598**	.737**	-		
EOU	.317*	.344**	.332**	-	
COMP	.282*	.377**	.311*	.715**	-

** Correlation is significant at .01 level (two-tailed)
* Correlation is significant at .05 level (two-tailed)

Cooperation, communication and partner preference

A one–way randomized ANOVA was conducted to test for the effect of group-type (Young-Young, Young-Old, Old-Old) on the three constructs. A significant effect on *Communication* at the $p < .05$ level was identified for the three conditions $F(2, 57) = 3.73$, $p < .05$. A post-hoc test using Tukey's HSD indicated that the Young-Young scored communication significantly higher than the Young-Old ($p < .05$). However, the mean scores for the Old-Old did not significantly differ to the Young-Young and Young-Old groups. In addition, no significant effect was identified on group-type for *Partner Preference*, $F(2, 57) = 1.96$, $p = .15$ and *Cooperation*, $F(2, 57) = 1.32$, $p = .28$. The descriptive results are reported in Table 3.

Ease of use and gameplay competence

A significant effect on *Ease of Use* was identified across the three groups, $F(2, 57) = 9.22$, $p < .001$. A post-hoc test indicated that the Young-Young scored significantly higher than the Old-Old ($p < .001$); as did the Young-Old compared to the Old-Old, ($p < .01$). Comparisons between the Young-Young and Young-Old revealed no significant differences. For *Competence*, as the assumption of homogeneity of variance was violated, the Welch's F test was used, revealing a significant effect, $F(2, 33.41) = 7.48$, $p < .01$. A post-hoc test using Games-Howell indicated that the Young-Young scored gameplay competency significantly higher than the Old-Old ($p < .01$). There were no significant differences when comparing the other groups.

To further assess the levels of competency in the gameplay we counted the number of levels completed for each pair in a 30 minute time period. On average, the Old-Old completed two levels of the game (40%), compared to four levels for the Young-Old (80%) and all five levels for the Young-Young (100%). Independent sample t-tests identified the Young-Young completed significantly more levels of the game then the Young-Old ($t(18) = 2.91$, $p < .01$) and Old-Old ($t(18) = 7.32$, $p < .001$). A significant difference was also identified between the Young-Old and Old-Old groups ($t(18) = 2.75$, $p = .01$).

Table 3. Means with standard deviations per group-type.

	Y-Y	Y-O	O-O
COMM	4.00 (.50)	3.51 (.65)	3.61 (.63)
COOP	3.88 (.53)	3.64 (.62)	3.58 (.69)
PAR PREF	3.89 (.53)	3.63 (.64)	3.45 (.89)
EOU	3.60 (.65)	3.39 (.55)	2.77 (.70)
COMP	3.61 (.34)	3.32 (.59)	2.82 (.89)

Comparison of age cohorts across groups

Independent sample t-tests were conducted between the younger participants in the Young-Young and the Young-Old groups. There was a significant effect of *Communication*, $t(28) = 2.88$, $p < .01$, which indicates a higher mean score of communication in the Young-Young group. This suggests that the younger participants reported better communication with partners of a similar age. No significant effects were identified for *Cooperation*, *Partner Preference*, *Ease of Use* and *Competence*.

Independent sample t-tests were also conducted between the older participants in the Old-Old and the Young-Old groups. There was a significant effect of *Ease of Use*, $t(28) = 2.63$, $p = .01$, which indicates a lower mean score of ease of use in the Old-Old group. This suggests that the presence of younger partners helped facilitate the gameplay for the older participants. No significant effects were identified for *Cooperation*, *Partner Preference*, *Communication* and *Competence*.

Observation and video analysis

A one-way randomized ANOVA was conducted to test for the three types of behavior from the video analysis. Based on the combined scores of each pair, a significant effect of *Physical Cooperative* behavior was identified, $F(2, 27) = 5.27$, $p = .01$. A post-hoc test using Tukey's HSD was conducted and identified that the Young-Old ($M = 7.00$) scored physical cooperation significantly higher than the Old-Old ($M = 1.80$), ($p < .01$). However, the mean scores of the Young-Young ($M = 4.20$) did not significantly differ to the Young-Old and Old-Old groups. In contrast, there was no significant effect on *Verbal Cooperative*, $F(2, 27) = .82$, $p = .45$ and *Non-compliance*, $F(2, 27) = .89$, $p = .42$.

