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Towards personalized cognitive-social-affective engagement among active seniors: A case study on UX and inclusive design

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Abstract: Cognitive-socio-affective engagement is crucial to maintaining quality of life in all ages. However, as age increases and technology becomes more permissive and seamless, the question is how to design technology and content for positive user experience as well as for inclusive design. Furthermore, in contrast to the common belief that aging leads to reduced brain plasticity, some researches have indicated that the actual problem may be that seniors learn too much and the actual problem is the ability to filter out. In this paper, we investigate: a) How can we design for cognitive-socio-affective-physical engagement taking into account cognitive load, motivation theory and inclusive design? b) i) Which among the design principles are more important for a sample of Malaysian seniors? ii) What are users' perceptions towards Augmented Reality in inclusive design? c) What are implications to inclusive design? User testing based on user experience (UX) are carried out. Based on Cognitive Load theory, Keller's Motivation theory, Koster's theory of fun and inclusive design, we designed for cognitive-socio-affective-physical engagement. Findings in user interface and interaction design highlight the importance of a Systems Theory approach with regards to diverse stakeholders, cognitive-socio-affective factors, UX and game mechanics prior to the development of personalised services, towards further open interoperability, richer learning analytics and better context-awareness.

Keywords: Human factors, cognitive-socio-affective-physical engagement, user experience (UX), augmented reality, inclusive design

1. Introduction

Advances and emerging trends in digital infrastructure enable open interoperability of data including matching and mixing of different chunks of data to suit different learning objectives, contexts and needs. Raptivity for instance, provides a clear example of matching and mixing of modules across learning contexts to enable instructors to create new lessons. Open interoperability thus leads to heterogeneity in data, and richer learning analytics. Consequently, capturing, collecting, storing, analyzing and mining data to improve the efficacy of services, have greatly contributed to not only better Open Educational Resources (such as the European OER), interoperability standards, and digital infrastructures but also better context-aware and personalised technologies.

Inclusive design reflects these scenario and trend. Microsoft defines inclusive design as "fluid". The United Kingdom (UK) defines inclusive design as "flexible, responsive, convenient, accommodating/welcoming and realistic". Aspects that can be inclusive are ability, language, culture, gender and age. We agree with these definitions. The belief is that learning/creativity is part of mental, social and physical healthcare. Healthcare is the United Nations' Sustainable Development Goals' (SDG) Goal 3: *Ensure healthy lives and promote well-being for all at all ages*.

Healthcare concerns both young and old. Some problems are cognitive, some social, some affective, some physical, due to addiction to handphones, resulting in lack of exercise, obesity and lesser productivity (Adaa, 2016; WHO, 2016). Hence, we need to design inclusively for the young and old in a lean manner to enhance user engagement based on their needs and preferences and motivate them to socialize more.

From a practical perspective, *Home Instead* (2018) suggests how technology can be used by Seniors and their Caregivers to help seniors to stay home longer and also reduce depression. These are:

a) Social Connection – Video Chat and Social Media (Long-distance chats with loved ones),
b) Safety – Emergency alert systems,
c) Exercise – Video Games,
d) Medication Management – smart phone apps to prevent medication errors
e) Health Tracking – simple maintenance and access to seniors' health information.

Further help for caregivers is exemplified by *Me & My Caregivers, Inc*., which was set up to promote *better communication among all involved parties*. In addition, via their Web service communication tool, seniors and caregivers can stay better informed. With more information and more friends, family members and health care providers can keep in touch with each other, enabling them to be more prepared and thus provide better care for the seniors. Features include: daily health journal and organizer, personal health record storage, emergency information, and calendar with timely email reminders.

The Speaking Exchange, a US initiative, provides another example of the use of technology to connect seniors, this time, to help others. It connects retired people living in care homes with students learning English in Brazil, via Skype. The seniors look forward to the chats while the Brazilian youngsters improve their English. Over time, both develop strong bonds. Similarly, the UK offers *Cloud Grannies*. It connects retired people in touch with children in India.

