Design of a Personalized Affective Exergame to Increase Motivation in the Elderly

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Abstract: Older people are among the most physically inactive. Game-based training programs (exergames) can motivate this group to exercise more. However, for long term benefit it is important to maintain engagement and motivation. Therefore, the emotions of the player should also be taken into account. This paper first gathers requirements to develop a motivating exergame for elderly people. This includes specifics regarding the target group as well as the inclusion of emotion theories. Based on these considerations, a concept for a framework is proposed how these requirements can be implemented with the help of personalization and sensor technology to create a successful and motivating exergame. A sample application demonstrates the flexibility of the presented framework.

1 INTRODUCTION

In the coming years, the proportion of older adults will increase. The elderly are among the physically inactive (Mathews et al., 2010). This, in turn, can lead to increased falls and fear of falling, which are two of the main reasons for hospitalizations. Falls result from incorrectly executed steps and lack of balance, among other things. But inactivity can also cause hypertension or diabetes, placing inactivity among the fourth most common risk factors for mortality (World Health Organization, 2010).

Sports exercises and balance training can counteract this and also take away the fear of falling. They help improving movement patterns, gait and posture (World Health Organization, 2010) (Leveille et al., 1999). It has been shown that an important factor in predicting fall risk is the ability to adapt gait (Caetano et al., 2016).

It is important for effective training that the given trainig program is followed. Daily repetitions are frustrating and do not arouse the interest of participants, resulting in approximately 65% of patients not adhering to the program and dropping out of physical activity (Bassett and Phty, 2003). Also, complicated and incomprehensible exercises lead to not performing the exercises (Dobson et al., 2016).

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A promising and inexpensive way of balance training are so-called exergames. The term exergame is a composition of the words exercise and game and describes computer games that are controlled by movement and thus promote the physical fitness and effort of the player (Oh and Yang, 2010). The goal here is to maintain and increase motivation in physical activity through fun (Lee et al., 2017). Exergames are available for both light and strenuous tasks and can be used in the home environment. Components of exergames can include step training, yoga, or strength (Taylor et al., 2011). Game consoles that detect sensor-based motion, such as the Nintendo Switch or Microsoft Kinect, can be used to capture physical activity (Vox and Wallhoff, 2017). Exergames have been shown to have positive effects on balance and strength training, improve mental health, and strengthen social relationships (Alhagbani and Williams, 2021) (Chen et al., 2018).

To maintain engagement while playing a computer game, the player should be in the so-called flow zone. In this zone, the person is completely absorbed in his or her activity and forgets the sense of time. In the flow zone, the player is neither over- nor underchallenged by the exergame and experiences feelings of happiness. This cognitive state influences the person's performance (Csikszentmihalyi, 2014). One way to maintain the flow state is by regularly adjusting the difficulty level based on the player's perfor-

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mance. In this way, the game settings are adjusted to the player's performance and abilities. It has been shown that an individualization of exercises increases the adherence of the training (Jordan et al., 2010).

For another way to adapt exercises to the user and keep the user in the flow zone, affective computing can be used. This is an area that deals with the emotions and affects of the user. In real time, this involves adapting the application to the user's emotional state. This can improve the usability of the system (Picard, 1999).

In the following, we will first present work in which exergames were adapted to the user using different methods. Subsequently, requirements that are important for creating an affective exergame are worked out on the basis of a literature research. Both requirements for emotion recognition and requirements for older adults are described. Afterwards, a concept for a framework will be presented that can be used to implement these ascertained requirements when creating an exergame for the elderly. The conceptual framework consists of several components, which will be explained in more detail. The paper is concluded by a short summary and outlook.

2 RELATED WORK

The most important goal of a game is to entertain the user. However, people amuse themselves in different ways.

There are already different works in which games have been adapted affectively. Besides presenting games for education (Bontchev and Vassileva, 2016), there are also works that discuss the design of affective games and game engines (Hudlicka, 2009). Using built-in pressure sensors in a controller, measuring the speed and uniformity of a user's movement, the difficulty level of the game was adjusted to the patient's performance (Sucar et al., 2014). Hossain et al. developed an exergame that uses speech analysis to analyze user emotion and adapt the game. The player gets feedback on his emotional state through vibration (Hossain et al., 2018).

Games in which the difficulty level is adjusted are also applied in rehabilitation. For example, the difficulty can be adapted based on the ratio between the number of hits and the number of trials (Pezzera et al., 2019). Also papers that use facial expressions to detect emotions and change the difficulty have been presented (Aranha et al., 2017).