Subsequently, the null effect in *Verbal Cooperative and Non-compliance* may be due to the physical nature of the game. Nevertheless, the video analysis indicates that the Young-Old intergenerational grouping was able to elicit more cooperative behavior in the physical domain.

Given variations in the number of levels played, to assess the general communication between groups, a count of the number of verbal expressions in the 'first' and 'last' played levels of the game were made (see Table 4). The table reflects the total pair scores, as opposed to the average paired scores preliminarily reported [23]. Statistically, the ANOVA results remain the same. Namely a significant

difference was identified in the amount of communication ($F(2, 25) = 6.23$, $p < .01$), with the Old-Old group recording the highest and the Young-Young group the lowest number of verbal expressions. Moreover, post-hoc tests found marked differences in the mean scores between the Young-Young and Old-Old (first level, $p = .03$; last level, $p < .01$) and the Young-Old and Old-Old (first level, $p = .07$; last level, $p = .03$) across both game levels. No significant differences were identified between the Young-Young and Young-Old groups.

Table 4. Descriptive number of verbal expressions per group for the first and last levels played.

	Group	No. of pairs	Mean	S.D
First level played	Young-Young	10	17.90	18.16
	Young-Old	10	20.90	14.93
	Old-Old	8*	42.88	25.93
Last level played	Young-Young	10	9.30	9.42
	Young-Old	10	18.90	18.87
	Old-Old	8*	45.63	31.65

* Two of the pairs were excluded from the analysis due to only completing one level of the game.

Observed behaviors

In reviewing the observed interaction between players we now highlight general differences between the group-types. It is important to note that across the groups, verbal communication was lowest during the introductory tutorial, while it appeared highest during the customization of on-screen content. We observed no aspects of fatigue or overexertion. In more detail:

Y-Y pairs: demonstrated the greatest ease-of-use, with the most time utilizing the customization features of the plants to prepare for the forthcoming level. They exhibited a range of orchestrated movements, including playful hand and body gestures not identified in the other groups. These included shadow boxing, flapping of arms, passing rain droplets between one another, and pulling on clothes to distort and manipulate the shape of their silhouette. As confidence and understanding grew in the game, the pairs tended to exhibit less verbal communication and waiver from the game, suggesting the game was somewhat repetitive to their skill level. In addition, they were often unfazed by making gameplay mistakes.

O-O pairs: for this group, the biggest constraint was understanding the gameplay logic. All pairs were cooperative in selecting features for their partner and discussing gameplay options. However, the Old-Old pairs typically spent most of their time discussing the rules and trying to work out how to upgrade and relocate their plants. As such, by predominately focusing on how to customize content, they lacked the same amount of gameplay exposure to the other groups. This explains the low number of completed levels, and high amount of verbal communication previously reported.

Game errors were typically repetitive, with noticeable usability problems with the silhouette detection. Namely, the older adults were more prone to accidentally triggering graphical buttons with the head of their silhouette, caused by a close proximity to screen. Conceptual difficulties were widely identified in understanding the game mechanics, and these ranged from a lack of awareness of how to balance a plant's health bar, to recognizing when a plant had died, or in differentiating between the tutorial and the actual gameplay. Uncertainties in how to control the weather elements further restricted the amount of physical movement, with three of the pairs remaining fairly static in their interaction.

Y-O pairs: in comparison to the Old-Old, the older participants in this group were more assertive in their understanding of the game, which can be contributed to the support of a younger partner. We observed that younger players were accommodating to their partner's preferences to customize screen features, as the older adults could be quite affirmative in what they wanted to select. However, the extent the older adults independently customized plant features was determined by their accuracy, as repeated mistakes led to some impatience and more dominant behavior exhibited by the younger players.

