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Game Design Proposal through Verification of Game “Locomo de Balamingo”

Supporting Exercise for Elderly: Standing on One Leg with Eyes Open

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Abstract

We developed a game called "*Locomo de Balamingo*" to improve assertiveness and sustainability of participants at the “Standing Exercise with Eyes Open” training, which is used for the prevention of locomotive syndrome. This training requires participants to balance on a single foot, keeping their eyes open for 60 s, three times for each foot with the aim of keeping their bones, joints, and muscles healthy. The subjects comprise healthy elderly persons. A Windows PC and Microsoft *Kinect* were used for human movement sensing to conduct this game. In this paper, we discuss the interface and game design of “*Locomo de Balamingo*” and describe its application in the training of elderly people. Moreover, in the case of healthcare games targeting elderly persons who do not have enough experience in using digital games, we aim to identify those aspects of game design, including failure experiences, graphics, and music, that are effective in enhancing the participants’ assertiveness and sustainability. Verification shows that although graphics with relatively bright and easy-to-understand scenes are preferred, some participants reported that they do not remember the graphics, or they do not particularly care about them. Thus, it is concluded that any scene can be invoked provided that the pattern does not give a sense of discomfort. The game design presented an intuitive interface using simple body movements, which functioned effectively. The addition of failure experience can also be considered an effective means of improving assertiveness. In summary, many instances of positive feedback were received from elderly participants, indicating that the game is useful in promoting the health of elderly people.

Keywords: serious game, healthcare, digital contents

1 Background

Efforts to maintain elderly persons’ health and reduce their medical care costs are currently being explored and implemented in response to the super-aging society. A field, called serious gaming [1], whereby video games are utilized in genres other than entertainment, is becoming increasingly popular both nationally and internationally [2, 3, 4, 5, 6]. The word “Gamification” [7] has also been generalized; hence, the advantage of a game is applied to fields, such as education and health. We are continuing the development and verification of rehabilitation/health care games through the incorporation of a medical design based on the idea that digital games can be utilized for health maintenance. As an example, we obtained evidence of usefulness/safety by demonstrating the experiment that *Kiritsuno-Mori Rehabilium* co-developed with the medical corporation of Nagao Hospital in 2012 [8]. This game was commercialized in 2013 as a game, called “*Rehabilium Kiritsukun*”, which supports standing training and is now being used in 50 facilities nationwide. It represents a foothold for the creation of new industries, such as the collaboration between the medical rehabilitation and digital game fields.

The Japanese Orthopedic Association recommends performing daily exercises, such as squatting and standing on one leg, with open eyes to prevent locomotive syndrome [9]. This training is called locomotive syndrome training, which is hereinafter referred to as Locotre. Locomotive syndrome refers to the state in which daily activities, such as walking, standing, and sitting, are obstructed because of the decay of locomotive body parts, such as bones, joints, and muscles. If it progresses, the risk of becoming bedridden requiring nursing care can be high. Daily exercise is effective in maintaining a healthy state [10, 11, 12, 13], but maintaining the monotonous movement of simply standing up is difficult. Therefore, we develop the game, called *Locomo de Balamingo*, to prevent locomotive syndrome. Our aim is make exercise itself enjoyable and improve assertiveness and sustainability for training (Figure 1). The training method adopted in the game is balance training, wherein a person stands on one leg with his/her eyes open. Participants perform an action that requires them to keep their eyes open for 60 s three times for each foot. If standing on one foot is difficult, holding an object, such as a chair or desk, for support is acceptable. The subjects are healthy elderly persons.

Figure 1 Title of "Locomo de Balamingo"

2 Purpose

Currently, few elderly people have experience using digital games. They tend to resist using personal computers and AV equipment. Therefore, an easy-to-understand interface for easy use is required at the game design stage. Furthermore, for rehabilitation and healthcare games, an uncertainty is faced on the inclusion of failures and stress-related experiences as elements to make the game interesting. Failure is an integral element of the overall experience of playing a game, but it is always potentially painful or at least unpleasant. In addition, the game can possibly be stopped as a result of stress caused by failure, which in this case, means stopping the rehabilitation itself. In our rehabilitation standing training game, failures are excluded because a high percentage of participants has low motor function. In other words, the game designs, including failure experiences, graphics, and music, is important in promoting the game applications in the case of health care games targeting healthy elderly people. Thus, in this thesis, the interface and game designs of the developed game are explained, and we clarify how it is applied to the training of elderly people. Moreover, we illustrate the usefulness of this video game in healthcare and present an effective game design.

