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A Multimodal Robot Game for Seniors

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Abstract. This paper describes the initial findings of a multimodal game which has been implemented on a humanoid robot platform and tested with seniors suffering from dementia. Physical and cognitive activities can improve the overall wellbeing of seniors, but it is often difficult to motivate seniors with dementia to train frequently and long enough using traditional training exercises. The idea of the presented concept is that robot games potentially can supplement occupational- or physiotherapists to promote more frequent and longer periods of training. The implemented multimodal game is based on tactile feedback and includes animated gestures and sounds. The game has been tested in a nursing home with four seniors suffering from moderate to severe dementia.

Keywords: robot, games, seniors, training, dementia, elder care, tactile

1 Introduction

Due to the demographic challenges of Europe and other regions, it is essential to create new ways of training seniors (+65) to achieve active and healthy ageing [1]. Dementia is a growing problem in public health because seniors constitute an increasing proportion of the population. In Denmark alone, the direct costs of treatment and care of seniors with dementia are almost 1,2 billion euro a year. Add in about 1 billion euro in indirect costs in terms of the value of relatives' own care of dementia patients. A physically active lifestyle can have a significant impact on the wellbeing of people with dementia and minimize the likelihood of becoming depressive with age. A 10 % reduction of risk factors related to lifestyle can reduce the disease burden in Denmark with 1.500 people annually. More importantly, a stronger cognitive mind gives improved life quality and better interaction with relatives and other people. However, seniors do often not train frequent and long enough.

The social and recognizable characteristics of autonomous humanoid robots can potentially be used to make training captivating and as a natural and enjoyable way to stay active [2][3]. The benefits to individuals are better overall health, maintaining mobility and self-sufficiency. In this paper, we describe how we have implemented and tested a simple multimodal game using a mature humanoid robot platform. The implemented game is intended to train fundamental cognitive and physical functions and can poten-

tially also be used to provide patients with insight into their own challenges and improvement. Within the last 50 years, the computer game industry has developed from basic lab experimentation to a billion-dollar mass-market industry. Robot based games are likely to undergo the same explosive development while solving one of the world's most present tasks – reducing healthcare costs related to the demographic challenge.
We have developed and tested the multimodal game with seniors focusing on validating basic functionality of the game in a dynamic environment and to get an initial idea of the target groups reactions. The solution has been evaluated in a nursing home in Denmark with four seniors suffering from moderate to severe dementia. The research is preliminary, but based on our observations and feedback from therapists the results are encouraging.

2 Theory

The characteristics of an autonomous humanoid robot, makes training engaging as humans tend to perceive robots differently from other machines. The tangible nature of the robot catalyzes interaction, and makes it possible to create many multimodal games which include physical movement. Additionally, a unique feature of using a robot for training, is that the robot can take the initiative pro-actively and start a training session.

2.1 Background

Related research has demonstrated how robots can be a motivating tool for seniors with a light degree of dementia. Aarhus Municipality has worked with the robot project "Strengthening the Brain" [4] since 2011 showing an improved ability to concentrate among seniors (measured using standard attention test (T.O.V.A.)) [5]. Using robot-based games, the goal of the training was to give the patients insight into their own memory challenges, personal strengths and weaknesses pertaining to memory, understanding the importance of training the mind as well as several memory strategies to use in daily life. The latter, was documented using a Canadian Occupational Performance Measure (COPM) which showed improvement compared to a control group. In 2012, a similar study was conducted showing positive results [6]. Recent results from 2016 by Aarhus Municipality and Aarhus University have showed an improvement of 23% in executive cognitive function measured compared to a control group using the Montreal cognitive assessment (MoCA) [7]. Although these results are promising, they cannot be transferred directly to the target group used in this paper who are institutionalized and suffer from a higher degree of dementia.

2.2 Game Theory

According to Crawford [8], the fundamental motivation for all game-playing is to learn. He states that games are a fundamental part of human existence and is the basic way that humans (and many animals) learn to survive. All games are essentially teaching us the skills we might need in real life in a safe environment. Lazzaro [9] conducted an independent cross-genre research study on why adults play games, and found that games can offer order that players want in real life. The excitement and relaxation effects of games are very appealing, and some apply the therapeutic benefits to get perspective, calm down or build up self-esteem. Although player enjoyment is central to many computer games, there is currently no universally accepted model of player enjoyment in games. Many heuristics are presented in the literature based on elements such as the game interface, mechanics, game play and narrative [10]. However, successful games are often characterized using the concept Flow, as proposed by Csikszentmihalyi [11], which is a mental state where a person is fully immersed in what he or she is doing.

