Investigations on the Impact of Anthropomorphism and Gamification on Breast Cancer Survivors' Expressed Preferences in a Physical Activity Promotion Intervention

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***Abstract*—Among the most common breast cancer treatment-associated effects, it is possible to recognize a high prevalence of arm/shoulder restricted mobility and arm swelling that deteriorate the upper-body function and may lead to chronic lymphedema. Within such a perspective, the need has been identified for breast cancer survivors to sustain a constant and specific physical activity. For that, homebased programs are being presented as a desirable path to be followed. Concurrently, an emergence of new technologies has led to major changes in society. For instance, technology from the video games industry has been used with emphasis in the recovery, and follow-up stages, to evaluate and motivate the patient after treatment. The present work aims to evaluate a set of contextual interfaces that use data acquired with a colour and depth sensor to monitor, and provide real-time feedback to, a given user. Furthermore, fundamental design guidelines from serious games are explored within the context of developing a system aid for physical follow-up care in the form of a set of exercises selected by the medical community. The proposed interfaces were evaluated in a clinical setting with a group of breast cancer survivors.**

Keywords–Patient-empowerment services; Preventive Systems; Self-management systems; Monitoring systems.

I. INTRODUCTION

While contributing for improved overall survivorship, contemporary breast cancer treatment techniques may result in several impairments in women's upper-body function and, consequently, contribute to a decreased quality of life [1]. As Breast Cancer Survivors (BCS) are living longer, the adverse effects resulting from the cancer treatment are more frequent. Upper body morbidity (e.g., decreased range of motion, muscle strength, pain and lymphedema) are among the most prevalent side effects. Regarding lymphedema alone, a swelling condition resulting from lymphatic ablation commonly associated with breast cancer treatment, it has been estimated that over 1 million BCS in the US and 10 million women worldwide may meet the criteria for breast cancer-related lymphedema [1].

While the assessment of the oncological outcome of the cancer treatment can be easily objectively quantified by disease-free and overall survival rates, the same does not hold for functional aspects closely related to quality of life. Assessment of BCS symptoms and health-related quality of life outcomes are usually made using Patient Reported Outcome (PRO) questionnaires that quantify significant outcome variables from the patient's perspective [1].

A prospective surveillance model for BCS has been proposed, highlighting the importance of monitoring for functional and physical impairment commonly associated with treatment [2]. Notwithstanding, and though some methods for monitoring and assessing do exist, an integrated approach able to achieve early detection, promote risk-reduction and self-management, while engaging the user in an appropriate follow-up strategy, is still being reported as missing [3].

In Section II, an outline of topics related to the application of typical elements of game playing is presented in order to contextualize the proposed methodology, that is presented in Section III. The paper concludes with a discussion of results in Section IV, regarding key questions relating to the application of strategies of anthropomorphization and gamification as means to promote engagement to particular physical activities within the context of patient empowerment systems.

II. RELATED WORK

Engaging patients in their healthcare can be recognized as a paramount topic that has evolved through time also as a reflection of specific technological and societal contexts [4]. In this sense, growing trends of the quantified-self movement, personal health records tools dissemination and interactive video games that combine physical exercise with game-play and have a primary purpose other than entertainment present themselves as currently active research lines.

A. Gamification

Physical activity promotion programmes tested in patients with disabilities and impairment problems demonstrate that patients' functionality can improve with an intensive training split that is contextualised and oriented as a pursuit in the achievement of a well defined goal. However, this task division is prone to present a major set-back, which is the lack of interest of the patient in performing repetitive tasks [5].

On the other hand, it is possible to note that a game, overall, aims to offer the player a challenge of a physical or/and mental nature that can be completed using a set of rules, being able to install feelings of amusement or entertainment in the participant while returning feedback in a form of grades or scores, while possibly unlocking new challenges based on the feedback received. Video games have the same goals, only a computer is used as an intermediary [6].

The concept of serious games is one that is hard to define, but it usually refers to games used for training, advertising, simulation or education. A particular example of such a gamified approach, commonly referred to as exergaming or exergames, can be described as a type of video game, or multimedia interaction that requires the player to physically move in order to play [7]. With the evolution of video game acceptance by the general public, serious games have begun to surge, spreading into healthcare where they can eventually provide a more personalized experience to users, improving not just physical, but also mental aspects of care. This surge, and the evolution of visual computing, seems to enable the development of personalized home systems, which could objectively evaluate the patient's state, while motivating for continued physical activity. Specifically for rehabilitation, research has been done, where small game prototypes were tested for specific circumstances, such as upper limb rehabilitation. [8].