In all pairs the younger participants would commonly self-delegate the role of selecting on-screen features and navigating between screens. In comparison, both players were identified to provide some instructional assistance in the form of short and direct prompts (*"too much sun"*, *"move here"*, *"cancel, cancel"*), as both cohorts could be quite vocal in their gameplay interaction. However, we observed the level of verbal communication of the younger adults (even within the same pair) varied across the gameplay, from vague remarks - "*Can you go back, we have to buy some sun block"*, to more explicit instructions – "[pointing] *you see the red bar there, that means not enough sun*".

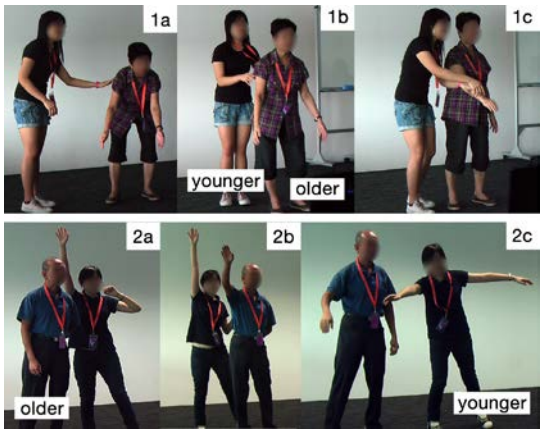

Figure 3: (*Top*) 1a-1c: various shepherding actions by the younger player; (*bottom*) 2a: younger player reaches to select on-screen button; 2b: senior player mimics partner's action; 2c: younger player reaches across to support partner.

Reflected in the high amount of physical cooperation in this group-type from the video analysis, the older adults were

observed to mirror the actions of their partner, commonly following the direction of a hand to select an on-screen object (Figure 3, 2a-2b). For assistance, the younger players were also observed to step in front or behind their partner, or diagonally reach across them to help shield and protect their plants (Figure 3, 2c). This became more reciprocal as the gameplay progressed, including the switching of physical positions in front of the screen. In rare instances, two of the younger participants were observed to physically guide the position and arm movements of their partner (Figure 3, 1a-1c), while we identified a few examples of the older participants exhibiting affectionate behavior, such as a light punch on the arm to gesture for 'well done'. This was only observed during the latter stages of the gameplay.

Post-game interviews

Next, we reviewed participant's subjective feedback on the applicability of the game from the post-game interviews. Across the groups, 70% of the older participants and 50% of the younger participants reported the game to be suitable for their age group, while 50% of the older participants and 67% of the younger participants perceived that they could bond with the opposite age group. Specifically, the Young-Old pairings reported the game to be most suitable for their age group (75%), compared to 65% in the Old-Old and 40% in the Young-Young. Likewise, 70% of the Young-Old perceived the game to be suitable for the opposite age group, compared to 60% in the Young-Young and 45% in the Old-Old pairs. Notably, while the Young-Young were most positive towards the game, the Old-Old's under-performance generated doubts over younger people's interests to want to engage with them. Alternatively, while a high percentage of the Young-Young perceived the game to lack variation or challenge for teenagers, they favored its simplicity for older adults.

In all cases, the pairs recognized that they could have communicated better - although they commonly reported improvements in interaction the longer the gameplay progressed. For the younger cohort, a positive feature of the game was the silhouette interaction, which was described as being both fun and novel to use. These included recommendations to utilize the dimensions of the projection screen more effectively (e.g. in forcing players to stretch to the corners); dynamically reduce the size of the player's silhouette to create more screen space; and include more lower body movements, such as stamping actions. None of the participants reported the game to be physically intense.

To provide a richer picture of participants' gameplay experience, two of the authors independently reviewed the content of the questions that probed participants' reasons for their perceived preference, suitability and engagement. This resulted in the emergence of several common themes.

