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Designing Games for Older Adults: An affordance based approach

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Abstract— The main purpose of this study is to determine the game principles that need to be adopted in order to create an enjoyable and engaging game experience for older adults, whilst ensuring that the purpose of the game, encouraging upper limb mobility, is respected. The study reported in this paper involved a group of older adults who played and gave feedback on an early game prototype which feed into the design modification process. Each player's action capabilities were measured and taken into account in the design process. This helped ensure that opportunities for action that the game afforded were adapted to players' need.

Keywords—*game design; older adults; kinect; engagement; user centred design; affordance*

I. INTRODUCTION

Older adults need to keep exercising to stay active and healthy [1]. One possible way of encouraging them to exercise is by playing movement based games that involve Microsoft Kinect, where body movement and gesture recognition are the main input signals used to control the game. Directly mapping movement into the game means players can see the effects of their movements inside the virtual environment instantly. By creating immersive and engaging activities in the game environment, the player stays more connected with the game when playing. In spite of this, there is still a need to address the problem of how we can design games that will keep older adults connected with the games. Maximising user motivation in a movement training or rehabilitation programme is a very important factor for keeping patients exercising so they recover faster. During a rehabilitation programme, participants are often found to be less motivated as the programme progresses [2]. One way to keep them engaged is to make the rehabilitation process a fun and enjoyable experience through the use of computer games [3]. There are many studies that have looked at the benefits of using movement-based games as a way of encouraging patients to keep exercising. Studies in [2, 3, 4, 5] have shown that using digital games can successfully motivate patients to keep exercising. Patients who used gaming devices such as the Nintendo Wii or Microsoft Kinect were found to be more likely to complete the rehabilitation process. However most of the games employed a minimalist design and were not analysed in terms of how effectively the actual design of the games facilitated the

rehabilitation process [6]. That being said, there are few studies that do focus on game design [7], notably the game playing itself and the development of an interactive process in the virtual environment that encourages the patients to control their movements in the real world in a certain way [8]. To address this issue further this paper focuses on how to design a game that will continually invite the players to move their upper body to engage with the game. The aim is to maximise the players' motivation to move in that way.

II. OLDER ADULTS AND GAMING

As the number of older adults in the population is increasing [9] so is the number of older gamers [10]. With various advances in the computer games industry, games are no longer being uniquely designed with a younger audience in mind for entertaining purposes [11]. Instead, games are now being designed for different audiences and different purposes, such as designing educational games for young children or designing rehabilitation games that encourage mobility for older adults and patients. There are some examples where older adults are not only playing computer games but are getting involved in the design process, where they help create game concepts by using a step-by-step approach [11]. Furthermore, a recent study has shown that older people are likely to use new technology if they can see how it will directly benefit them [12]. Although one in five of the 51-65 year olds in the UK do report playing computer games [13], senior citizens in general do not play as many games as younger adults, often preferring to watch television [14]. Market research suggests that this group of older adults would prefer to play PC games rather than console games. Furthermore, the research also suggests they prefer to play games that encourage them to think and solve problems, and are less interested in fast paced games where the benefits are less obvious [15].

III. THE AFFORDANCE BASED APPROACH

User centred design (UCD) is an essential aspect of Human computer interaction. It takes targeted users as the central point in the design process with all design decisions revolving around that point. The process normally involves task analysis, prototype development with users, evaluation and iterative design [16]. UCD can be effectively used as a process to

understand human behaviour rather than a way of developing a useable system. It could therefore be a useful way of improving design when developing movement based games for older adults. However, it has been shown that when the targeted users have special needs the costs of applying UCD increases as the users have more diverse requirements [16].

A recent study conducted by [8] implemented a user centred design approach when developing an exercise game for older adults. In this study, the researchers used both qualitative and quantitative methods. Firstly they conducted a focus group with the participants to explore the users' experience with respect to other health activities and gauge overall gaming experience. They then adopted user testing process which included a mixture of questionnaires and interviews. The feedback obtained from the focus group and testing sessions provided clear directions on the game playability and engagement.

