LINarm++

Affordable and Advanced LINear device for ARM rehabilitation

Deliverable D5.3

Training scenarios and virtual environment

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Executive summary

The sensory system, the patient model and the training scenarios are strongly interlinked., however the sensory system and the patient model are described in deliverable D4.2 in separate document. Both deliverables are public prototypes.

This deliverable deals with development of several training scenarios to be used with the LINarm++ device. Five different training scenarios were developed that combine motor training with cognitive training. Training scenarios are compatible with the designed patient model.

System validation was performed on a HapticMaster robot with a force sensor to develop and verify training scenarios for the LINarm++ system. Healthy subjects were involved in preliminary pilot trials with the proposed setup.

Introduction

Rehabilitation robots are devices that assist the recovery of patients whose motor functions are impaired as a result of stroke, spinal cord injury or other condition. Their benefit is twofold. First, they offer accurate sensors for measurement of forces and positions, thus providing a method of objectively evaluating the patient's motor performance. Second, robots with active motors can help the patient train simple or complex movements, taking some of the strain off therapists. Training with such robots yields long-term results comparable to exercise with a therapist. Frequently, they are combined with virtual environments in order to make rehabilitation more interesting and motivational.

Tasks and virtual scenarios

Since post-stroke patients tend to suffer from lack of interest in the ongoing rehabilitation procedure, scheduling and design of rehabilitation training should be properly adjusted in order to ensure adequate motor ability improvements and sufficient rehabilitation task engagement. This is achieved through the use of dedicated computer games, which ensure that the patient's attention is properly gained and maintained throughout the provided rehabilitation task. Also important is the possibility of adaptive stimulation of subject's activity in terms of motor and cognitive engagement. A set of various games was developed which will be explained in this section. Games were developed using Unity development kit. Games differ in level of engagement required from the subject.

For motor task the difficulty is changed in two ways:

- by increasing or decreasing the speed of the objects which need to be caught or followed,
- by increasing or decreasing the damping of the robot.

For cognitive task the difficulty is changed by presenting harder or easier cognitive task.

Pendulum game

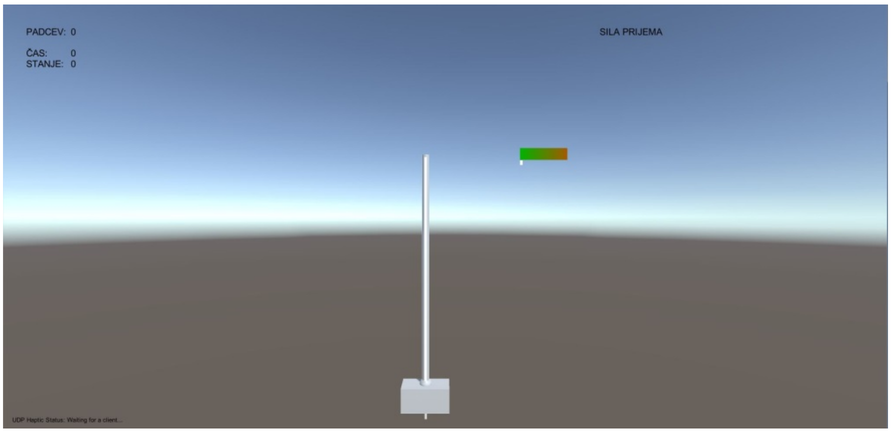


Figure 1 Pendulum test game.

Pendulum game (Figure 1) was developed to test the sensory system for measuring the physiological responses. To get responses from the subjects which are high on the scale of physiological responses a very difficult and engaging game was required. Hence a game of inverted pendulum test was developed. The inverted pendulum is an unstable system which needed to be stabilized by the user which had to balance the pendulum by applying a virtual force to the cart (robot end-effector). The amount of force needed and the pendulum dynamics were adjusted through the mathematical model by changing the parameters such as gravity, friction, damping, mass, and pole length. The main purpose of the game was to test the sensory system; however the results were also used to set initial parameters for patient model for experiments on healthy subjects which were performed with Stroop game (explained later in this document).