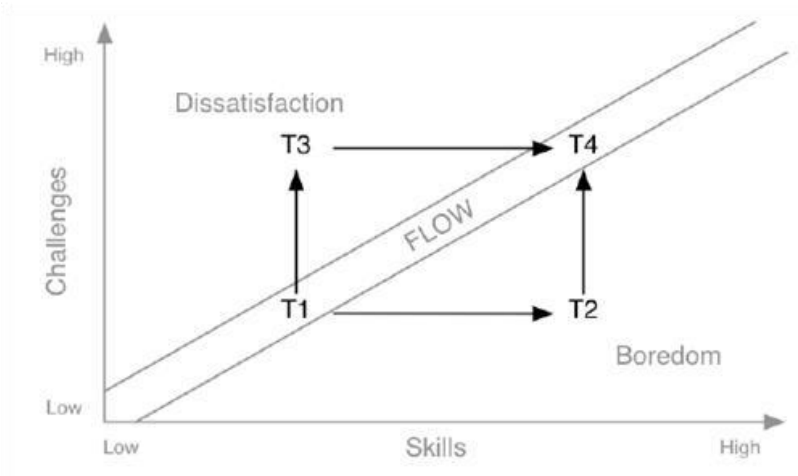

Fig. 1. Illustration of the relation between skill and challenge. In state T1 and T4, there is a balance between skill and challenge and the player is in the state of flow. In state T2 and T3 there is no balance, and the player is either bored or frustrated.

It is a feeling characterized by great absorption of energized focus, full involvement, and success in the process of the activity. As illustrated in Figure 1, Flow can only occur when there is an appropriate balance between challenge and skill. In the state T1, the difficulty of the challenge is in an appropriate relation to your (undeveloped) skills. T2 is the situation where you develop your skills to a level where the challenge becomes too easy and therefore boring. In T3, the difficulty of the challenge is higher than your skills, leading to discontent and frustration. T4 is also a flow state, but in a more complex situation than in T1. Flow is not a stable state because your skills will keep developing [12].

Although Flow is a well-established construct for examining game experience, an inherent problem is that it is not immediately obvious how to translate between the flow construct and an operative description of game-play [13]. Another inherent problem with the concept of Flow, is that there is no standard approach for measuring it.

3 Equipment

Driven by the exponential growth of processing power, it is now possible to develop robot solutions for the masses at affordable price levels. This development opens for new opportunities in creating robot solutions which can be used in novel areas including physical training of seniors.

Fig. 2. The humanoid multimodal robot platform Pepper by Softbank Robotics. The robot comes with several sensors and can make multimodal expressions using gestures and sound.

To ensure robustness, we have chosen to rely on mature hardware technology using a commercially available robot platform. Many commercial platforms are available, but we have chosen to use the Pepper platform which is a humanoid robot from Softbank Robotics (see figure 2). The advantage of this approach is that it reduces development risks and make it is easy and fast to validate new game concepts.

4 Game Implementation

The training exercises we implemented using Pepper are light to moderate workouts designed as interactive games in which the robot proactively encourages the seniors to participate. The design of the specific game followed these principles:

- Simple, recognizable narrative that is easily understood

- Simple gameplay and objective, including an uncomplicated competition element
- Strong visual and aural stimulus using simple and easily recognizable gestures, sounds and tactile interaction

4.1 Game Description

We have currently implemented several multimodal games using Pepper. However, only one game has been evaluated in a real nursing home setting. This game is designed for 2-5 people, placed in a circle around the robot. The robot acts as a token being passed back and forth between the players. When the robot has approached a player, the goal of the player is to touch the back of the hand of the robot (see figure 3).

Fig. 3. Senior playing a game with the humanoid robot by touching the back of the robot's hand.

If successful, the player will get a game point and the robot will make a short energetic expression using arm gesturing, light and sound (see figure 4).

Fig. 4. Robot making an energetic expression using gestures, sound and light after successful interaction.

Based on the player's number of points, the robot's arms will slowly change position from being static in front of the robot to gradually more dynamic animated movements. The idea is to make it more and more difficult for players to reach and touch the hand as their number of points increase (see figure 5).

Fig. 5. Robot making animated movements with its arms. The complexity of the movement depends on the player's number of points.

While not touched, the robot will wait passively for 5 seconds. After an encounter or time-out, the robot will move backwards to the initial position and rotate to face the next player. When the players are sitting down, the robot trains the upper torso as well as eye/hand coordination. When the players are standing up, the game also trains balancing and walking sideways. The game flow can be defined in pseudo code:

```
1 DEFINE n AS NUMBER OF PLAYERS (2-5)
2 DEFINE x AS THE CURRENT PLAYER
3 DEFINE point(x) AS THE NUMBER OF GAME POINTS
4 SET x = 0
5 WHILE x < n
  6 Move robot forwards
  7 WHILE time < 5 seconds
     IF touch == true
     THEN    make energetic expression
             point(x) = point(x) + 1
             GOTO LINE 9
  8 END WHILE
9 Move robot back to initial position
10 SET x = x + 1
11 Rotate robot to a new angle
12 Animate arms based on point(x)
13 END WHILE
```