B. Anthropomorphism

Different elements can be considered to be included in serious games as strategies to promote improved adherence [9]. Of those, it is possible to highlight virtual representations of the self, through which players are presented to the possibility of assuming the role of a character in the game [10]. On the topic of player controlled game characters, the Illusion of Virtual Body Ownership (IVBO) considers the effect of game players experiencing a sense of artificial body parts to be their own, within the context of an Virtual Reality (VR) setting [11]. Previous research [11] tends to suggest that the IVBO may result from an interaction of both synchronous visual, motor and tactile sensory inputs, as well as pre-existing visual and proprioceptive body representation factors. Included in the group of the latter factors, is the virtual body realism in terms of visual human resemblance, or anthropomorphism [12]. On a related note, the Uncanny Valley appertains to a theorized relationship between humans and robots [13] (e.g., Fig. 1).

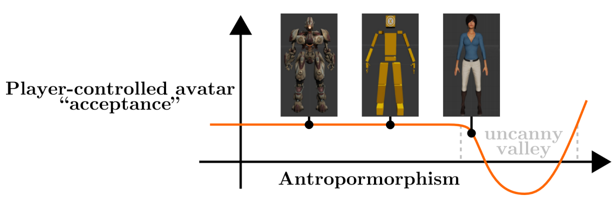


Figure 1. Example assessment of the strength of the IVBO in relation to the degree of anthropomorphism of an user controlled avatar, and the hypothesized uncanny valley effect [13], adapted from [11].

The hypothesis is that there should exist a positive relationship between how human a robot looks, and how comfortable people are with its appearance, up to the moment a robot would get too close to being human in appearance, without being fully human, at which point human reaction would became negative [13]. Its impact in game design has been evaluated although there seems to not exist absolute evidence to support, or disprove it [12].

III. Proposed Research Approach

While there are several games that include serious topics, the inclusion of serious game elements is not yet enough to induce learning or real-world action [14]. Overall, despite engagement being considered a valuable resource, research on patient engagement technologies regarding impact on health outcomes has been limited [15]. Given this, this work's main goal is to develop and assess a game to promote an adequate exercise routine for BCS, to be used independently, as a self-management system to support breast cancer survivorship while monitoring one's physical status. The overall architecture of the proposed system is outlined in Fig. 2.

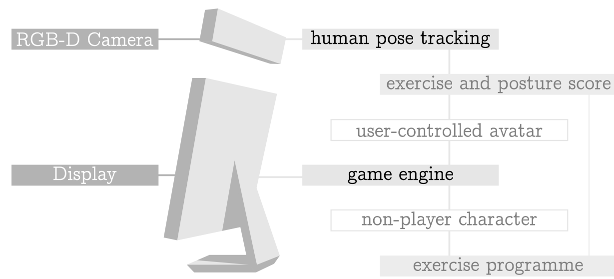


Figure 2. Overall architecture of the proposed system, comprising the use of colour and depth data to monitor, and provide real-time feedback to, a user in the context of a physical activity promotion for breast cancer survivors.

We consider the Microsoft Kinect as an easily accessible, Color and Depth (RGB-D) sensor-device that enables to monitor a user's movement and provide feedback through the usage of an avatar, so that the user is aware of the performed movement, aiming at promoting adherence to exercise [16]. Both versions of the Kinect range sensor, i.e., the $\text{Kinect}^{\text{SL}}$, which is based on the Structured Light principle, and the Time-of-Flight variant $\text{Kinect}^{\text{ToF}}$, were considered [17]. To create the game environment, Unity was selected as the game engine, given its accessibility and widespread use.

In this paper, we pursue the following main topics:

1) anthropomorphism as a strategy to engage, and
2) gamification as a mean to promote physical activity,

about which we present a body of exploratory work.

A. Exercise programme selection

A standardized exercise programme consisting of shoulder flexion, abduction, and horizontal adduction was selected in accordance to the National Institute for Health and Clinical Excellence (NICE) guidelines [18]. The individual exercises comprised in the programme are illustrated in Fig. 3.

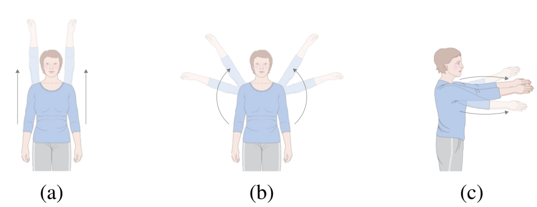


Figure 3. Illustration of the elements of the exercise programme considered for BCS physical activity promotion intervention, consisting of shoulder flexion (a), abduction (b) and horizontal abduction (c). Adapted from [18].