Catch-and-avoid games

Game 1- Falling balls and bombs

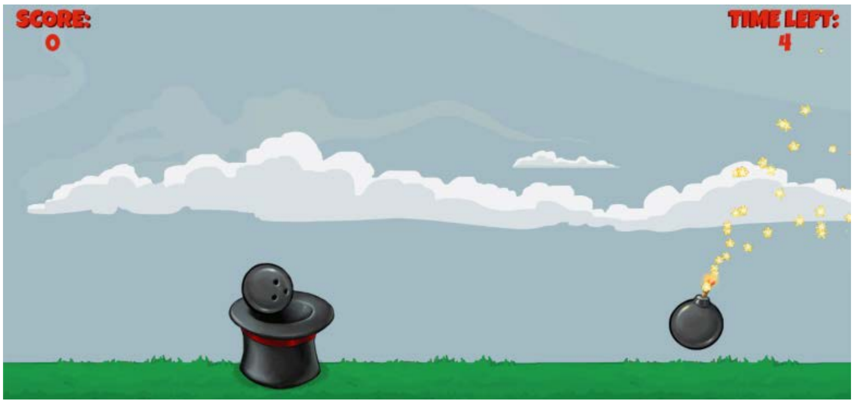


Figure 2 . Catch-and-avoid game – falling balls and bombs.

The Game 1 (screenshot from the game is shown in Figure 2) presents a basic catch-and-avoid task, focusing on subject's motor engagement. Cognitive task in this game is very simple. Subject controls a moving hat (which can move in horizontal direction), while bowling balls and bombs are falling down from the upper corner of the scene (see Figure 2). Subject needs to catch the balls and avoid the bombs.

Game 2 – Rebounding the bowling balls

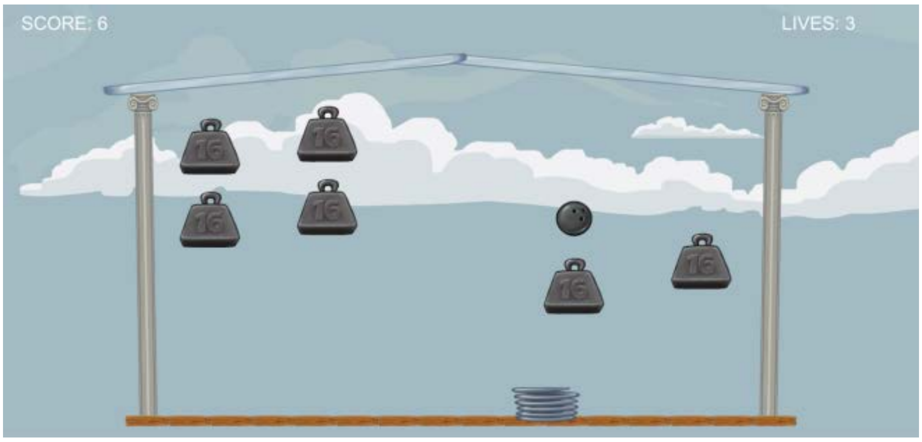


Figure 3 Catch-and-avoid game - rebounding of bowling balls.

Game 2 is very similar to first game, it again requires mainly the motor engagement, but as an upgrade to the previous game, provides also occasional cognitive engagement. User controls the spring located in the bottom of the scene. Balls are falling down and the user needs to rebound a bowling ball to hit the weights which are hanging above the spring.

When the weight is falling down the user needs to avoid the weight (see Figure 3). Since simultaneous falls of several weights are possible, this requires some cognitive engagement.

Reverse catch games

While in Catch-and-avoid games the user controls an object positioned in the bottom of the scene to catch the falling object in Reverse catch games the objects on the bottom are stationary and the user controls the horizontal movement of the falling object.

Game 3-Drop the ball in correct hat

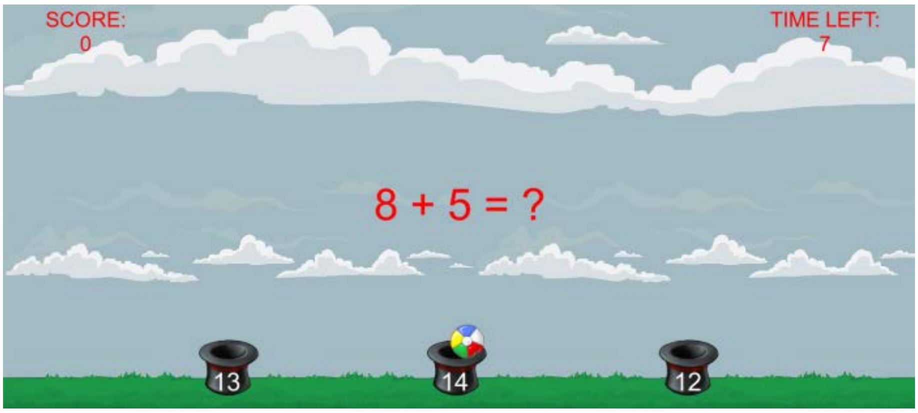


Figure 4 Drop the ball in correct hat.