1.1 Objectives/research questions

The above initiatives are admirable and involve easy-to-use technology with user-centred design, aimed at connecting different stakeholders. Along the same lines, this research aims to design Website/mobile contents to develop motivation for cognitive-socio-affective-physical engagement, but for Malaysian youths and seniors. In the initial framework for inclusive design, Lee and Wong (2017a) recognize that it is not common for young and old to communicate or work together as above. Nevertheless, it is hoped that as young-young and old-old are more connected within their age groups, they will build up interesting ideas or discussions which will benefit other young and old groups.

Two models, i.e., a knowledge-based model synergizing interchangeably with a resource-based model have been applied over the years with promising results for youths. The design of information systems to develop and improve cognitive-socio-affective-physical community-based engagement in Smart Cities have been presented in Lee and Wong (2017b) and personalization of services in Lee, Chan and Guy (2017).

This research continues from the inclusive design proposal in Lee and Wong (2017 a, b) and Lee, Chan and Guy (2017) and Lee and Wong (2018). These research are interested in developing epistemic agency and creativity (with and without gamification) and its transfer to inclusive design in learning itself and to intergenerational healthcare. We hope that subsequently, seniors and youth can engage different groups with different needs, locally or elsewhere. We also note that some of the mobile or Web-based AR applications require people to spend a lot of money to get the device to play the game. Hence, we need to design contents/activities which are lean in design and management as much as possible.

The inclusive design in this paper is framed within a user experience (UX) and object-oriented/linked and thus extensible and scalable perspective. Another paper frames discussion on designing for usability, learnability and user experience based on Sweller's cognitive load theory, ARCS motivation theory, Koster's theory of fun for games design and Schell's game mechanics and mapping with Schrepp, Hinderks and Thomaschewski's (2017) user experience (UX) questionnaire's attributes.

Our research questions are as follow:

- **Research question 1** Based on literature review, how can we design for cognitive-socio-affective-physical engagement taking into account cognitive load, motivation theories and inclusive design?
  Next, based on user testing,

- **Research question 2** Which among the design principles are more important for a sample of Malaysian seniors?
  We also note that Augmented Reality is superimposed Reality. Hence, it can add/reduce cognitive load.
- **Research question 3** What are users' perceptions towards Augmented-reality in inclusive design?
- **Research question 4** What are implications to inclusive design?

The outline for this paper is first, related work on design considerations, related work on augmented reality, methodology, followed by findings and conclusions.

2. Related work

2.1 Design considerations

Many websites on well-being are very helpful and informative. Many websites suggest how to help improve in simple steps, catered to people of all ages and all abilities. To design, Norman (1988) and Nielsen's (2012) design principles provide some suggestions. Many in user interface design and interaction design such as Preece, Sharp and Rogers (2015) would suggest user experience.

Norman's (1988) user interface design principles and concepts explain these other design principles and why some designs are more usable and learnable than others. These are: a) consistency, b) visibility, c) affordance, d) mapping between a control and its effects, e) constraints and f) feedback. Affordance is a *visual* attribute of an object or a control that provides the user *clues* how the object or control can be used or operated. The clues can be either the *shape* or *colour* of an object. It however, works in sync with other design principles. *Activational feedback* confirms that control was activated successfully whereas *behavioural feedback* confirms that the activation/adjustment of the control has had some effect.

Similarly, Nielsen's (2012) defines usability as comprising of three main factors. He sums up usability from five to three factors:

a) **Utility** = whether it provides the **features you need**.
b) **Usability** = how **easy & pleasant** these features are to use.
c) **Useful** = **usability + utility**

Usefulness is primary and enabled by ease of use. These two aspects are also key to Davis, Bagozzi, Warshaw's (1989) Technology Acceptance Model (TAM) as they influence users' likelihood to continue using the developed system. Most importantly, the TAM model recognizes that there are external factors influencing these two key factors. Venkatesh and Davis (2000) point out in TAM2 that perceived usefulness and usage intentions in terms of social influence (subjective norms, voluntariness, image) and cognitive instrumental processes (job relevance, output quality, result demonstrability, perceived ease of use) are part of these external factors.