3 Game System and User Interface

This game uses a Windows PC as the hardware and Microsoft *Kinect* for human movement sensing.

Figure 2 Standing 2 m from Monitor

Considering that it is used by the elderly, we constructed an interface that allows the game to progress intuitively with neither a game controller, keyboard, nor mouse. Although the training handled by this game is one-leg standing, the system cannot determine whether the user stands on one foot or not. We planned to incorporate sensing using a mattress or a rug. However, we finally determined that the disadvantage of increasing the burden of equipment installation was large, and decided not to adopt it. A TV monitor that was 32 in. or larger is recommended for ease of viewing for the participants. *Kinect* is fixed to the top of the monitor, and the user stands approximately 2 m from the monitor (Figure 2). We designed the sensing by *Kinect* to sense the movement of the user closest to the sensor to avoid malfunction caused by the recognition of non-users, such as the person watching. However, it is preferable for the user that the rear side is a wall or a similar surface, on which other elements do not reflect. As an auxiliary function, it has a compact window to check the sensing situation, and can be switched between display and non-display (Figure 3).

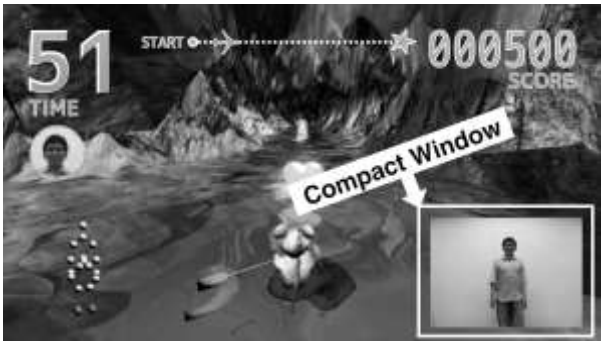

Figure 3 Compact Window

All game progress is achieved by manipulation using body poses. The users raise both hands at the game standby screen, then the screen transitions to the start confirmation screen. By keeping both hands horizontal for 5 s, the gauge shaped as a human body is accumulated, and the game starts (Figure 4). The face photo is simultaneously taken and used for imaging as an element indicating the user's avatar and as a link with him/her in the ranking. Both hands are used from stage 2.

Figure 4 Gauge at Game Start

Hence, hand objects appear on the left and right sides of the screen when the hands are raised. The user must be shown that items, *bombs*, and *coins* can be acquired. Instructions use simple sentences. The raising of both hands to catch the left and right items starts the game. No actual operation is done after completion of the game and it moves to the first standby screen.

4 Game Design

When the game starts, the background (hereinafter referred to as "scene") moves such that the avatar in the center of the screen progresses toward the rear of the screen. A user controls the avatar and aims at the goal while taking *hearts* or *coins* that appear on the screen (Figure 5).

Figure 5 Hearts and Coins on Screen

The game motivation is to obtain a high score by taking *hearts*. A user must stand on one foot without staggering to enable him/her to continue obtaining *hearts* and scoring high. Keeping muscles and joints healthy improves the ability to remain upright, thereby increasing the amount of *hearts* obtained. Through this process, the avatar evolves by passing through the rings that appear in the middle of the scene. The points that can be obtained with one *heart* also increase. The *coins* that randomly show up have a higher score than the *hearts*.

Locotre recommends that single-leg standing be done for 60 s three times a day on each foot. This game facilitates three consecutive plays with the same foot according to this recommendation. In the first stage, *hearts* are lined up in the center of the screen, and the user remains standing with one leg straight. In the second stage, the game is played by simultaneously using both hands to improve the motivation by a failure experience that adds a cognitive duty. In addition to the *hearts* in the center of the screen from the second stage, more *hearts* appear to the right and left. *Hands* appear on the right and left of the screen when the user raises his/her hands. The left and right *hearts* can then be taken. However, randomly appearing *bombs* result in a penalty point; hence, the hands need to be lowered at this time. The actions of remaining standing on one foot without staggering and with moving the hands up and down depending on the circumstances can create a double-task situation, where two actions are simultaneously completed and become an element of cognitive function maintenance training. The degree of difficulty is higher than that in the first stage. In the third stage, the difficulty is almost similar to that in the second one, but the interval between the *hearts* arranged in the center is narrower. As a result, although the user can take many *hearts*, he/she feels the increased speed, and the leg tends to wobble because of fatigue. Thus, the difficulty level further increases.