Gameplay satisfaction. Despite the introductory tutorial, the perceived lack of on-screen instructions to explicitly guide players, meant that participants used considerable time exploring how to play the game, and this was a source of frustration for the Old-Old pairs: *"We spent most of the time trying to find out the rules of the game* [rather than play it]*"* (Old, Pair 24, O-O). Compared to the Old-Old, the Young-Old pairs were more positive towards the challenge of the game and the teamwork required. While poor instructions were also perceived to hinder their initial understanding, paradoxically, this was seen to encourage cooperative behavior in understanding the purpose of the game. By contrast, the Young-Young pairs were less affected by the lack of instructions, with one participant remarking that: *"The fun thing about the game is learning how to play the game"* (Young, Pair 23, Y-Y). However, a bigger constraint for this group was a lack of a substantial storyline, leading to criticism of too much gameplay repetition.

Gameplay suitability. The Young-Young pairs were skeptical of the suitability of the game for other people in their age group, and commonly perceived the content to be more engaging for younger children. This was due in part to the playful garden theme and the perception that other people in their age would prefer 'action-type' games. Interestingly however, in a number of cases, the youths in this group did not necessarily associate themselves with the same type of game interests. Alternatively, when the Old-Old felt that the game was appropriate for their age, they often cited physical attributes as a positive feature: *"This game could motivate a person like me if I am not physically strong, to at least use my hands and my body… I have some sense of control over the game"* (Old, Pair 30, O-O). By contrast, those who dismissed its appropriateness were fuelled by a lack of self-achievement and understanding due to poor usability. This led to remarks of the game experience being *"blurry"* with *"no conclusion"*.

Like the Old-Old pairs, a high number of the older participants in the Young-Old foresaw physiological benefits in playing the game – *"How fast our eyes and mind work together, that's very challenging"* (Old, Pair 11, Y-O). Similarly, the younger participants in the Young-Old were more optimistic to the potential of the game for their age group, and in playing with grandparents compared to the Young-Young pairs: *"The time we spent together, had fun together, all that, joked, talked to each other. Yeah, I think it's possible to bond with them* [grandparents]*"* (Young, Pair 9, Y-O). Despite this, the youths commonly perceived that for longer periods of use, additional gameplay features would be needed to increase the amount of challenge.

Stereotyped perceptions. Many participants over-generalized and demonstrated the use of age stereotypes in their answers, especially on questions regarding the suitability and physical engagement of the game. This was evident across all groups, although in general the perceptions of others were more biased in the Young-Young and Old-Old pairs. Namely, there was a belief that older people would not play digital games because of their

age and inactivity (i.e. 'they don't move around a lot'), while for the young they would be too impatient to play with seniors. In particular, a number of the younger participants associated the applicability of digital games with the health of their own grandparents, which may suggest limited contact with elders outside their family. For the older participants, there were noticeable discrepancies between how they perceived the game for themselves, compared to how they perceived it for others in their age group, e.g. *"A lot of seniors I would say, not me of course, I like a lot of physical activity, but a lot don't like"*(Old, Pair 2, Y-O).

Cognitive flexibility. As might be expected, the older participants demonstrated less cognitive flexibility in terms of their understanding of the game mechanics. More interesting however, while the younger participants readily accepted differences in the gameplay elements to real life knowledge (i.e. in the nurturing of plants), a number of the older participants found it difficult to do so. At times, this resulted in conflicting conceptual models in understanding the gameplay logic, and subsequently weaker performance in the game: "*For plants there is no such thing as too much sunlight… we ourselves also will want to be protected from too much sun … if it can kill a plant, the thunder can kill us. No, we shouldn't be taking risks for the sake of a plant"* (Old, Pair 13, O-O).

Intergenerational cooperation. The Young-Old pairs were cognizant of the cooperation during the gameplay. When asked, a few of the seniors acknowledged leveraging on their partner's understanding of the game: "*We agree on what we are doing. I say upgrade, and she says sell, OK then we sell, upgrade, things like this. There's someone to tell me. Maybe my upgrading could be wrong, her selling is a better idea*" (Old, Pair 14, Y-O).