These design principles affect cognitive-socio-affective engagement mainly at the user interface level and then, user interaction levels. We are interested in augmented reality as it is superimposed reality. The augmented reality markers can be easily changed/adapted to different contexts, objectives and learning needs and are portable anywhere anytime, thus making them conducive channels for cognitive-socio-affective-physical engagement. Some related work on augmented reality technology and games/exercise are reviewed below.

2.2 AR technology and games (physical engagement)

Recreational and exercise games provide engagement/fun while exercising. According to Schreier (2011), *zombies, run!* an Augmented Reality-infused application that encourages users to walk, jog, or run has been successful. When users interact with the app, users have to choose their destination and the app will start narrating stories making users feel like they are part of the story. When users are using the app, they are able to access multiple choices- game options - in order to encourage them to exercise. The application comes with features such as the sound effects of zombies chasing, narrations of stories and few other unique features for the user. Along the way, users are able to collect some in-game attributes to help them to survive in the game, and users can even decide to help people out in different areas of their cities because their decisions can make a difference to other users' lives in the game. This game has a feature called *zombielink* which enables users to look at their running route and keep track of their pace while the users are running. Users are also allowed to choose songs to listen while they are running and record down which songs can encourage them to run faster. With all these unique features, the *zombie, run!* app uses reward systems such as collecting items or helping others and scary stories to motivate users to walk, jog or run further.

Similarly, *BallStrike* uses Augmented Reality to help people to burn their calories and slim down. This app helps people by turning work into games. Users have to interact with the app by hitting the virtual balls that appear on the screen. This app works by using the camera of the computer to detect users' movements such as punching, and kicking then creating virtual objects for the user to interact with (Nedelcu, 2013). This app creates challenges for users, as users have to reach out till the edge of the screen in order to make the virtual balls explode. The app also helps to calculate estimated number of calories that has been burned, the number of ball missed, the points collected at that stage and the remaining time. Users can get motivated to get higher scores than their previous records. This makes them want to work even harder to surpass their previous records. Various stages with increasing levels of difficulties challenges users to work out more.

Another mobile application that encourages people to exercise is called *Superhero Workout*. An app that uses the function of camera-based motion tracking to record down the number of reps as the user exercises, it adds in a thrilling sci-fi story for users. In the game, users will have special abilities after they workout, such as shooting, having a virtual armour, and other powers. The game includes well written stories by a team of amazing actors, writers, developers, and designers. They ensure that users can be part of the story and become superheroes and fight off aliens with various exciting workouts. Users will also gain achievement points when they are advancing through the missions (Williams, 2014). The exercises include all types of workouts for all parts of the body with statistics included. The apps will also calculate the users' calories and moves via the motion-tracking system from the mobile's camera.

2.3 Summary

From the above review, the design of the Web-and mobile-based engagements needs to persuade through its objectives, design, and multimodal forms and interactions. In short, to: a) motivate cognitive-socio-affective engagement by encouraging seniors to interact with their families and/or look beyond their own homes (Section 2.1); b) be motivating in terms of rewards (Section 2.2); c) model rewards/gamification to cater to as many needs as possible and to be visual (Section 2.2). In an extended meta-meta-analysis paper, the neuroscience/brain plasticity/learnability aspects are discussed.

3. Methodology

3.1 Research Design

The purpose of this study is to investigate:

a) How can we design for cognitive-socio-affective engagement taking into account cognitive load and motivation theories? Which among the design principles are more important?
b) What are users' perceptions towards Augmented-reality in inclusive design?
c) What are implications to inclusive design?

Other than Norman (1988) and Nielsen's (2012) usability design principles, two theories play key roles in the design of user interface and interactions: Cognitive Load theory (CLT) (Sweller, 1998) and Keller's (2010) ARCS Motivation theory. The former is chosen as we need to cater pragmatically to both seniors and youths. The latter is chosen as we are interested in user experience and ARCS contributes towards it.

CLT balances and optimizes the way information is presented to the user, taking into account that different people can accept only certain amounts of information processing load for meaningful and fruitful cognitive access to occur. Figure 1 illustrates the different types of loads involved during information processing on the left. It highlights the need to decrease mental effort in order to improve performance.