The score, collection rate of *hearts* or *bombs*, title, and rank are displayed following the completion of all stages (Figure 6). These are the elements that maintain motivation to grasp the current situation and aim for even higher scores.

Figure 6 Title and Rank

The *Golden Balamingo Statue* occasionally appears at the end of each stage, giving a high score (Figure 7). This is an element of luck that encourages the continuation of training and aims to further increase the score of users, who have become able to reliably acquire high scores.

Figure 7 Golden Balamingo

As a fundamental policy of the game design, training is performed thrice on each foot, standing for 60 s while enjoying the high score and competing with other users. This enhances competitiveness and continuity. In addition, maintaining cognitive function by double tasking is a side effect of the enhanced enjoyment.

5 Graphics and Sound Design

Graphics and sound in video games are important factors to increase the user's pleasure and avoid boredom. In this game, six themes are created. These themes intend to enable random selection of scenes. Each scene and avatar controlled by the

user is explained below.

5-1. Sky

Sky is a scene involving a blue sky with visible clouds. The final destination is a floating island with cherry blossoms in bloom. The avatar is a Japanese fighter aircraft, the Type 95 Carrier Fighter. The avatar changes to a newer model (i.e., from Type 96 Carrier Fighter, A6M Zero (Zero Fighter), to A7M Reppu) each time it passes through the ring (Figure 8). This scene setting mainly targets male users and is supposed to remind them of their childhood days. However, it is also assumed herein that people have a negative impression of this motif; thus, care must be taken, especially for overseas applications.

Figure 8 Japanese Fighter Aircraft

5-2. Sea

The motif is the fairy tale “Urashima Taro.” In this scene, the avatar Urashima Taro is heading to Ryugu-Castle under the water. The avatar is a little boy on a turtle. The number of surrounding fish increases every time he passes through the ring, providing a bustling environment (Figure 9). This targets female users by giving them a refreshing and sweet atmosphere.

Figure 9 Scene under Water and Surrounding Fish

5-3. Spaceship

This scene depicts the interior of a spaceship (Figure 10). A robot is expected to be adopted as an avatar, which increases in size each time it passes through a circle. In this scene, an image of Sci-Fi having a high affinity with the genre, called *Deo game*, results in it being attractive to male users. This scene is popular among children, especially boys. However, they are not the correct target.

Figure 10 Robot in Spaceship

5-4. Ruins

This scene is created with an image of the exploration of the Egyptian ruins. The avatar enters the scene in search of a treasure. The avatar is a scarab, which is a creature that symbolizes Egypt. The scarab becomes more attractive as it goes through the ring by changing its color from bronze to gold and adding feathers in seven colors as well as accessories (Figure 11). The ruins are popular sightseeing spots. The scene aims to capture the joy of travelling.

Figure 11 Scarab with Accessories

5-5. Cave

This is a scene in which a mouse rows a boat in a cave (Figure 12). The goal is to find golden acorns. The boat changes from a raft to a luxurious Japanese ship as it passes through the ring. The scene aims to provide adventures, such as exploring mysterious places and ruins.

Figure 12 Mouse in Cave

5-6. Japanese Style

This is a scene containing objects that provoke a Japanese atmosphere (Figure 13). The avatar is a folded paper crane, which changes from a crane, to a peacock, to a phoenix as it passes through the ring. This scene produces an artistic space of the Japanese culture based on its expansion in Asia.

Figure 13 Peacock

A scene of a Christmas image of a snowman was also created for use at special events (Figure 14).

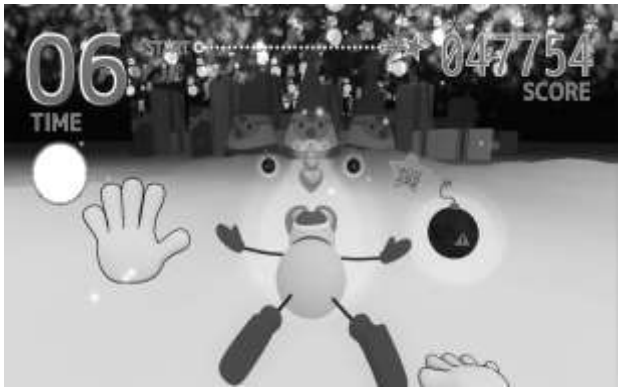

Figure 14 Christmas Version

With regard to the sound element, the background music is composed in conjunction with the image of each scene, such as Japanese or Egyptian style. The sound effect is utilized to inform the user of his/her playing situation in an easy-to-understand manner (e.g., it is used when acquiring a *heart* or a *coin*, passing through a *ring*, and catching a *bomb*). The sound effect, particularly at the time of obtaining *hearts*, is frequent. Thus, consecutive sounds themselves aim to create an enjoyable and pleasant environment.