Norman's Work on product design emphasises the need to understand and explore the needs of the intended users of a product [17]. A User centred design approach can therefore help answer the question if the products are successfully applied for their intended purposes. It can also help focus more on the user's individual needs, define the problem clearly, and create a context in which the process is happening [18]. Nevertheless, designing movement based games for older adults should not only focus on usability issues, but also on how to engage older adults with regular game playing, and how to ensure that playing the game is an enjoyable experience for them. As it is a movement based game adapting the game to the action capabilities of the player will be very important to maximise engagement. A game that requires speed and execution of action that the player cannot perform will not facilitate good interaction.

Understanding the user is therefore seen as a very important component for successful design. When designing for older adults we need to understand what motivates them to play movement based games, and how the games can be adapted to accommodate their differing cognitive and physical capabilities. Furthermore, the context in which these games are being played is another factor that influences the design. Games that are played by older adults in a more social context, such as a nursing home will have different requirements than the games that are designed to be played by users alone at home.

In this study we used an affordance-based approach to design a game, where the user's action capabilities have been taken into account. When we use the term affordance, we are not referring to properties of objects but instead the opportunities for action a particular event or environmental context affords the user. The term coined by the psychologist Gibson [19], more accurately refers to the actionable properties of the environment/actor system.

Our game design was not only centred on the type of action the user can perform but also when (response times) and how it can be performed (range of motion). The focus was on using the graphical information presented in the game as a means of guiding the user's actions. The brain controls actions based on perceptual information that is picked up through the senses,

and this information that controls decisions about how and when to act [7]. For gaming to work with older adults, the perceived affordance, or opportunity for action, of the game needs to give the player a meaningful indication about what actions are possible, and what they should do next given their own personal action capabilities. The affordance is the act or behaviour invited by an object, person, place or event [20]. It is the relationship between the player and the game, and is the guiding principle of the interaction between them.

IV. METHODS

An early design cycle started by allowing older adults to play and test commercially available Kinect games after which they discussed their experience [21]. From this preliminary study the authors came up with a game idea that would involve creating a quick prototype that would enable older adults to play at an early stage of development so they could be part of the design process. An iterative testing process was then applied, following the introduction of an initial prototype which was created based on a theme that was appealing to older adults [22].

The objectives of the iterative testing when designing a movement based game for older adults were to understand the specific user needs, understand how the game should respond to each user's specific physical abilities and how users are interacting with each game features. The iterative testing also gave the older adults the opportunity to be involved in the design process by sharing their experience with the design team so they could modify the game accordingly.

By also observing how the older adults played the game, we aimed to understand how the users interact with the game, what body movements are suitable for them, and how they respond to different game elements. The observations also evaluated different game features that were added into the game.

Prior to taking part in the study, each user was interviewed about his/her experience and motivation to play computer games. During the iterative game testing, participants were asked to give feedback on the game and suggest how they thought the design could be improved.

A. Defining Requirements

To define the requirements to implement in the initial prototype, data were collected in three different stages:

- 1) Feedback from older adults after playing commercially available movement based games;
- 2) Observations by the designer on how older adults play and respond to these games;
- 3) Conducting a focus group with participants to talk about their experience.

The observations and focus group highlighted the frustration the older adults had experienced when they played commercially available games. From the observations recorded during these sessions, only a few participants were able to move in the correct way at the appropriate time to successfully interact with and play the game. Despite the apparent natural mapping between real movement and the actions required to

play the games, the older adults were unable to achieve any level of presence when playing these games. This was mainly due to their inability to time their movements to the pace of the game, and adjust their actions to the spatial/temporal constraints imposed by the game. In the focus group participants stated that when the system did not respond to their movements they did not know what to do next and lost interest in the game. When the participants were asked about what they thought of the game visuals and environment, they said that they were unaware of these types of details of the game environment. Some participants said that there were too many sounds in the sport games that distracted them.