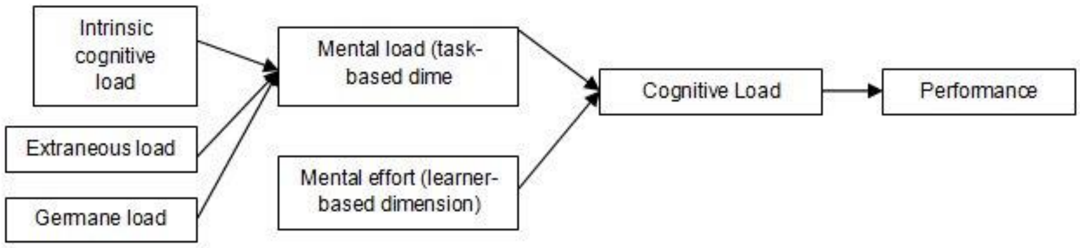

*Figure 1***.** Sweller's (1998) cognitive load model

Keller's (2010) ARCS Motivation model involves **A**ttention, **R**elevance, **C**onfidence and **S**atisfaction. Recommended strategies within each phase/component are:

- **A**ttention: perceptual and inquiry arousal
- **R**elevance: experience, present worth, future usefulness, needs matching, modelling, choice
- **C**onfidence: likelihood of success, objectives and prerequisites, meaningful success, incremental growth, feedback, learner control
- **S**atisfaction: rewarding/sense of achievement, useful skill or opportunities in real setting, feedback and reinforcement arising from appreciation of the results.

Inclusive design in our study is inspired by Resnick's (1999) low floor, wide walls, high ceiling as he and proponents of creativity tools believe that we need to think from multiple dimensions. These criteria refer to easy entry, broad scope/diversity and higher targets/goals (so that one will always aspire higher and higher) respectively. Analysis is based on content analysis.

3.2 Sample

Since this study concerns inclusive design, the target users consist of two groups. First, active seniors aged between 60 – 75, who are members of an active seniors group and second, undergraduates aged between 19 – 25 who have mobile devices and no experience in AR. Respondents are the people who are interested to participate, i.e., voluntary.

3.3 Data Collection

The primary method will be a survey on needs and preferences carried out in the pilot study and the user testing. The user experience instrument is used as is from Schrepp, Hinderks and Thomaschewski's (2017) User Experience Questionnaire (UEQ). They opine that six attributes contribute to attractiveness (appeal):

- *Attractiveness*: Overall impression. Do users like/dislike it? Is it attractive, enjoyable or pleasing?
- *Perspicuity*: Is it easy to get familiar with the product? Is it easy to learn? Is the product easy to understand and unambiguous?
- *Efficiency*: Can users solve their tasks without unnecessary effort? Is the interaction efficient and fast? Does the product react to user input quickly?
- *Dependability*: Does the user feel in control of the interaction? Can he or she predict the system's behaviour? Does the user feel confident when working with the product?
- *Stimulation*: Is it exciting and motivating to use the product? Is it enjoyable to use?
- *Novelty*: Is the product innovative and creative? Does it capture the user's attention?

Our user testing and analyses are based on the full version for the capstone (final year) projects but the interpretations in this paper are based on the short version since the short version has been validated by Schrepp, Hinderks and Thomaschewski (2017), is predictive of the full version, and is more meaningful due to its hierarchical ontological links between attributes contributing to attractiveness.

4. The *MOVEIT*! System

Figure 2a shows the *MOVEIT* home page. The image that is labelled Photo of the month is the photo, which obtained the highest ratings of all the other photos at the end of the month. The three images below provide details to users about the contents of the websites. The Photo album page (Figure 2b), cooking, forum pages allow users to store photos of their memories in an online album so that they could share their memories with others. For instance, they could share where they have been travelling, and the most liked recipe. When their photos are uploaded to the website, captions can be inserted.