6 Validation at the Locomo Exercise Club

Locotre is adopted in this application targeted at healthy elderly people. Hence, regarding the situations in which this game is used, the occasions for use should be regarded as groups, municipalities, or related events that are engaged in regional health promotion activities. Since November 2014, the Locomo Exercise Club has been held at the campus of our university once every 2 weeks to increase the number of elderly game users (Figure 15). Approximately 20 elderly people participate in this club each time, and they have knowledge and experience of rehabilitation and health care games, including "*Locomo de Balamingo*". As a verification, we conducted a questionnaire on the interface, game design, and graphics of "*Locomo de Balamingo*" with 16 elderly people, who regularly participate in this Locomo Exercise Club (average age: 74.1 ± 4.5 years; 1 male; 15 females).

Figure 15 Locomo Exercise Club

The following three topics were questioned regarding the interface: the meaning of scoring in the game, the meaning of the feedback of the deviation of the center of gravity caused by the avatar expression, and the method of avatar operation. The answers were based on a Five-point scale from "absolutely unknown" to "very easy to understand." As a result, approximately half of the avatar manipulation methods became very easy to understand, and the meaning of scoring and feedback is not completely understood (Figure 16).

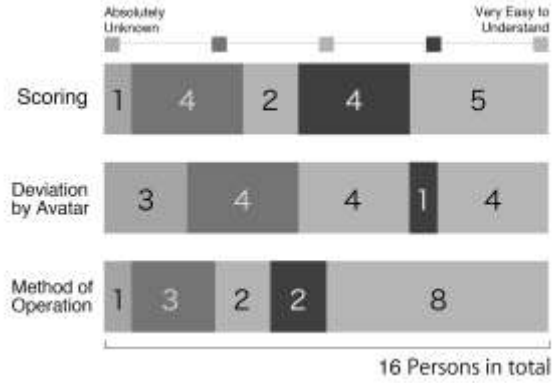

Figure 16 Results of Survey regarding Interface

With regard to the game design and with respect to each of the three stages of "*Locomo de Balamingo*," the degree of leg use (five-point scale) during play, the feeling of tiredness after play (seven-point scale), and the motivation to replay after play are asked at each of the three stages. One-way ANOVA was used to make a comparison with the three stages. As a result, a significant difference was found between the results of the first and third stages ($p < .001$) and the first and second stages ($p < .001$) regarding the use of the leg during play. The use of the legs in the last two stages was high (Figure 17). A

significant difference was also found between the first and third stages ($p < .001$) and the second stage ($p < .05$) for the feeling of tiredness after play. The feeling of exhaustion in the third stage in each case was high (Figure 18). Finally, a significant difference was observed in the motivation to replay the third and first stages ($p < .001$) and the second and first stages ($p < .005$). The motivation for replay of the latter stages was high (Figure 19).

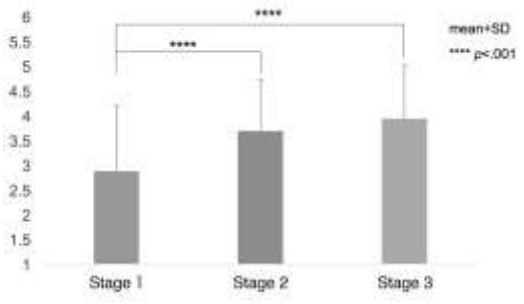

Figure 17 Use of Legs

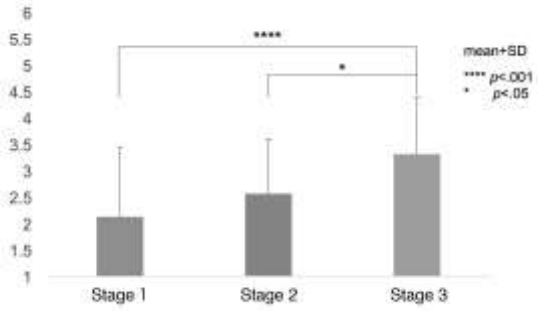

Figure 18 Feeling of Exhaustion

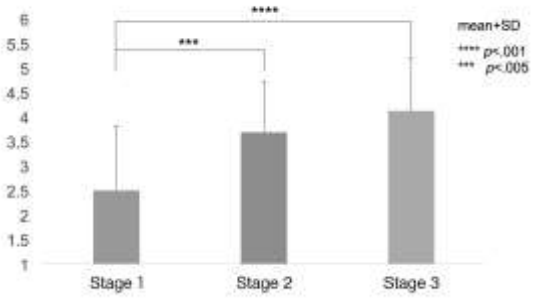

Figure 19 Motivation for Replay

The following opinions were expressed in the free descriptions of the difference in and the comparison of the three stages: "I can play the game with confidence because the first stage does not have any *hearts* and *bombs*". "All I do is stand in the first stage, so I do not know the meaning of the game." and "I enjoyed the second and the third stage most." Some favorable opinions were also raised regarding the increase in the game nature caused by the addition of failure experiences.