In (Rodriguez-Guerrero et al., 2017), (Erdogan et al., 2018), and (Darzi and Novak, 2019), the difficulty of rehabilitation games was adjusted using features from physiological signals of the players. However, these games are limited to upper extremity rehabilitation in seated exercises. Moreover, these systems are often tested with patients of a younger age group and not with seniors.

There are still many challenges in the area of affective computing because due to the variety of emotions and the difficulty to distinguish them from each other. In addition, the context in which the system is to be used, the variety of emotions to be recognized, as well as the target group must also be taken into account. Despite considerable progress, the full potential has not yet been realized. Partial solutions can help to deal with this complex problem.

3 REQUIREMENTS

To create an affective exergame, requirements can be divided into two areas: *Requirements for the Elderly* and *Requirements for Emotion Recognition*. It is necessary to combine these two areas in order to develop an optimal exergame. In the case of requirements for older people, the special needs of this target group must be taken into account. This includes impairments in hearing and seeing, as well as (senso-) motoric limitations. For the requirements of an affective game, existing emotion theories have to be considered. In the following, the requirements of the two areas will be presented in more detail.

3.1 Requirements for the Elderly

As already mentioned in the beginning, older people often suffer from impairments such as a poor sense of hearing or vision. The increased risk of falling must also be given special consideration when designing an exergame. However, commercial exergames were not designed with such aspects in mind, making them mostly unplayable for older adults. (Konstantinidis et al., 2015) (Gerling and Masuch, 2011) Therefore, these games must be designed so that seniors can play them as well. This includes having exercises in both standing and sitting positions. In addition, the exercises should be adapted to the ability of the players, with a tolerance range in the accuracy of the execution of the movements (Brox et al., 2017).

Due to age-related illnesses, older individuals often experience social isolation. Also during the COVID-19 lockdown, the elderly were the worst affected by social isolation (Privor-Dumm et al., 2021). Exergames can be used to improve psychosocial well-being (Alhagbani and Williams, 2021). This can be done, among other things, through a multiplayer mode or through competitions by counting points (De Schutter and Vanden Abeele, 2008). In competitions, it must be noted that the points scored are calculated depending on the skills of the player. If the performances are compared with an average player (without any handycaps), a negative feeling of failing the game may arise (Gerling and Masuch, 2011).

Based on these considerations, not only the exercises themselves and the points scored, but also the difficulty of the exercises should be adapted to the player's abilities. Thus, more active players need to be challenged on a higher lebel compared to rather inactive ones (Brox et al., 2017). The goal should be to achieve a flow state in which the player focuses only on the game (Csikszentmihalyi, 2014). Therefore, the goals of the game must be achievable to maintain motivation, and should be adjusted as needed.

3.2 Requirements for Emotion Recognition

To maintain motivation, the approach of affective computing can be used. For this purpose, the emotions of the players have to be recognized. Thereby, not the basic emotions according to Ekman (Ekman, 1992), like disgust or surprise shall be identified, but learning-centered emotions (Sann and Preiser, 2017), like joy, confusion or boredom, or also moods. Because emotions are often felt individually and situationally, the emotion recognition system must be trained to work with context-dependent data.

In order to react individually to the emotions, the affective states, intensities and triggers can be stored in user profiles. Such a profile serves as a basis for adjustments, e.g. of the difficulty. Regular updating is essential to capture new triggers and emotions. With the user profile, appropriate adaptation strategies for the game can be found to ensure player engagement (Hudlicka, 2009).

Different sensors can be deployed to measure the data needed for emotion recognition. In addition to recognition based on facial expressions, emotions have also been analyzed using health data. For this, it is important that the sensors are used non-invasively and that continuous real-time measurement is possible (Hudlicka, 2009). The sensors should be comfortable to ensure acceptable usability. For this purpose, it is important that no attachment of electrodes is necessary. In addition, cables can distract subjects and prevent them from completing the task, so these should also be avoided. Accordingly, the hardware should be robust with regard to a sufficient signal quality. Furthermore, direct and immediate data access must be possible in order to continuously adapt the system to the user's condition. Therefore, no proprietary software of the manufacturer should be necessary, where the collected data can only be further used after an export (Peter et al., 2005).

4 PROPOSED APPROACH

The requirements described above were taken into account in the development of the conceptual framework. In addition, three main objectives representing the individual needs had to be considered:

- Assist the person in completing the training
- Increase the person's motivation by making the tasks more fun
- Increase the person's sense of competence

Figure 1 shows the proposed framework for an affective exergame. The individual components are described in more detail below.