On the other hand, the youths tended to emphasize their assistance, while downplaying the weaker gameplay ability of their older partner: "*There was one part, a dead plant. I was trying to tell him to move his shadow over, so he can select that one, so he can revive it. Actually he managed to move his body over, but something, maybe just a conflict between the shadow detection"* (Young, Pair 9, Y-O); and *"I realized my message across to her wasn't that clear. I'm not going to ask her to move to this spot, when she wants to move that plant. I told her quite a number of times before… I was thinking maybe sometimes I speak not so clearly*" (Young, Pair 11, Y-O).

DISCUSSION

In investigating intra and intergenerational gameplay, the overriding challenge of this work has been to identify the extent distinct types of players interact together. In particular, to understand the contrasting behavior between player's perceptions of the prototype game for self compared to others. As acknowledged, this included at times, contradictory and stereotypical behavior.

Based on the post-game questionnaire, the Young-Young group perceived greatest ease with the game, compared to the older adults who demonstrated greatest difficulties. While this may come as little surprise, the Young-Old exhibited interesting characteristics of behavior in regards to the scaffolding of the game tasks. Namely, higher levels of physical cooperation, observed to be primarily attributed by the physical assistance of the younger players.

The results of the Young-Young and Young-Old did not report a significant difference in gameplay competency. To account for this lack of difference, it may be plausible that the cooperative interaction of the Young-Old pairing contributed to a level of 'know-how' in the game. Further, age-related decline in cognitive control could explain some of the difficulties faced by the older participants in understanding the game mechanics, without the assistance of a younger partner [11]. The increased level of physical cooperation for the Young-Old group compared to the other groups was not reflected in the cooperation score for the post-game questionnaire, with a non-significant result across the group-types. One possible reason is that (given the assistance) participants did not perceive their interaction to be fully cooperative, as previously highlighted in the observational and post-interview findings.

As reported, there was a significant difference in the communicative behavior across the group-types, with the Young-Young self-reporting the highest levels of communication. A possible reason why the Young-Young group perceived themselves to have a higher level of communication may relate to more positive perceptions of their gameplay competency (on average completing all levels of the game). Subsequently, it is plausible that the participants may have used this level of accomplishment as a heuristic means of assessing their level of paired communication. By assuming that the level accomplished is dependent on the amount of communication they had with their partner, the young-only group may have perceived they fared better in the gameplay. While it is inconclusive, this analogy may hold potential for future work to explore.

Towards intergenerational gameplay

Based on our findings, we have identified a number of recommendations perceived to be important to further investigate in the design of intergenerational games. Compared to previous studies, existing recommendations relate to the intuitive mapping of digital functions and the usability of games [29], game configuration setups promoting other family members as intermediaries [30], or game design for children with a strong onus on educational learning [4]. By contrast, our outcomes differ in the interaction issues obtained by comparing between age groups. There are guidelines for physical activities and instructional guidance [e.g. 7] that cross over with our related themes. However, these recommendations address interaction issues for older adults with limited physical functionality, and thus present a different set of

requirements to our research. Specifically, we recommend exploring:

Role differentiation and interdependence. To sustain motivation and long-term interests, practitioners need to consider the collective versus individual roles of the players. For example, it was suggested, rather than one player hover under a thunderous cloud to prevent a lightning strike, this could require the combined efforts (in what was described as *"common effort"*) of both players. Although a simple analogy, in extending from our previous findings [22], the balance of building positive interdependencies between players to contribute towards shared goals should be considered in relation to utilizing (and capitalizing) on different skill sets, and in the case of older adults, tapping into more abundant life experiences and prior knowledge. At the same time, careful consideration needs to be placed on the extent tasks require players to complete the same activity or set of actions, compared to differentiating their roles for more individual contributions in the game. These roles may be related to the amount of cognitive control required by the players in the assigned tasks. As identified in this work, a key challenge is to sufficiently engage older participant's cognitive abilities without overwhelming them in the process.