To further define requirements; an intensive study of related research has also been conducted. The game flow model [23] was adapted to evaluate the immersion within the presented prototype game. The game flow model was developed to evaluate different elements of a game to maximize the player's experience.

To understand the motivation of older adults to play computer games, we firstly conducted individual interviews with the participants. We asked them why they want to play movement based games. One participant replied "it is a way for me to get in touch more with my grandchild". Another participant stated that he loves to play movement based games as he likes to add a challenge to his exercise activities. Another participant said he likes technology and would like to use it in every aspect of his life. Another participant said that this is a new experience for her and she likes to play games from time to time and it would be a good idea if the games helped her to stay active. When they were asked which game they would like to play and why one participant said it doesn't matter as long as she can play the game. Another participant said he would like to play sports games. Another participant said that she doesn't want to play complicated games where she doesn't know what to do.

B. The Game

Our initial prototype consisted of a 2D game, developed using Actionscript 3.0 and Adobe Flash Pro CS6. The game was interfaced with MS Kinect using the AS3NUI library. The game is called Butterfly Catch where the objective is to catch butterflies by controlling a virtual net. The movement of the net in the virtual environment is mapped to the movement of the player's left hand or right hand. Fig 1 shows the main game interface. The butterflies are sent from both the left and right hand sides of the screen from 6 predefined horizontal zones as shown in Fig 2. Our main input device is the Microsoft Kinect sensor. Even though the sensor can provide a full representation of the skeleton of the user, we only used the hand as an end effector.

The structure of the tasks were simple, catch butterflies using the net, avoid the flies, and get rewards. All game elements are clearly visible (butterfly, net and background), and the mapping was straight forward (hand movements directly controlled the location of the net).



Fig. 1. The main game interface.



Fig. 2. The predefined six horizontal and vertical zones, the horizontal zones were used to send butterflies, while vertical zones were used to

C. Participants

A group of 7 participants (2 Males and 5 Females; M= 83.1 years, SD = 7.23 years) took part in the study. The participants were recruited from local sheltered accommodation. Some of the participants had previously experienced playing movement based games. A Timed up and Go test [24] was performed by each participants to evaluate his/her physical capabilities. The test records the time each participant needs to stand up correctly from a sitting position on a chair with arms then walk a distance of three meters, turn and come back and sit correctly in the chair. The mean time taken for the participants was 14.01 seconds (SD=4.96). According to the interpretation of the test a normal person will need less than 10 second to perform this test. Table 1 summarizes the participants' information:

TABLE I. PARTICIPANTS

Participant code	Gender	Age	Physical Capability (Timed up and Go test)	Experience playing movement based games
P1	F	82	11.3 second	No
P2	F	82	25.0 second	No
P3	M	96	11.9 second	Yes
P4	M	86	11.0 second	Yes
P5	F	86	14.5 second	No
P6	F	76	12.0 second	No
P7	F	74	12.7 second	No

D. Iterative User Testing

The game was tested over a period of three months. Participants played the game once a week. In each session they were allowed to play the game as much as they wanted. Observations of game play were conducted in each session. After each game session the player was interviewed and asked for his/her evaluation. All the participants had the opportunity to play each prototype at least one time.

V. THE INITIAL PROTOTYPE

A. Initial Prototype's Features

The initial prototype had 13 game features to be tested. Table II shows all these features.

B. Iterative User Testing of the Initial Prototype

All participants found that the objective of the game was complicated and they asked for it to be modified to make it easier.