The flow of the game is illustrated in figure 6 and a video of the game can be found at https://youtu.be/Bb_23Er6JaE

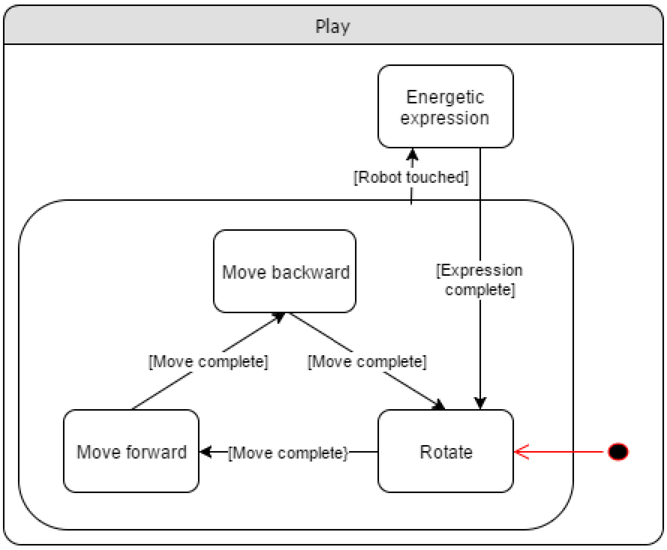

Fig. 6. An overview of the robot game. The robot will approach all players individually by moving forward, backwards and rotating. If a participant touches the robot's hand, the robot changes behavior.

4.2 Robot Gesturing

After successful interaction (a player touching the robot's hand), the robot is programmed to make an energetic expression lasting 2-3 seconds using pre-selected animations and sounds. The expressions are randomly picked from a library of pre-selected built-in positive sounds and animations. After each successful interaction, the robot will slowly reposition its arms. Each movement is a function based on the number of game points of each individual player (see table 1). The idea is to gradually make the robot gesture more dynamically for each successful interaction, making it slightly more difficult to touch the robot's hands as game points increases.

Table 1. Overview of arm movements

Point(s)	Change arm position using
0	No change
1	Elbow Roll Wrist Yaw
2	Shoulder Roll Shoulder Pitch
3	Shoulder Roll Elbow Yaw Elbow Roll Wrist Yaw Hand Roll

5 Experiment

We have evaluated the game on a target group of players consisting in four participants in their 80'es. Three women (A, H and T) and one man (E). All participants of the group suffer from dementia in a moderate to a high degree. The session was planned to last for one hour. Two participants stayed for the entire session, and two participants had to leave after 45 minutes due to fatigue. The experiment was documented using photo and video, but no systematic quantitative measurement was performed. After the training session, the experiment was evaluated with the main occupational therapist and the head of the nursing home.

We observed a positive response by all participants who seemed engaged in the game while playing. The participants tended to move their arms together with the robot when gesturing (see figure 4), and to laugh and smile when the robot was gesturing and playing sounds. The participants would keep commenting the robot by calling it "sweet", "cute" etc. treating the robot as a living being.

As also observed in earlier experiments [2][14], the game must be kept very simple, or else it will become too difficult for the seniors to play. The functionality of increasing the game difficulty with the number of points (i.e. gradually more dynamic arm movements) did not seem to affect the game play, i.e. the participants did not link the behavioral change of the robot to their number of points, and either ignored or did not understand the competitive element of the game. When evaluating the session, the staff were generally positive, and suggested that the robot could be a successful tool for entertainment and assistance in the future. The occupational therapist who observed the entire session described it as "very exciting", "very impressive" and "a definitive success".

In a similar experiment [14], we evaluated the same game with the exact same participant group using a simpler mobile robot (the Double Robot from Double Robotics, which is basically an iPad on a set of wheels). Here, the results were more mixed. Although the therapist reported that participants appeared livelier after the training session, laughing and talking about the robot and the training, it was also observed that the robot did not work optimally due its form-factor. The seniors found the robot platform too difficult to use and did not benefit from the game as a social activity. Observations from the current experiments, shows that implementing a game on a humanoid platform like Pepper seems to increase engagement for this specific target group. However, adjusting the challenge to the skills of the player did not seem to have any significant effect of the players participation and engagement in the game.

6 Conclusion

Although this research is very preliminary, it is our impression that using a multimodal humanoid robot as Pepper, works well with seniors who are suffering from moderate to a high degree of dementia. This becomes clear when comparing the results with a similar game experiment based on a simpler robot, in which participant lost interest faster and feedback were mixed. We did not observe that adapting the game challenge to the skills of the players affected the game experience significantly for this target group, i.e. the physical and social elements of playing with the robot (moving, touching, observing and commenting) overshadowed the competitive element.

Although more research is needed, it is encouraging that humanoid multimodal robot games are not rejected by the target group suffering from dementia – a group who are often difficult to train using traditional tools. However, the games must be very basic.

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