A Cooking Game for Cognitive Training of Older Adults Interacting with a Humanoid Robot

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Abstract: In this paper, we present the design and the implementation of a cooking game for older adults interacting through a humanoid robot. We discuss the motivations and the requirements that have driven such design and indicate how it has been implemented. The main goal is to stimulate the cognitive resources of older adults in order to limit their decline. For this purpose, we have exploited the multimodal possibilities of the humanoid robot and have identified two robot personalities, which are suitable to improve users' engagement, and thus their potential participation in cognitive training programmes.

1 INTRODUCTION

By 2050, the number of individuals over the age of 85 is projected to be three times more than today (World Health Organization, 2021). In this scenario, most older adults will need physical, social, and cognitive assistance. Indeed, ageing has a considerable impact on the health of older adults in terms of cognitive and physical impairments, which influence the abilities to complete and perform basic activities of daily living, such as cooking, shopping, managing the home, bathing, dressing.

Nowadays, a large proportion of dementia care is provided by informal caregivers, usually family members. These caregivers often experience a negative impact on their psychological, emotional and physical well-being due to the high workload. (Carros, Meurer, Loffer, & Unbehaun, 2020). Given the high health care expenditure at older ages, and such effects on family caregivers, new technologies to assists older adults with cognitive impairments are urgently needed.

Non-pharmacological interventions, such as physical training, cognitive training, social stimulation activities have been used to mitigate the cognitive decline by maintaining or improving cognitive abilities, social well-being, and the quality of life of older adults (Carros, Meurer, Loffer, & Unbehaun, 2020), (Cruz-Sandoval, Morales-Tellez, Sandoval, & Favela, 2020), (Kim, et al., 2015).

Nevertheless, traditional interventions require experienced instructors who may be unavailable. Assistive technologies can provide useful support to address this problem. They are technologies that have the aim to assist different types of users during their rehabilitation. They can help older adults maintain their independence during daily routines and can also be an important instrument during their rehabilitation (Nishiura, Nihei, Nakamura-Thomas, & Inoue, 2021).

In recent years, humanoid robots have increased their similarity to human behaviour starting from the gestures and facial expressions to the ability to understand questions and provide answers. Thanks to such human characteristics, the interaction between people and robots is becoming more natural.

Some authors use the term Socially Assistive Robot to indicate a robot that assists users through social interaction and effective interactions to provide assistance and obtain measurable progress in rehabilitation and learning (Feil-Seifer & Mataric, 2005).

Previous work has investigated how robots can act as therapy assistants for children with autism (Jain,

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Thiagarajan, Shi, Clabaugh, & Matarić, 2020), or as a tutor or a teacher helping the scholars to create math knowledge (Janssen, Van der Wal, Neerincx, & Looije, 2011), nutrition, and healthy eating (Rosi, et al., 2016), or as assistant or trainer for older adults with cognitive impairments (Pino, Palestra, Trevino, & De Carolis, 2020) (Manca, et al., 2021).

This work focuses on the design of a game for older adults interacting with a humanoid robot. We consider this kind of technology in this context because it can potentially promote seniors' cognitive, physical, and emotional well-being and also reduce the workload of the healthcare system (Vänni & Salin, 2019).

A humanoid robot is a system that can employ different interaction strategies, such as verbal and non-verbal communication, the use of facial expressions, communicative gestures, and sensors. These capabilities are essential to creating social and emotional interaction with the users to increase their acceptability and users' engagement, which may increase the possibility to reach the goal of the assistance in less time and with better results (Carros, Meurer, Loffer, & Unbehaun, 2020) .

Robots to support and assist patients can be a valuable tool to help them during their cognitive training. In such context, digital cognitive training through serious games (SG) may potentially benefit those with cognitive impairments more than traditional training due to enhanced motivation and engagement (Manca, et al., 2021).

Serious games are digital applications specialised for purposes different from pure entertainment, such as education, and stimulating cognitive and physical functions. In the literature, different studies show how digital games can obtain positive results stimulating older adults and helping them improve their cognitive abilities with respect to traditional training (Tong & Chignell, 2013).

Combining a humanoid robot and a serious game can be an exciting solution to obtain measurable progress in cognitive functions and stimulate the user to continue the training programme.