TABLE II. INITIAL PROTOTYPE FEATURES

Number	Feature Description
F1	Only one user plays the game at any one time.
F2	Player has to avoid the flies, catch butterflies, and will be rewarded with energy bars which can be used to get rid of the flies.
F3	The objective is to clear certain number of flies from each level.
F4	The number of flies increased with the level progress.
F5	Game is over if the user does not catch enough butterflies to clear the level from the flies.
F6	A number of points were given for each successful catch, the points were doubled if the player keeps catching and not missing any butterflies, once the player failed to catch one, the number of points is set back to its default value and he/she loses some points.
F7	The initial design took into consideration each player physical capabilities, so no butterflies were sent to the zones where he/she could not reach.
F8	Butterflies are sent only to the zones where the user can reach (up, down, left and right). They are randomly sent with an equal probability for each zone.
F9	Player speed and range of movements were recorded in each game session.
F10	Support for creating a profile for each player, where all their data will be saved.

F11	The player can use left or right hand to play, the player is allowed to switch the hand during the game play, however only one hand is controlling at a time.
F12	Large text messages were animated and displayed to encourage users when they are performing very well or very badly.
F13	Game can be paused at any time by the player by giving the pause signal (stretching left or right arm 45 degree).

Even though the butterflies were flying at a relatively slow speed, participants P2, P6 and P7 found that butterflies were flying too fast. The suggested solution was to link the butterflies flying speed to player performance.

Table III shows how many sessions each participant played in the first prototype, it also shows the average game session duration for each player, the maximum level the player achieved and the average score in the gaming sessions. In this prototype the average score did not only affected by participants' action capabilities, but also his/her misunderstanding of the game objectives, as some participants tried to catch flies so this resulted in some points being deducted from their scores. The average of their maximum level achievement was 5.1. The maximum level achieved by each player is the level the player reached before catching 5 flies, the player made one level progress when he/she caught 12 butterflies.

Although the butterflies were coming from 6 different horizontal zones that the user could reach, some zones were difficult for the user to reach such as zone 1 which was too high. As the player was able to reach the zone at least once in the game, it was included in the possible zones to send the next butterfly from and had the same probability as other zones. This was in hindsight not very fair as the player hadn't reached that zone as frequently as the others. This feature was modified by linking the probability for each zone with the number of times it has been successfully accessed by the user.

TABLE III. PARTICIPANTS DATA IN FIRST PROTOTYPE

Participant Code	Total number of sessions	Average duration in seconds	Maximum level achieved	Average score
P1	4	224	3	60
P2	9	114	4	66
P3	6	169	6	253
P4	6	172	5	158
P5	4	151	4	137
P6	6	300	8	542
P7	21	199	6	90
Total/Average	56.0	189.9	5.1	186.6

P2 had visual and sight deficiencies and needed better contrast of elements in the foreground from elements in the background. A new feature was requested to help her play the game.

In each level game playing started as soon as the player was detected by the Kinect sensor. However we found that the user needs more time to prepare for the level by moving the controller around to explore the environment before they encounter any tasks or obstacles.

Even though the feature to switch hands was available, all participants did not use it and kept playing the whole session with the same hand. To encourage them to switch hands we introduced a new reward that would be given to players who switched their hands during game play. In addition, players would have to switch hands to accomplish specific tasks. The game would ask them to catch a certain butterfly with a certain hand.

In addition, the game encourages players to shift their body from one position to another by making steps. Very few participants actually moved their bodies when playing the game, with most of the players preferring to stand on the same spot and try to reach for the butterflies or wait for the butterfly to get closer to him/her. Observations also indicated that only participant P3 and P4 tried to bend their knees while they were trying to catch butterflies from the bottom.

Players reported that they did not pay any attention to the text messages that were displayed on to encourage them. These needed to be accompanied by an audio signal as well.

Punishment for players who failed to achieve a task by subtracting points from his/her score had a negative effect on participants. They didn't like the idea of losing their previous achievements if they did not perform well in subsequent tasks.

Other comments suggested by participant P6 that the game would pause automatically when they stopped playing rather than having to try giving a pause signal. The main purpose of pausing the game was to take rest. Players preferred to leave the game session as soon as they wanted without trying to do a pause signal.

The game sometimes forced the players to perform sudden movements, so that he/she had to suddenly move from the far left to the far right, or while moving in straight line he/she had to move suddenly up or down. Participants P1, P3 and P5 did not like these movements. The players needed to anticipate the next actions required so they had enough time to prepare and adapt their posture so that they could execute those actions.