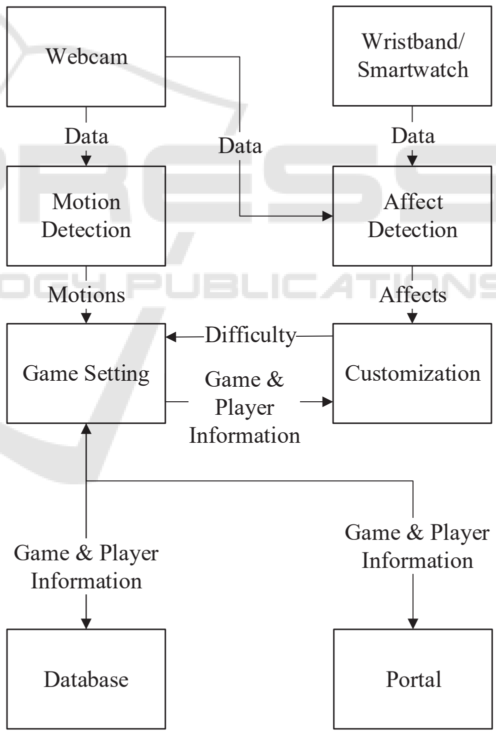

Figure 1: Framework for an affective exergame.

The overall concept of the framework is modular. Flexibility is provided in terms of extensibility and the combination of different games with sensors and methods for customization.

4.1 Motion Detection

The crucial component for the game to be an exergame is that the game is typically controlled by movements. A camera, ideally with depth information, is used to see whether the required exercises are performed. With the help of the image information, the exercises can be recognized. By using a camera, the game charackter may be controlled and placed in an augmented reality scene. As a result, the player finds himself and his surroundings reflected in the game.

The camera could be a depth camera. This has the advantage that additionally the accuracy of the execution of the movement can be evaluated. Another advantage of a depth camera is that skeletal data can be used directly. This eliminates the need for complex image data, which can result in computationally expensive computations. Depth information may also lead to an increased acceptance of video recordings.

In contrast to the depth camera, a commercially available webcam might alternatively also be used. This is an inexpensive alternative and is already available in many end devices such as laptops or tablets. Webcams can also be used without much experience. However, the previously described advantages of a depth camera are not available here, which means that recognition accuary and maybe acceptance problems may be expected.

4.2 Emotion Recognition

During the game, sensors will be used to record the physiological state of the players. Machine learning will be used to determine the emotional states from the data obtained. Different classifiers shall be compared with each other to achieve an optimal result. The classification should achieve that the respective emotion can be named.

For this purpose, data sets have to be recorded beforehand, in which not only the physiological data are recorded, but also the subjectively perceived emotions of the player in the situation. With this self-assessment, a benchmark database can then be generated for the comparison of different emotion recognition methods.

Non-invasive sensors that can be used easily shall be applied to collect the data. Therefore, the physiological parameters of skin conductance, heart rate, and temperature shall be recorded using a smartwatch or wristband. Also, wrist acceleration can be used to detect rapid movements and determine the frustration level. The Empatica E4 (Empatica Inc, 2021), which can measure the above parameters, comes into consideration. This type of hardware additionally avoids cables for attaching the sensors and transmitting the data, which could distract the subjects. Furthermore, a wristband or smartwatch is intuitive, simple to use and usually requires no further explanation. In addition, image and sound recordings can be used via the webcam, which is used to control the game. The emotional state can be determined based on facial expressions. It should also be possible to integrate other sensors besides those of the smartwatch or wristband and use them for further evaluation.

4.3 Customization

Before a player plays the exergame for the first time, an external person, e.g., a caregiver or a trainer, could enter information about, among other things, the player's movement limitations, age or health level. Alternatively, some exercises could be performed in advance to automatically determine the player's abilities, such as mobility and balance. Based on these prerequisite informations, the difficulty of the exergame can be adjusted. Discrete adjustment of difficulty (easy, medium, hard) should be avoided to prevent under- or over-challenging people. In addition, levels that are too difficult can increase the risk of falling. Instead, the difficulty level of the exergame should be continuously adjusted to the player's performance. However, the difficulty level should not exceed the player's capabilities. Therefore, this player information must be taken into account during the adjustment. In order to maintain motivation, the goals should be achievable. If a previously defined goal cannot be achieved, e.g. due to movement restrictions, the goal must be adjusted. These adjustments should be done automatically by the game, so that users can play it at home without a trainer.

Both the goal of the game and the difficulty of the game must not depend only on the initial player information, but also on the actual emotional state of the player. The states from emotion recognition, see section 4.2, should be used to motivate the player by keeping him in the flow. For example, if it is detected that the player is bored, the game can increase the difficulty level, while not exceeding the player's capabilities.

4.4 Database

The emotions as well as current information about the game (game name, difficulty, speed, score, game duration) shall be stored in a database, in which a separate entry is created for each player. The player's skills and goals shall also be stored in a user profile in the database, which is individual for each person.