The aim of this work is to present and discuss the design of a serious game that exploits a humanoid robot capabilities. We also indicate the requirements considered in the design of the application for supporting older adults in a cognitive training. A serious game prototype has then been implemented following the requirements, which can be used to assess the benefits of the proposed solution. The article is structured in four sections. Section 1 provides the motivations for this work. Section 2 discusses the state of the art in the area of robots in cognitive training with older adults. Section 3 describes the approach proposed, mainly providing a brief description of the serious game designed and how it can be delivered designing two possible personalities in the robot behaviour. Section 4 details the design of the game proposed, the technologies used for the implementation, the possible interaction modes, a possible robot personalities implementation, and reports on a preliminary evaluation with two experts. Finally, we draw some conclusions and provide indications for future work.

2 RELATED WORK

There have been several contributions dealing with the use of robots for elderly care. Various goals have been considered in such context, such as providing social companionship, or physical or cognitive assistance.

Typical tasks considered include assistance in daily living activities (e.g. reminders to take medicines), cognitive training (Manca, et al., 2021), therapy facilitator for alleviating dementia-related behavioural symptoms (Cruz-Sandoval, Morales-Tellez, Sandoval, & Favela, 2020). A systematic review shows how socially assistive robots could potentially increase the well-being of older adults and, at the same time, decrease the caregiver's workload (Kachouie, Sedighadeli, Khosla, & Chu, 2014).

Concerning the benefits of cognitive training using robots, some studies have found that training with a robot can improve the cognitive function of older adults. A study conducted at Osaka City University compared a speaking humanoid Kabochan Nodding Communication Robot with the same robot but without the communication elements. In the 8-week trials with 34 older adults with dementia, they found an improvement in cognitive functions in the communication robot version, particularly in executive function, and verbal memory function (Tanaka, et al., 2012). Another study, conducted by Kim et al (Kim, et al., 2015), aims to understand the differences between traditional cognitive training and cognitive training with a humanoid robot. Eighty-five older adults over 60 without cognitive impairment were recruited for the 12-week trials. The authors measured the cortical thickness, a change in which is associated with cognitive decline, and the cognitive functions before and after the intervention. The robot-assisted cognitive training was organised using 17 cognitive training exercises, including five programs for memory, two for language, two for calculation, four for visuospatial function, and four for executive function. The researchers found that participants who received cognitive training showed less cortical thinning than the control group. While the traditional training obtained a better general cognitive score, robot training produced meaningful structural brain changes and increased executive function associated with attenuation of the cortical thickness.

Another study (Pino, Palestra, Trevino, & De Carolis, 2020) evaluated the effectiveness of human-robot interaction to reinforce therapeutic behaviour and treatment adherence. The 8-week trials involved twenty-one older adults with Mild Cognitive Impairments (MCI) and the humanoid robot Nao to stimulate some specific memory areas: attention, categorisation, and association as learning strategies. The researchers selected five tasks for the training: reading stories; questions about the story, associated and not associated words, recall, and song-singer match. In the study, the researchers found that human-robot interaction can reinforce therapeutic behaviour and adherence to treatment.

Serious games could be a solution to provide cognitive training and engage the users to continue the therapy. Various studies have evaluated different strategies for alleviating the cognitive impairments in older adults and evaluate how serious games may obtain better results than traditional training.

Tapus et al. (Tapus & Vieru, 2013) evaluated if the use of different cognitive games in a robot can increase the cognitive attention of users. The researchers sought to stimulate some brain functions: sustained attention, selective attention, divided attention; working memory, and psycho-mobility in older adults with MCI. In the 8-month trials, nine subjects over 70 with an MCI diagnosis interacted with two humanoid robots (Nao and Bandit) and a tangible interface. The cognitive training was a music-based cognitive stimulation game. As a result, the study indicated the overall effect of improving user performance on the memory task in a music-based cognitive game through the assistance of a robotic system.

Carros et al. (Carros, Meurer, Loffer, & Unbehaun, 2020) aimed to understand the potential of robot-based assistance and identified enablers and barriers to the potential implementation of the robot systems with different serious games. In the 10-week trials with six older adults without cognitive impairments and four caregivers in a residential care home, they developed cognitive and physical training using a Pepper robot. The cognitive and physical training was organised in three phases: motivation, in which the users interacted with the robot using a music quiz game; physical, in which Pepper demonstrated some physical exercises and performed and explained the exercises as a trainer; and finally a cognitive phase. As a result of the study, the older adults gave positive feedback for the interaction with the robot. In the beginning, the residents were reluctant to interact with the robot, at the end the residents started to pet the robot as it were a young child or a pet. Concerning the attitudes and acceptability of the robot, the older adults provided positive feedback. The researchers found that robot-based assistance quickly became familiar with the patients and improved their engagement and satisfaction.