The exercise routine is composed of three sets, each comprising ten repetitions of one of the three exercises included in the programme, and small breaks between sets.

B. Expressed acceptance assessment

Analysis of engagement can be considered valuable in providing insights into game mechanisms that can then be applied to games for learning, or physical activity promotion [19], although not trivial to measure. In order to assess the acceptance of particular contexts of a given physical activity promotion intervention, a criteria set, based on [20], was used as basis for user expressed acceptance assessment. The criteria comprised the following aspects of testing:

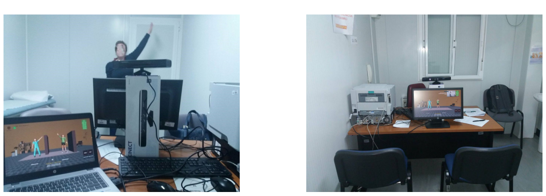
- c_1) suitability for the task,
- c_2) information accessibility,
- c_3) continuity correction,
- c_4) visual pleasingness,
- c_5) self-descriptiveness,
- c_6) adequacy of user workload.

Based on that criteria, a questionnaire composed of six questions was formulated in Portuguese, and a five point scale, ranging from strong disagreement (1) to strong agreement (5), considered for range of response options.

C. Study on anthropomorphism

1) Participants and design: Seventy-two adults (mean age of the cohort was 57.79 ± 11.16 years, all female) participated. They were recruited via personal invitation from surgeon-led follow-up consultations of BCS. Written informed consent was obtained from all participants. All participants were fluent in Portuguese and did not get paid for their participation.

2) Procedure and materials: Participants were invited to participate in this study via personal invitation at the end of a follow up consultation at the Breast Center of São João Hospital during the period from the end of October until the beginning of December, 2016. Participants were informed that the study was part of the development of an aid designed to promote physical activity recommend for BCS. The recruited participants were prompted to use the system, in an adjacent room to the consultation room (as illustrated in Fig. 4).

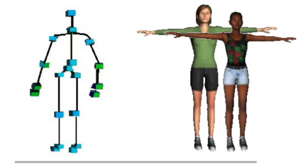


(a) Experimental set-up (b) Perspective of the user

Figure 4. Acquisition environment for the study on anthropomorphism and the tested system comprising a Kinect^{SL}, laptop and additional screen.

The architecture illustrated in Fig. 2 was adapted so that it would entail a Non-Player Character (NPC) in the form of a virtual assistant that exemplified the movements to be performed according to the established exercise programme while the user was exercising. The same programme would be repeated four times, considering additional breaks between routines, one for each of the considered levels of the user controlled avatar anthropomorphism (illustrated in Fig. 5).

Levels of user controlled avatar anthropomorphism (while exercising)	
no visual feedback	
skeleton	a_1)
humanoid avatar	a_2)
mirror	



a_1) a_2)

Figure 5. Illustration of the user controlled character: avatar based characters animated with the user's tracked movement with different levels of anthropomorphism a_1) and a_2).

After using the system, each patient was inquired of its satisfaction level of the usage of the system through a questionnaire that required the user to rate each of the tested interfaces according to a five point scale ranging from least preferred (1) to most preferred (5). Each session took approximately 30 minutes, comprising the usage of the system for the proposed exercise programme and the filling of the questionnaire.

3) Results: Each of the four interfaces were evaluated using the aforementioned score in a five point scale after the user completed the exercise programme using all of the proposed interfaces. Table I presents the mean expressed preferences for the user controlled character variations.

TABLE I. AVERAGE AND STANDARD DEVIATION (SD) OF EXPRESSED PREFERENCES OVER THE INTERFACES COMPRISING VARIATIONS FOR THE USER CONTROLLED CHARACTER TESTED BY SEVENTY-TWO BCS IN A CLINICAL SETTING.

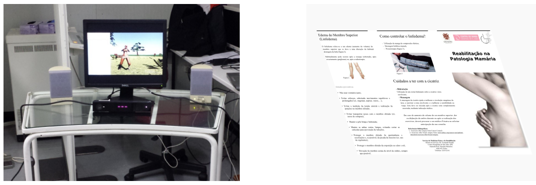
		avatar		
	no visual feedback	skeleton	humanoid	mirror
Average	4.10	4.22	4.22	4.19
SD	0.77	0.88	0.77	0.82

Although it seems to not exist an abrupt drop on the collected expressed preference between evaluated interfaces with different levels of user controlled avatar anthropomorphism, both skeleton and humanoid examples seem to be preferred over the alternatives with either no visual feedback, or mirror-based feedback.