Users can also connect to the MOVEIT community page (Figure 2c). This allows users to have more engagement in another social media platform to share their interests and moments with others. The difference is *MoveIt!* is structured and enables easier search and rewards. We thought that the more structured Website would make it easier for seniors. The forum allows single access to all pages.

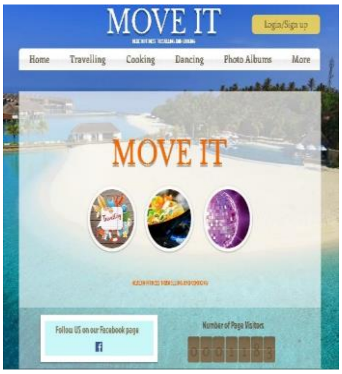

*Figure 2a***.** Welcome Page

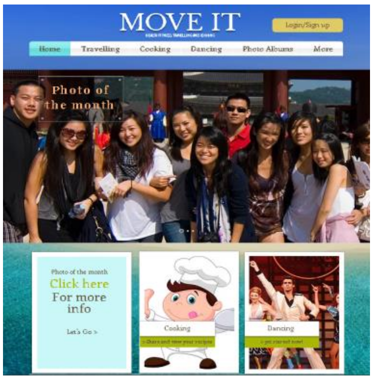

Figure 2b. Photo Albums Page

Figure 2c. Community page

Figure 3 shows the screenshots for the Dancing page. The main function of this page is to encourage the seniors to engage in exercises by doing line dancing and maintain their stability and prevent falling by going through the Otago exercise. The exercises and the dance videos are both equally divided into four different levels of difficulties and each level of Otago exercise provides a series of videos that allows users to follow along to do the exercise. As for the line dance, each level provides only one video that teaches users how to do a simple line dance. Augmented reality content is added to the young adults' version of the dancing page.

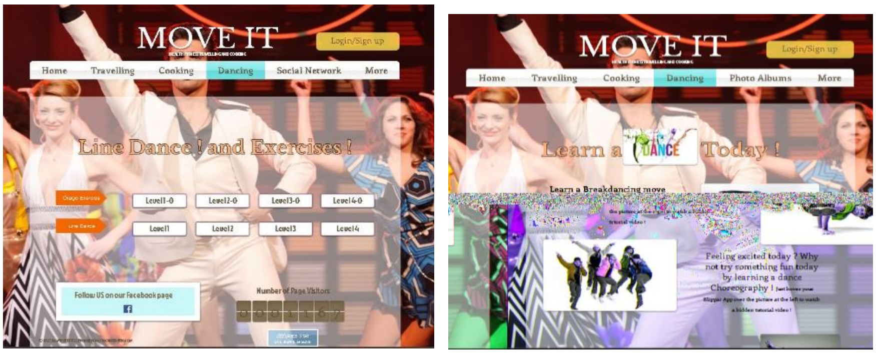

Figure 3. MOVEIT Dancing page for the elderly (left) and young adults (right)

5. Results and Discussion

As mentioned in the methodology section, for user testing, the full version of the UEQ was used by the seniors and the youth. This was because the user testing was carried out in middle 2017 but the short version of the questionnaire was published later part of 2017. The short version has been validated by Schrepp, Hinderks and Thomaschewski (2017), is predictive of the full version, and is more focused. Hence, in Table 1, the first column shows attributes from the long UX questionnaire and the second column the attributes from the short UX questionnaire, which Schrepp, Hinderks and Thomaschewski (2017) recommended to use. These scores represent the outcomes from the seniors' perceptions. We prefer the short questionnaire's 'compression'/categorization of 26 attributes into 6 interlinked, hierarchical/ontological attributes.