Regarding the acceptability of the robot by older adults, Abdollahi et al. (Abdollahi, Mollahosseini, Lane, & Mahoor, 2017) investigated if an intelligent, emotive social robot could improve the quality of life and acceptability of older people with dementia. Ryan, the robot used in the experiment, was equipped with cognitive games based on Montessori-based activities. The cognitive training's goal was to stimulate reminiscence and memory. The main tasks during the training were based on activities related to life histories of the patients, recollections of photo albums, questions about the stories of the photos. The trial duration was between 4-6 weeks and six older adults had access to the robot 24/7 in the senior living facility. As a result, the study found that the patients were interested in having a robot as a companion and accepted it.

In this paper, we present the design of a serious game for a humanoid robot. Different multimodal interactions with the humanoid robot are proposed in order to provide a more engaging interaction and obtain better results in terms of cognitive improvements. The multimodal interactions are exploited in different was in order to allow the robot to show two different personalities. While in the literature there has been some previous work that used a robot with different personalities for rehabilitation therapy (A.Tapus, C. Tapus, & Matarić, 2008), and various studies have used serious games for cognitive training (Manera, et al., 2015), to the best of our knowledge, this is the first time that a humanoid robot playing serious games for cognitive training with different personalities has been proposed for stimulating cognitive resources, such as memory.

3 THE PROPOSED APPROACH

3.1 Requirements

Taking into account previous experiences reported in the literature, and an interview with psychologists, we have designed a serious game that requires the users to perform different tasks designed to stimulate various cognitive resources.

Often programmes for patients with cognitive impairments organise the cognitive stimulations involving the participants through different activities, such as using serious games, performing social activities, and physical activity with increasingly complex exercises, music therapy, group stories, and stretching exercises. Such different activities are considered because sometimes the older adults feel bored and without motivation during the training and no longer continue the therapy (Kim, et al., 2015). These problems can be attenuated by stimulating the engagement in the user during repetitive cognitive training sessions. For this reason, we propose the use of the various interaction modalities, also to represent different robot's personalities, to improve the engagement during the cognitive training and motivate the user to continue the training, also considering some encouraging previous experiences in this respect (Manca, et al., 2021).

The semi-structured interview was performed remotely with a neuroscience researcher and two psychologists in January 2021. The main purpose of the interview was to gather information about the design of the game proposed, discuss the multimodality interaction options, and the possibility to develop different personalities in the robot.

Designing personalities for the robot interaction may create an enjoyable interaction; increase engagement during the tasks, enhance user's attention, and improve task performance accordingly.

For this purpose, we identified two possible personalities to be performed in the sessions: extravert and introvert personalities that can improve the attention and the engagement of the users. Such personalities can be exhibited in the user interaction by exploiting the interaction modalities differently.

The relevant types of personalities have been identified following the Big five Factor model (John & Srivastava, 1999). The OCEAN paradigms is often used to classify the five big personalities traits:

- Openness: represents the degree to which someone is imaginative, curious.
- Conscientiousness: reflects the extent that someone is careful, deliberative and self-aware of their actions.
- Extraversion/introversion: the extent to which an individual is assertive, outgoing, talkative, and sociable.
- Agreeableness: is the extent to which someone is cooperative and friendly.
- Neuroticism: the degree to which someone is easily angered, not well-adjusted, insecure, and lacks self-confidence (Smith, Nolen-Hoeksema, Fredrickson, & Loftus, 2002).

The extraversion and the introversion personalities were chosen for our project because previous work indicates that they are the most observable personalities (Lippa & Dietz, 2000).

Another aspect that emerged is that modulating the multimodal interaction according to the increasing difficulty level can be a useful support, and can be exploited to stimulate different cognitive areas. The organization of the game in different levels of difficulty is necessary to evaluate the improvements from the cognitive domain, and also to stimulate the user to continue the therapy.

The following requirements have thus been identified based on the interview and the state of art analysis:

- The game must be organised into three difficulty levels. According to the level selected, different parameters (e.g. number of questions, time to answer) and ways to exploit the interaction modalities are provided.
- The vocal interaction should be supported as it is the most immediate modality to interact with the robot;
- The game must support different interaction modalities: vocal, gestures, and touch.
- The game should provide reinforcement feedback during the sessions.
- The sessions should last at maximum 40 minutes.
- The design of the visual interface in the robot screen should satisfy the guidelines for design an accessible interface for older adults.
- The robot should show two personalities: extravert and introvert, and exploit verbal and non-verbal cues to identify two personalities according to the literature (Tay, Jung, & Park, 2014).
- The game should stimulate multiple cognitive domains.