The graphics questions asked the users to rank multiple scenes in the game. Approximately 70% of the users (11 out of 16 people) ranked the "Japanese Style" scene as first, followed by the "Sky" and "Sea" scenes, which were relatively bright and easy to understand. In contrast, some of the following opinions were also observed: "I do not remember the pictures," "I only saw hearts and *bombs*", and "I do not care about it."

7 Discussion

As indicated by the questionnaire above, despite the fact that there have been some negative feelings with respect to "Deviation by Avatar" and "Methods of Operation", it can be said that both of them are to a great extent reasonable for the players. In actuality, the players at the Club have experienced no trouble with playing the game. Therefore, the intuitive interface utilizing a simple body motion using *Kinect* is said to function effectively. However, in some cases, *Kinect*'s sensing has malfunctioned in places where there are some people around, where future technical evolution is expected, or when searching for new sensors and sensing methods. *Kinect*'s sensing is necessary to indicate the game score in a more understandable manner. Despite not completely understanding the game mechanism itself, the users controlled the avatar well and were able to gain high scores. Thus, the feedback method does not need to be improved.

Regarding the game design, the comparison of the first stage without failure experience and the second and third stages with failure experience showed that both "leg use" and "fatigue" levels were higher in the latter. The motivation of replay also showed the same result. In addition, ~~a~~ssertiveness increased despite the increase in momentum. The participants initially showed negative reactions to the game, saying things such as "It seems to be difficult" or "I can't do it". However, they now used it steadily every time, and the awareness of high score acquisition improved. In an existing video game mainly targeting healthy people, Juul said that "Though we may dislike failure as such, it is something that helps us reconsider our strategies and see the strategic depth in a game, a clear proof that we have improved when we finally overcome it" [16]. Through this research, the game design with the addition of the failure experience is considered an effective means of improving competitiveness, which encourages exercise even for healthy elderly users who require health care.

The legibility and ease of understanding are important for graphics, and clearly showing patterns related to game scores, particularly *hearts* and *bombs*, is necessary. While users tended to prefer beautiful and bright scenes, some did not care about the differences in a dark atmosphere scene. Others also preferred the dark cave scene. Thus, the scene preference was dependent on the user. In conclusion, any scene can be invoked, provided that the pattern does not give a sense of discomfort.

8 Future Initiatives

We are currently engaged in game utilization activities centered at the Club. However, our ultimate goal is to build a situation in which training can be expected to continue at home. We added a network function based on this game and created a prototype that enables it to check the usage situation, score, and ranking via the cloud (Figure 20).

Figure 20 Ranking via Cloud

Although we attempted to implement the game at home, troubles occurred in the PC setting and with the connection to the internet. The case of use by elderly people was also anticipated to be a more difficult situation. In addition, occupational therapists note the danger of elderly people falling over while playing games that involve standing on one foot. This game also seems to be tough to use at a private home.

However, the game is supported by the Locomo Exercise Club and other health-related events, and has been enjoyed by children, who accompanied the elderly users (Figure 21). The game is currently permanently installed at the Itoshima City *Fureai* Health and Welfare Center. In the future, we aim to continue marketing the service to facilities and events using network functions. These efforts were adopted as Fundamental Research (A) Issue No. 16H01802, which began in 2008, and has a research title of "Research on Online Game Design to Support the Elderly to Form a Prevention of Nursing Care Community." Further research is ongoing.

Many positive opinions were obtained from the questionnaire used at the Locomo Exercise Club at the end of the second year. These comments included "I first thought 'Playing the game at my age?', but now it's quite fun and I am determined to keep doing it" and "Unlike the previous exercises, this exercise performed with a game sense makes me feel youthful, and it is very good."

We will continue to widely disseminate health promotion by ICT using games as the main method, and thereby contribute to the global expansion of healthy life expectancy.

Figure 21 Boy Enjoying Game

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