D. Study on gamification

1) Participants and design: Sixty-eight adults (mean age of the cohort was 59.09 ± 10.92 years, all female) participated. The same recruitment method mentioned in Subsection III-C (Study on anthropomorphism) was used. A sub group of 22% of participants (15 out of 68) were randomly assigned to receive printed information resources, in form of a pamphlet produced at the Breast Center of São João Hospital.

2) Procedure and materials: As in the study on anthropomorphism, participants were invited to participate after a surgeon-led follow-up consultation at the Breast Center of São João Hospital. The recruitment took place from the beginning of November until the end of December, 2017. Participants were informed about the study being part of the development of an aid to promote physical activity recommend for BCS, and prompted to use the system, in an adjacent to the consultation room (as illustrated in Fig. 6).



(a) Experimental set-up (b) Printed pamphlet

Figure 6. Side-by-side illustration of: a) Acquisition environment for the study on gamification for the tested system comprising a Kinect$^{\text{ToF}}$, laptop and additional screen; b) Printed pamphlet produced at the Breast Center of São João Hospital and distributed to BCS.

The architecture used for the study on anthropomorphism, was considered, and kept the NPC virtual assistant exemplifying the exercise programme. To provide real-time feedback of the user's own movement only a human avatar was used. Differently from the previous study, the user controlled avatar was animated with the human pose provided by a Kinect$^{\text{ToF}}$. Another novelty introduced by the Kinect version (and corresponding SDK and respective tools) is the gesture builder tool, which allows the creation of a database containing movements, which allows to perceive to which degree of completion is a given movement being performed. After building a library of the selected exercises, this was used to score the performance of the user. The normal scoring of the game attributed 1 point for every 1% of progress in each repetition, and a final score was presented as a percentage of the routine completed (the complete routine corresponds to 3000 points).

After the usage of the system, each patient was inquired to express level of acceptance that required the user to rate each of the previously identified criteria according to a five point scale ranging from strong disagreement (1) to strong agreement (5). Each session took approximately 10 minutes, which comprised the usage of the interface for the proposed exercise programme by the user and the filling of the questionnaire.

3) Results: Table II presents the mean expressed acceptance for the proposed Gamified Aid for Monitoring Exercise (GAME) with a humanoid player controlled character and an NPC virtual assistant, against an informative printed pamphlet. Of the total cohort of sixty-eight BCS, fifty-three were randomly assigned to use the GAME and fifteen assigned for being shown the printed pamphlet.

TABLE II. AVERAGE AND STANDARD DEVIATION (SD) OF EXPRESSED ACCEPTANCE FOR BOTH THE PROPOSED GAME, AND A PRINTED PAMPHLET CONTAINING INFORMATION ABOUT THE SELECTED EXERCISE PROGRAMME.

	GAME		pamphlet	
Criteria	Average	SD	Average	SD
c_1)	4.60	0.74	4.00	1.11
c_2)	4.72	0.50	4.08	1.27
c_3)	4.92	0.32	5.00	0.00
c_4)	4.88	0.29	4.60	0.84
c_5)	4.96	0.19	4.60	0.84
c_6)	4.88	0.39	4.00	1.11

In the context of the evaluation, it seems to exist a stronger agreement, across considered criterion, for the proposed GAME being a preferred medium over printed materials.

IV. Conclusion

The present work investigates the impact of providing real-time feedback to BCS within the context of a physical activity promotion intervention. A system comprised of a RGB-D sensor with a processing pipeline to monitor the user, and in that way animate a user controlled avatar, was considered.

In the first exploratory study, the effect of different levels of anthropomorphism of the user controlled avatar was investigated. Seventy-two BCS participated in the cohort. The results seem to agree with the hypothesised Uncanny Valley effect, in the sense that a more anthropomorphised representation of the self (a mirror), seems not to be the preferred interface. Although not possible to assess from the presented results, but also supported considering previous research, i.e., [11], subjectively constructed proprioceptive body representations of the self, seems to be an apparently worth considering factor in the context of BCS, with potential impact to adherence to systems using anthropomorphised avatars.

In the second study, a gamified approach considering an humanoid avatar and an NPC assistant was evaluated against a printed pamphlet. From a total of sixty-eight participants, a subgroup of 15 was randomly assigned to be shown the pamphlet containing information about appropriate care following breast cancer treatment, including the recommendation to perform simple exercises to be repeated throughout survivorship. The remaining participants played a game where an NPC assistant would exemplify the recommend exercise programme, while a humanoid avatar would replicate the user's movements, and in real-time provide feedback of the exercise being executed. Overall, the collected expressed acceptance suggests that the proposed gamified aid for monitoring exercise seems suitable for the task, informative, visual pleasing, self-descriptive, and providing an adequate workload to the user.

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