- The game should reproduce daily activities that the older adult is able to perform.
- Animations (robot’s movements) may be exploited to define the robot’s personalities and may also increase the user engagement.
- It would be useful to provide an additional application where the therapists can monitor the state performance of the users during the interactive sessions.

3.2 Game Design

Considering previous work, including a systematic literature review (Palumbo & Paternò, 2020), and the interview with the psychologists, we decided to design an application connected to some daily activity. Thus, we chose to design a cooking game requiring users to recognise the recipe ingredient's chronological sequence, the typology of the ingredients, and their weight. It aims to stimulate working memory, semantic memory, and procedural memory. During the game, the robot shows and vocally synthesises the ingredients for the selected recipe. Then, it starts the quizzes, during which the user should use visual attention and working memory to recognise the right ingredients and select them over other options. Additionally, the game stimulates working memory by which the user must remember the correct sequence for the dish preparation. In this game, the type of interaction allowed is vocal, graphical and touching the robot sensors. The game is organised into three difficulty levels. For each level, various parameters, such as speed of the sequence of the exercises, the number of elements, the time available to complete the task, the volume and time available for the task are modulated.

We decided to use recipes with well-known ingredients. In this way, we decrease the differences between people who are expert to cook and those who are not, and we obtain a good baseline for stimulating and evaluating memory improvements. The three recipes chosen are chicken curry, beef chili, and brownies.

Hence, the designed application starts with an initial introduction in which the robot asks the user's name and starts introducing the game instruction, and the recipe description. During the recipe instruction, the robot emphasises the sequential order, the typology of the ingredients and their weight.

After this part, the application starts with a first question that regards the ingredient's sequence. The user has 30 seconds to recognise the first ingredients among the four proposed. For each question, the user has three possibilities to answer it.

The application is organised into three different difficulty levels: easy, medium, hard. At each difficulty corresponds different configurations of some parameters: the number of ingredients in the recipe, the reaction time, the question type (questions about the chronological sequence, the weight of each ingredient and the specific type of ingredients used in the recipes, e.g. the use of dark chocolate or the red onion upon milk chocolate and white onion) and the total number of questions.

The following table 1 summarises the different configurations considered for the levels in the prototype.

Table 1: Difficulty level's parameters.

Level Easy	
N° recipe ingredients	4
Reaction Time	30 seconds
Typology of Question	Chronological Sequence
	Weight
Total number of question	8
Level Medium	
N° recipe ingredients	6
Reaction Time	20 seconds
Typology of Question	Chronological Sequence
	Weight
	Ingredients typology
Total number of question	16
Level Hard	
N° recipe ingredients	8
Reaction Time	16 seconds
Typology of Question	Chronological Sequence
	Weight
	Ingredients typology
Total number of question	20

The questions are associated with the levels as described in Table 2.

S represents questions regarding the chronological sequences, W stands for the questions regarding the weight of the ingredients, T are questions regarding the type of the ingredients (e.g. chocolate type: milk or dark).

Table 2: Questions Sequences.

Level Easy	S	W	S
Level Medium	S	W	T
Level Hard	S	W	T

According to the increment of the difficulty level another type of interaction is provided: the touch on the hand's robot. The touch interaction with the robot's sensors is enabled when the difficulty level is increased because it requires more coordination and attention. In particular, the touch interaction with the robot hands is provided for the medium and difficult levels, and is associated only with the question concerning the type of ingredients. For example, when the robot asks "Which is the type of onion, red or yellow?". The user should touch the right robot hand to answer yellow or the left robot hand to answer red. In order to indicate the association between the possible answer and the correspondent robot's hand, two stickers with the corresponding colours have been applied on the robot's wrist. Thus, at the binary question, the screen shows two buttons with the two different colours associated with each option.

Additionally, the game provides different feedback, depending on whether the user answers correctly or not. The feedback is modulated using different cues: verbal cues, animations and gesture and providing visual feedback. Feedback is provided to stimulate and encourage the users to continue the session, and help them to memorise the right answer. Nonverbal feedback as animations are important elements that can improve user's engagement during the interaction.