Gameplay assistance. The imbalance in skill levels both within and between the age groups present barriers and opportunities in interaction. On the one hand, player assistance from the youths increased their task load in the game, with the reward of greater assertion and reciprocity from the older adults. On the other, this could also become a cumbersome process, creating some frustration. Gameplay adaptation could compensate for (age-related) differences in player's skills and reaction times, particularly in the early stages of learning. Equally, the deployment of assistance techniques may detract from the expectations, rewards and generational values perceived in playing with people of different abilities. Indeed, in a number of cases the older adults explicitly favored being led by the youths. Subsequently, the use of any system adaptation needs to carefully consider these potential tradeoffs.

Focal points. We observed that verbal communication was highest when participants had to problem-solve together. In particular, this was most evident in situations where they had to customize on-screen features. To reduce any underlying tension between players, mechanisms should be provided early in the game, as well as between levels, to encourage the mutual exchange of ideas and information. These should ensure that early challenges are not overly imposing, in order to build confidence between the dyads.

Physical engagement. Interests by older adults in more physical attributes of the game draw questions over the levels of intensity and self-monitoring of activities, and whether these should be more generalized or targeted forms of physical fitness. Rather than limit the number of functions, recommendations included extending the range of body movements and perceived exertion to reflect participant's active and independent lifestyles. Moderate forms of physical activity reduce, among others, the risk of fall and injury, stroke and type-2 diabetes in older adults [31], suggesting if appropriately designed could provide secondary effects to playing intergenerational games. As such, games that target physical activity (e.g. coordination, strength) may have a strong motivational influence in their adoption and use. Not only for older adults, but younger people who recognize the physiological benefits for grandparents and older non-family members.

Instructional support. It appeared that the older participants had a tendency to prefer more explicit instructions, while the younger participants preferred instructions that allowed autonomy in their decision-making. We observed in early situations when participants did not know each other they are less likely to intervene with support. Subsequently, early instructions are essential for those adults who require more active training, but low cognitive load. Drawing from a wealth of studies within behavioral science that address problems of information recall and task performance [e.g. see 16], the challenge is to understand the types of salient features that can guide players without stifling the engagement of others due to additional learning demands. Given the amount of repetitive pointing needed to instruct graphical features at a distance to screen, this may be supported by a simple gesture command to highlight relevant information.

Metrics for validation. There are no known metrics available to successfully validate intergenerational gameplay within game design. Although this encompasses a broad area, appropriate measurements to accurately assess aspects of social interaction and communication would be a valuable commodity.

FUTURE WORK

This study reports on the immediate effects of engagement over a single gameplay session. It is hypothesized that conducting a longitudinal study with the same pairs of participants may change the mediated interaction observed. This would be beneficial to evaluate for those older adults who were slow to learn the game – as a better understanding of the game mechanics might positively transform their cooperative and communicative behavior. Dyadic differences in interacting with people known (e.g. friends and family), as opposed to playing with strangers, or reducing/increasing the age range of either cohort could also impact upon the established results.

For example, in this study there were more female than male participants, while there was a larger age range for the older age group (55-74 yrs), as compared to a smaller age range for the younger group (15-20 yrs). These are factors that may have influenced our findings, and therefore are worth considering in future studies. Similarly, we note that cultural differences, in our case related to Eastern social norms and communication practices of using Singaporean

participants, might have influenced the player interaction. Cross-cultural differences should also be considered in future work. Finally, the game-type evaluated, and differences in gaming expertise (which naturally favored the youths) must also be acknowledged as influential factors.

CONCLUSION

The aim of this study was to primarily evaluate the cooperative and communicative behavior between younger and older players. The unique contributions of this work relate to identifying gameplay differences between group pairings in the context of playing a novel silhouette game. In particular, the understanding of how the young and old negotiate and accommodate for player differences in co-located play. Detailed data analysis indicates a more complex picture of player engagement (e.g. in terms of perceived suitability, user satisfaction and usability) than was previously reported in our preliminary findings [23]. Future work aims to re-develop and extend the prototype game, as more studies are needed to address the challenges of designing for heterogeneous and dynamic age groups.

ACKNOWLEDGEMENTS

This research was funded by A*STAR SERC Human Factors Engineering TSRP Research Grant (No's. 092 153 0094 & 092 153 0095).

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