Table 1.
Perceived strengths on a Likert scale of 1 to 7

Active seniors' perceptions based on long UX questionnaire	**Active seniors' perceptions mapped to short UX questionnaire**	**Youths' perceptions**
[71%] 11. Obstructive (1) – **Supportive** (7) 14. Unlikable (1) - **Pleasing** (7) 16. Unpleasant (1) – **Pleasant** (7) 22. Impractical (1) – **Practical** (7) [69%] 2. Not understandable (1) – **Understandable** (7) 6. Boring (1) – **Exciting** (7) 13. Complicated (1) – **Easy** (7) 20. Inefficient (1) – **Efficient** (7) [66-67%] 1. Annoying (1) – **Enjoyable** (7) 7. Not interesting (1) – **Interesting** (7) 26. Conservative (1) – **Innovative** (7)	[71%] 11. Obstructive (1) – **Supportive** (7) [69%] 6. Boring (1) – **Exciting** (7) 7. Not interesting (1) – **Interesting** (7) 13. Complicated (1) – **Easy** (7) 20. Inefficient (1) – **Efficient** (7)	[81%] 1. Annoying (1)–**Enjoyable** (7) [80%] 8. Unpredictable (1) – **Predictable** (7) [76%] 2. Not understandable (1) – **Understandable** (7) [73%] 10. Inventive (1) – **Conventional** (7)

5.1 Average scores

For seniors, the average user score across the 26 attributes (from the UEQ mentioned in Section 3.3), is 4.10769 over 7. This results in 58.6813%. However, average score per item is 4.107692 over 7 (58.68%).

In a customized version for youths in *MoveIT!,* the dances are changed and augmented reality added. For young adults, the average item score across the 26 attributes is 4.35 over 7 (62.1%). More than half of the participants do find it enjoyable as the average score for this attribute is 5.7 out of 7 (81.4%).

5.2 Strengths

Overall, users enjoy the website as the average score that they gave for question 1 is 4.6 (66%). Attributes 11, 14, 16 and 22 scored 71%, attributes 2, 6, 13 and 20 69% and attributes 1, 7, and 26 between 66-67%. Based on the short-UX attributes, pragmatic attributes averaged 64% whereas hedonic attributes 62%.

As for the user testing with young adults (with Augmented Reality), attributes 1 (*enjoyable*) and 8 (*predictable)* scored 81 and 80% respectively, attribute 2 (*understandable*) 76% and attributes 7 (*interesting*) and 10 (*conventional*), 73% respectively. For both, findings are promising though there is much room for improvement. Factors which may increase user experience scores are likely to be i) authentic rewards in various forms, whether in terms of tangible or intangible rewards and ii) based on game mechanics reviewed above, manageable challenge. Part of this is explained in the gamification paper (Lee & Wong, 2018).

5.3 Linked systems: Usability, UX and attractiveness

The following systems are outcomes from the above theoretical foundations and are interlinked to *MoveIT*! to enable sharing of resources in line with the Open Educational Resource movement. These systems are currently standalones but can be linked at the database with use and retrieval of relevant seed, captured or curated or user/community-contributed media. *Three Variants of Bingo, MoveIt!'s twin,* focuses on Norman's (2012) design principles especially consistency and affordance. The three variants are numbers, photos and a memory game. The memory game variant is presented in Figure 4a. The three variants also include two levels of patterns as visible or background challenge (depending on the needs of the users) as part of embedded gamification. Two examples of these winning patterns is presented in Figure 4b.

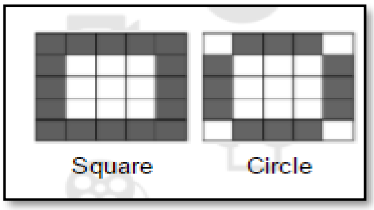

Figure 4a. Three variants-bingo (memory game variant) *Figure 4b.* Two examples of winning patterns

Top five attributes after user testing for the 3 variants of bingo are *Efficient, Enjoyable, Exciting, Pleasant*, and *Understandable*. Scores are slightly higher than that of *MoveIT!*. We find that some seniors who are used to playing games in their past time, look forward to challenge. Having the winning patterns (disabled during the user testing for fear of adding on to the cognitive load arising from multiple colours in the photos variant), would provide this challenge. It may even encourage the non-gamers to play as given the cue (the pattern), it would be easier to match and identify where the "answers" are.