The third game was developed to ensure shared motor and cognitive effort engagement. This is ensured by providing the subject with a simple mathematical equation, inducing the need for performing adequate move-to-catch manoeuvers (see Figure 4).

Game 4 – Stroop game

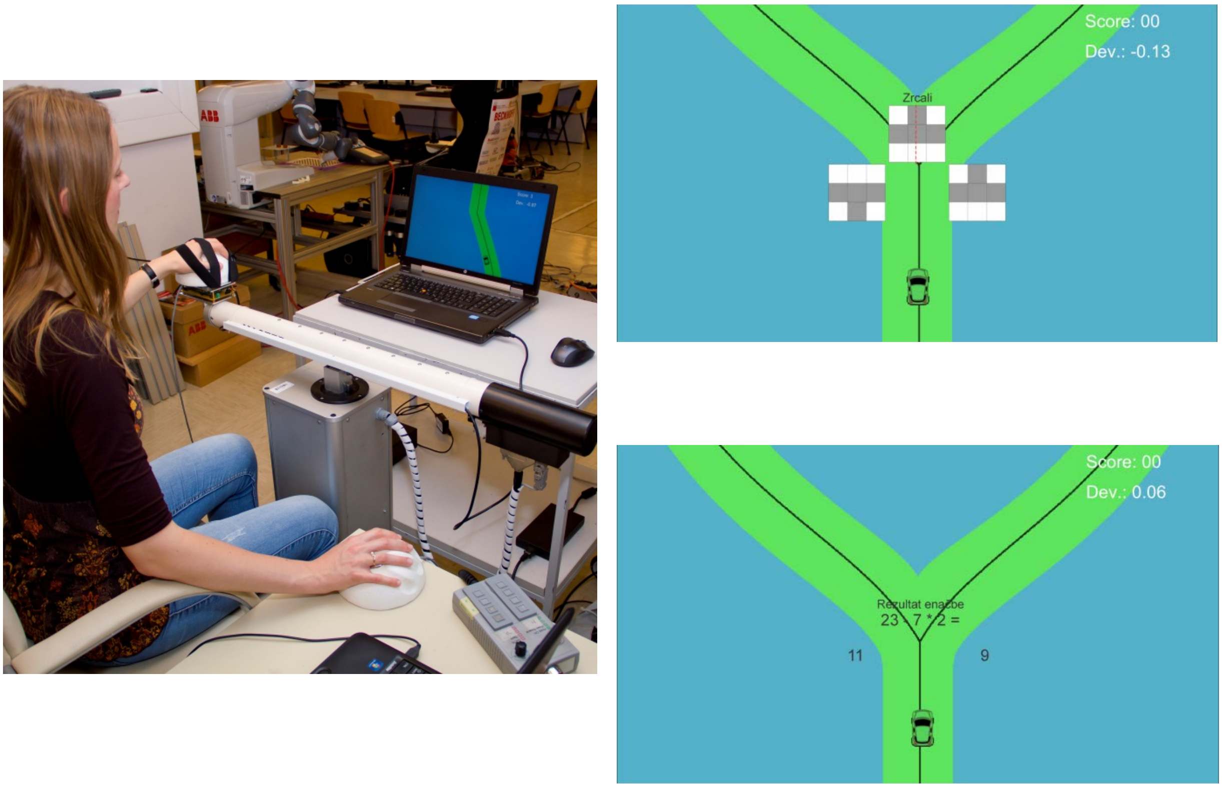
Figure 5 Game based on Stroop test.