VI. THE SECOND PROTOTYPE

A. Second Prototype's Features

In the second prototype new features were added. Some of the features in the initial one were modified. Table IV summarises the changes.

B. Iterative Testing of the Second Prototype

The second prototype introduces more features and provides a better user experience compared to the first prototype. Even though the objective of the game was made easier, some players still kept trying to catch the flies.

Table V shows how many sessions each participant played in the second prototype. In this prototype the score of participants P3, P5 and P7 were affected by misunderstanding of objectives. However the average of all participants' maximum level achievement was increased to 6.3. The average score was higher because no deduction of points implemented.

TABLE IV. SECOND PROTOTYPE FEATURES

Features remained the same	
	F1, F4, F7, F9, F10, F11
Number	Modified Features
F2	Player has to avoid the flies or catch butterflies only.
F3	The Objective is to catch a certain number of butterflies at each level.
F5	Game is over if the player hits a fly five times.
F6	A number of points were given for each successful catch; the points are doubled if the player keeps catching and not missing any butterfly. Once he fails to catch one the number of points goes to a default value. There is no deduction of points.
F8	Butterflies are sent only to the zones where the user can reach (up, down, left and right). They are randomly sent with a probability distribution linked to how frequent the player accesses each zone.
F12	Large text messages accompanied by audio signals to encourage users when they are performing very well or very badly.
F13	Game can be paused any time when the player stops moving or leave his/her position.
New Features	
F14	Encourage players to switch hands by giving them rewards if they switch hands.
F15	Encourage players to move from point A to be B and give them rewards.
F16	Ability to contrast the background on demand.
F17	Players are given an initial preparation time at the beginning of each level.
F18	Flies are marked with a red X to convey to the user that he/she should avoid them.
F19	Flies are sent only in advanced levels.
F20	In the first two levels butterflies are only coming from middle.
F21	A yellow glare was made around butterflies to make them more visible on the screen.
F22	Movements of the knees are monitored and recorded.

In second prototype the task remained to avoid flies; however they were marked with a big red cross (X) to indicate not to catch them. Participants P2, P5 and P7 said that they misunderstood the objective at the beginning. This led us to use only one objective at a time in the next prototype. It is also highlighted that we should not use two contrasting objectives in the same game. Most participant reported that it was difficult to perform an avoidance action but easy to perform a catching action. As a result in the third iteration of the game, the player only had to catch butterflies with the avoiding flies part being removed completely from the game. Furthermore some players finished their gaming sessions very quickly because they also tried to catch the flies instead of avoiding them. In one game session, participant P5 failed to catch anything and stayed for a long time at the same level. To solve this we suggested giving a guaranteed level of achievement which is implemented by sending a huge swarm of butterflies at once so players can catch something.

TABLE V. PARTICIPANTS DATA IN SECOND PROTOTYPE

Participant Code	Total number of sessions	Average duration in seconds	Maximum level achieved	Average score
P1	5	175	8	404
P2	8	155	5	214
P3	1	195	6	573
P4	1	186	5	472
P5	3	162	3	71
P6	7	389	10	1127
P7	8	248	7	460
Total/Average	33.0	215.7	6.3	474.4

The game playing should never keep going until players feel tired or exhausted. Even if the player is performing well, each game session is supposed to occur within a time frame that is not less than a certain amount of time and should not exceed another amount, to ensure that game playing does not end too quickly and will not last for too long. In another session participants P3, P6 and P7 started playing very well but quickly got tired when the level was advanced with increasing game difficulty. In this instance his/her performance dramatically dropped off. We suggested linking the game difficulty with current player performance, so it will increase when player performance improves and decrease when player performance decreases. We also found that it was beneficial to add audio signals that help guide players during the game. When Participant P2 who has difficulties seeing was playing, other participants tried to help her by giving tips such as “go up”, “move down”, and “catch it”. A new feature was suggested to add more audio that could simulate this process further and help guide the player’s action.