Three other applications complement these two systems. These are aimed at different levels of difficulty corresponding to the seniors' age and/or degree of aging. The primary design factor is cognitive load. The more active seniors will be presented with the *Three-board Mobile Bingo game* (Chin, Lim & Lee, 2017). The more aged will be presented with the *GuessIt!* drawing-spelling game (Foo, Lim & Lee, 2017) and the *Augmented Reality-enhanced pet game* (Hoo & Lee, 2017). All systems still have much room for improvement.

These systems partly function as stress relievers by enabling browsing through various kinds of social networking applications and by enabling real-time updates in every aspect of one's lifestyle. However, not every senior is as keen as youths on exercise as mobility, sight and energy reduces. Successful examples are as follows: Van Schaik, Blake, Pernet, Spears and Fencott (2008) find that their Virtual Augmented Exercise (VAE) combined with cognitive exercise (solving simple puzzles and hitting targets based on the answer), have evidenced promising results. Knowledge@Wharton High School (2016) further point out that context-awareness can enhance interaction with Augmented Reality (AR) and content.

Another example, the game Pokémon Go, is so interesting that according to Knowledge@Wharton High School (2016), the game motivates people to walk extra few kilometres a week without the player even noticing. They highlight that the intrinsic motivation in this situation is driven by the reward, i.e., catching a Pokémon. She also notes that one of the players, a 24-year-old Toronto photographer, manages to lose 25 pounds over three and a half weeks because the game motivates him to walk about 260 kilometres.

6. Significance and conclusion

We have assumed that seniors and young people may want to either contribute back to society similar to *The Speaking Exchange, Cloud Grannies, Me & My Caregivers, Inc*., *Home Instead* (2018) or socialize with others in the community to exchange knowledge. This supports design-thinking-based Aging2.0, Davis, Bagozzi, Warshaw's (1989) TAM. Significance of the study are:

The design of fun and rewards for diverse aspects, to encourage cognitive-social-affective-physical engagement and thereafter, identification of important design principles:

a) Effectiveness of Schrepp, Hinderks and Thomaschewski's (2017) UX questionnaire as a lean evaluation approach to identify which pragmatic/hedonistic attributes are more important for each target group.

b) For extensibility and inclusive design:

   i. Being relational-object-oriented, the applications would be extensible due to their modularity in design enabling them to capture different types of data - if the architecture and database are to link to systems such as in a). Open interoperability arising from such open system would lead to heterogeneity in data, and richer learning analytics, better context-aware and personalised services.

   ii. For further customization for inclusive design and personalized services, the richness of the media can be adapted to suit different context, objectives, abilities and ages. Consequently, it also hints that perhaps, gamification can be used as a link between usability and usefulness, with usefulness as primary to increase channels of customization and as/more important than usability design principles.

In terms of impact on the eventual intention to accept and use the system, this group of seniors subsequently requested for a smartphone workshop as they would like to learn how to better use the smartphone. They also started their own free-style dance moves during their meetings. We hope that they will continue to enjoy and maintain their quality of life.

At this moment, there are limitations to the study as our sample size is too small and duration of user testing is only for one week, due to these being capstone (final year) projects. Hence, findings are still preliminary and cannot be generalized. Findings scratch only the surface of what neuroscience has found.

In the next round of capstone projects, at a higher level of engagement, Wong and Lee's (2018) study integrates game mechanics (and Augmented Reality) for cognitive games and also to encourage exercise using hand gestures via Leap Motion. Screenshots of the exercise games are shown in Figures 5a, b.

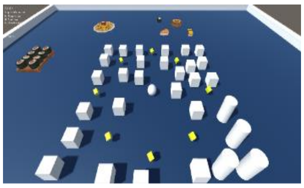

Figure 5a. Rolling ball (easy)

Figure 5b. Rolling ball in a maze (difficult)

Another two systems involve community event sharing (Kiran Kaur & Lee, 2018; Bong & Lee, 2018), Augmented Reality curation guessing-game/picture shape recognition collage system (Mak & Lee, 2018), an Augmented Reality-based e-commerce system (Handoko & Lee, 2018) and dynamic customer pricing system (Tang & Lee, 2018). The last work-in-progress system uses Salesforce.

Acknowledgement

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