To develop the patient model, we first needed an appropriate set of results on healthy subjects. Since the games presented in previous section are designed for patient, they are too simple for healthy subjects. Therefore, we have designed a much more challenging game, both in sense of cognitive challenge as well as motor challenge. The game combines a motor task and a cognitive task, for motor task the game requires the movements left-right and for a cognitive task a version of well-known Stroop test was implemented. Words of three basic colors (words RED, GREEN and BLUE) are falling from the top of the screen and the user needs to move them to the appropriate cloud which is on the bottom of the screen. The words can be colored in any of the three basic colors and are typically in color which is different from the word describing the color. For example, (see Figure 5) if the word is BLUE and is in green color, the appropriate cloud is a cloud of a blue color. The speed of the falling words can be adjusted and also the force required to move the robot in left-right direction can be adjusted. Both in sense of motor and cognitive challenge the game can be made appropriately challenging for the healthy subject, which is needed to simulate the appropriate conditions to acquire relevant results to develop the patient model. The game can of course be easily adapted for patients, by lowering the speed of falling words.

Tracking game

Game 5 – Driving a car

Third kind of games prepared for LINarm ++ project is tracking game. The task is to drive the car along the road with junctions. The task combines both motor and cognitive task. The motor task is to move the car left-right, while the car is moving forward along the road (for practical reasons the car is positioned in the bottom of the scene and the scene with the road is moving from upper edge of the scene downwards to bottom edge of the scene). The cognitive task is to correctly answer the question presented before each junction. The user then needs to turn on the road represented with the correct answer. Figure 6 shows the experimental system and two examples of cognitive tasks. In first task (see Figure 6 b) above) an image appears before the junction. Image comprises of a pattern of white and grey squares and a red line in the middle of the pattern. The task is to select a correct image which represents the mirrored image mirrored along the red line. In Figure 6 b) above the correct answer is the right image. The second task is a mathematical task (see Figure 6 b) below).



a) b)

Figure 6 Experimental system with the subject a), two tasks, which need to be solved during the training b): mirroring the image (above), solving a mathematical task (below).

The tracking game was used to make experiments for difficulty adaptation. Experiments were conducted on 20 health subjects.

Table 1 Results of difficulty adaptation of the game in different conditions. Green marker marks the conditions where results show differences which are statistically significant.

	t	df	*p*	Cohen d
condition 1 – condition 2	-2,3	19	0,03	0,31
condition 1 – condition 3	-2,5	19	0,02	0,26
condition 1 – condition 4	0,1	19	1,00	0,01
condition 2 – condition 3	0,7	19	0,52	0,08
condition 2 – condition 4	2,1	19	0,05	0,32
condition 3 – condition 4	2,1	19	0,05	0,27

Condition 1 – driving along a road, user can freely choose in which direction to turn in the junction.

Condition 2 – driving along the road with added cognitive task. In junction user needs to turn in direction of correct answer.

Condition 3 – same as condition 2, but with added haptic damping of the robot, which requires more work from the user to move the robot.

Condition 4 – same as condition 1, but with added haptic damping of the robot, which requires more work from the user to move the robot.

	driving and steering	cognitive task	haptic damping
condition 1			
condition 2			
condition 3			
condition 4			

Results show that there is a statistical difference between conditions with cognitive task (see Table 1). However, when adding haptic damping of the robot, which requires more work from the user to move the robot, the differences are not statistically significant anymore. First row of Table 1 compares condition 1 with condition 2, condition 2 is condition 1 with added cognitive task. Results show that the condition 2 is more difficult. Line two compares condition 1 with condition 3. Condition 3 is condition 1 with added cognitive task and additional damping. The difference between condition 1 and 3 is again statistically significant, meaning that condition 3 is more difficult than condition 1. This could also be contributed to added damping and not to added cognitive task. However, if we compare condition 1 to condition 4 (same as condition 1 but added haptic damping) we see that the difference between the conditions is not statistically significant. Added damping therefore does not attribute to increased difficulty. This shows that the added damping was too low for healthy subjects to show any relevant differences in required additional work. The conclusion here is that additional cognitive challenge does increase the overall difficulty of the task. The results also show that the parameters for motor difficulty need to be carefully selected to achieve the desired increase of the motor difficulty increase.

Conclusions

In parallel with the sensory system also the training scenarios were developed. Five different training scenarios were developed and tested. The scenarios differ in required motor performance. The more advanced training scenarios include also adaptive cognitive challenges to make the training more intensive and efficient. At least part of training scenarios will be validated with patients after the final integration of the system. The training is adapted to individual user needs with the assistance of the patient model described in deliverable D4.2.