VII. THE THIRD PROTOTYPE

A. Third Prototype’s Features

In the third prototype new features were added. Some of the features in the second one were modified. Table VII summarises the changes.

B. Iterative Testing of the Third Prototype

From the feedback of the players and the observations of the designer, it was felt that time based playing was more suitable for older adults. This meant having each level timed to a certain duration, allowing each participant to play the game for a significant amount of time to keep him/her active. It was decided to limit each game level was to 2 minutes, after which a level break is shown where the user can either continue or quit playing the game.

Table VI shows how many sessions each participant played in the third prototype. Each session was timed to 120 seconds, players made one level progress when he/she caught 12 butterflies.

TABLE VI. PARTICIPANTS DATA IN THIRD PROTOTYPE

Participant	total number of sessions	average duration in seconds	maximum level achieved	average score
P1	2	120	7	798
P2	7	120	6	257
P3	1	120	7	215
P4	1	120	7	1071
P5	3	120	4	175
P6	7	120	10	1348
P7	6	120	7	718
Total/Average	27.0	120.0	6.9	654.6

The implementation of the guaranteed achievement was important to keep users motivated. When he/she failed in all their tasks they should be given a task that they will be able to attain so they always have a sense of achievement. Linking game difficulty with their performance had a positive influence on their game enjoyment, with all participants stating that they felt more confident playing this version of the game, and they liked catching the swarm of butterflies.

TABLE VII. THIRD PROTOTYPE FEATURES

Features remained the same	
	F1, F4, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15, F16, F17, F20, F21, F22
Number	Modified Features
F2	Player has to only catch butterflies.
F3	The Objective is to catch as many as butterflies in 2 minutes.
F5	Game is over when the time for each level is up.
F18	No Flies are introduced in the game.
F19	No Flies are sent at any level.
New Features	
F23	Each level is based on time.
F24	Audio directions to help the player catch the butterflies in the game.
F25	Introducing the guaranteed tasks so every player is rewarded regardless of current performance.
F26	Game difficulty increases and decreases during game play, it does not only increase.

VIII. DISCUSSION

This game prototype was subjected to iterative user testing. After the third prototype, the game was found to be more appealing to the participants. At each iteration new features were introduced and evaluated.

The average score was found to increase in each prototype especially when no deduction of points implemented and players could achieve better results. In the third prototype the game playing was based on time so that the maximum level the player achieved depends on how many butterflies he could catch during the game playing. Furthermore each player was capable to achieve presence in the game; with the least score is

175 at level 4. This achievement can be enhanced if participant plays the game more often, because the game collects more information about his/her physical capabilities and performance in each session then it adopts the difficulty level according to that.

TABLE VIII. RESULTS

Scenario	Solution
Player didn't take any steps.	Give rewards for making a step to the left or to the right.
Players didn't switch hands.	Give rewards for switching hands, introduce some tasks to be performed with a specific hand.
Players didn't bend their knees.	Give them rewards for bending the knee. But watch for his action limitations.
Player couldn't accomplish any task.	introduce the guaranteed tasks.
Player found the game objective is too complicated.	Use one objective at a time; don't use two contrasting tasks in quick succession.
Player has less speed and accuracy of movement.	Adapt game elements to the player's performance.
Player gets tired during game play.	Auto pause the game.
Player's performance was good then it becomes bad.	Game difficulty should be linked to player's performance. Do not punish the player if he/she does not accomplish a task.

Table VIII presents a summary of the unsatisfactory scenarios that were found during the iterative testing along with their suggested solutions.

The main conclusions that can be drawn from this work are the following: When designing movement based games for older adults, it is important that the game adapts to the player's different action capabilities. The presentation of the visual elements in the game should guide the player's actions. This can be done by designing the game play with regard to the player's performance and action capabilities. Using different rewarding techniques is essential to maximize a player's engagement with the game play.

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