4.5 Portal

Players should be able to access their data to see. This can be their own progress as well as an overview of the levels in which they have encountered difficulties. Each user shall additionally have the possibility to share their progress with the other players. In this way, players can compare themselves with each other, if they wish. This should increase both the psychosocial well-being and the motivation of the players.

4.6 Game Setting

In the Game Setting the different aspects are bundled and the game is controlled. In addition, the database entries are managed and access to the portal is provided.

There are different types of games that can be implemented within the framework. In the following, two game variants will be presented, based on the introduction in section 1.

When designing an affective exergame, it is important to train different motor skills in order to ensure a balanced workout. Therefore, it is useful to include balance and gait training as well as strength training in the game.

In the area of balance and gait training, walking ability can be improved and confidence in rapidly executed steps can be increased. This can improve mobility. Such training could be implemented playfully by letting the player collect objects by walking sideways. As the difficulty level increases, the user is encouraged to move faster. This strengthens balance and self-confidence. However, the player's abilities must be taken into account, see section 4.3.

To strengthen the arms, a game could be created that requires reaching for different objects that are displayed on the screen. This game can also improve hand-eye coordination and arm mobility. This game could be played both sitting and standing and is therefore suitable for everyone.

In both games, there may be additional items that may not be collected. The items can provide continuous feedback to the player during gameplay. This is firstly visual feedback. This can be achieved by noticeably increasing or decreasing the high score or by the disappearance of the touched objects. Additionally, auditory feedback should be available. While a positive sound is played when collecting items, a negative sound should be played when touching items that are not to be collected. Additionally, it is possible to provide both visual and auditory feedback on the player's performance. This can cheer up and motivate the player.

5 APPLICATION EXAMPLE

In a student project, the proposed concept was implemented in a modified form. In this project a 2D jump'n'run game was developed which is controlled by facial expressions using the Unity engine (Unity Technologies, 2021). The facial expressions corresponding to different emotions are used to trigger different actions of the player, such as jumping, ducking or shooting. An example is shown in Figure 2. It shows that a happy emotion causes the character to jump. The game is intended to serve as a therapy-accompanying training measure for facial paresis in stroke patients. It is supposed to strengthen the patient's facial muscles and thus improve the patient's emotional facial expressions.

The concept was adapted so that in the component *Motion Dectection* no movements of the limbs were detected with a camera, but different facial expressions were detected, i.e. angry, disgust, scared, happy, sad, surprised and neutral using the real-time emotion recognition provided by Omar Ayman (Ayman, 2018). In the *Affect Detection* component, as a skin conductance sensor the Grove GSR sensor V1.2 (Seeed Technology Co., Ltd., 2021) was used together with a Raspberry Pi, to determine the stress level of the player. In the *Customization* component, depending on the stress level, the difficulty level in the game was changed. This was expressed by changing the number of enemies in the game as well as the number of lives of the player.

This example gave evidence of the flexibility of this concept. By implementing different games and using different sensors, the presented framework can be used for different affective exergames.

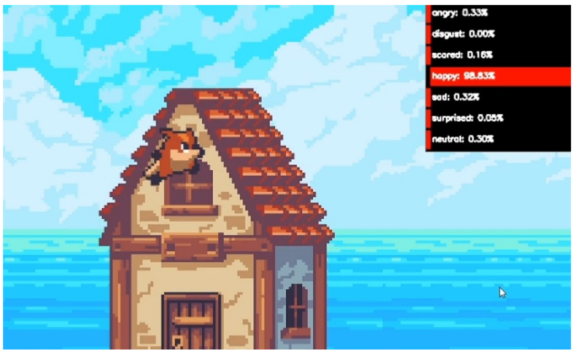

Figure 2: The emotion happy causes the character to jump.

6 CONCLUSION AND FUTURE WORK

A concept for a framework was presented that uses affective computing to adapt exergames to the emotional states of the players. This should increase and maintain engagement and motivation in the long term and sustainably. During the development of the concept different requirements were considered. This has resulted in a conceptual framework that includes a combination of game-based concepts, mechanisms for personalization, sensor technology and affective computing. The information of the latter two directly influences the gameplay of the exergame.

Currently, the concept is being implemented with movements of the limbs and will be evaluated with elderly people. The aim is to evaluate whether athletic abilities are increased by using the system. The user experience of the system will also be evaluated.

To this end, games are currently being implemented that are controlled by movement and are intended to generate different emotions. A benchmark database of emotions will then be created based on these games. Subsequently, the artificial intelligence can be trained to recognize the different emotions based on the physiological data. A final test will evaluate the user experience and check whether the exergames react appropriately to the emotions.

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