3.3 The Humanoid Robot

The humanoid robot used in this work is the Pepper developed by Softbank's Robotics. Pepper is a 1.2-m-tall wheeled humanoid robot, with 17 joints for expressive body language, with three omnidirectional wheels to move around.

Pepper has multimodal interfaces for interaction: touchscreen, speech, tactile head, hands, bumper, LEDs and 20 degrees of freedom for motion in the whole body. The robot is equipped with a LG CNS screen of 10.1 inches with a resolution of 1280x800 for supporting touch interaction.

Pepper is equipped with motors that allow it to move the head, arms and back, six laser sensors and two sonars, which allow it to estimate the distance to obstacles in its environment.

Pepper can detect the provenance of sounds and voices and turns its face in the direction of those who are talking thanks to four directional microphones on its head. The robot speaks or reproduces sounds thanks to two speakers in the ears. The robot is equipped with 4 microphones on the head. Regarding the vision pepper is equipped with two identical 2D cameras, a 3D camera located and a stereo camera in the forehead. For connectivity is equipped with Ethernet and Wi-Fi.

4 THE PROPOSED GAME

4.1 The Development Environment

For the development of the robot, Softbank robotics provides a library called QiSDK and an android studio plugin called Pepper SDK.

Pepper SDK, an additional plugin for Android studio, increments the additional features provided by Android studio. In particular, it provides a feature to generate and modulate the gesture and the robot joint's movement called Animation editor. The animation editor (Figure 1) allows the user to create and edit the animation timeline. In particular, we have created the animations modulating different joints of the robot: the head yaw, the head pitch, and for the left and right arms respectively the pitch, roll, yaw and hands.

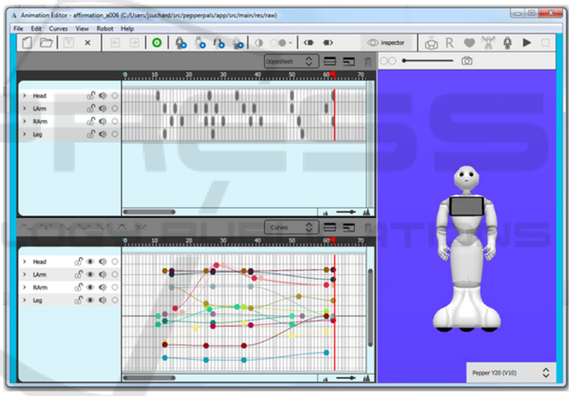

Figure 1: Animation Editor.

Additional features provided by the plugin are related to the robot's connection and emulation. The robot connection allows the developer to connect to the robot and the tablet installed on its chest. The robot emulator allows the developer to simulate the robot in 3D and its tablet, and additionally, grants the interaction with the robot using the Robot Viewer. Robot Viewer is composed of a robot view interface, motion view, dialogue view and log view. The robot view displays the real or virtual robot in 3D. Motion view grants the user to control the robot's monuments. The dialogue view allows the developer to control the dialogue outputs and enter simulated or real dialogue input. Log view provides the log occurring during the process.

For supporting the dialogue, a chat editor is provided. The Chat Editor is an extension of the Android Studio's text editor. Its main purpose is to help the user to write chat topic files, which are files that contain different rules, that help the robot and the user to develop interactive vocal dialogues (Softbank Robotics, 2021).

Figure 2 reports an example of a chat topic file used during the introduction phase for the cooking game.

```
topic: ~chatbot()
# Defining extra concepts out of words or group of words
concept:(name) [Marco Eleonora Fabio Benedetta]
# Replying to speech
u:( _~name)  Nice to see you $1  ^execute(myExecutor, $1, login)
```

Figure 2: Example chat topic file.

The concept name collects all the possible users allowed to access the game. After the user says one of the possible names in the concept, Pepper replies saying "Nice to see you $name" and records the user's name in the system.

A topic is an object containing rules written using the QiChat syntax, which is a language used to write dialog topic files. The rules associate the human input with a relevant robot answer. In the example, in Figure 2 a topic is defined with the chatbot name. Then a concept is defined. A concept is a list of words or phrases that are linked with that specific concept. In Figure 2, the list of words allowed are the names of the users who can have access to the game. Then the user rule (u:) is defined, a user rule has the effect of making the robot say or do the answer specified in the line. In this case, if the human inputs (e.g. the user says “Eleonora”) matches with a word containing in the concept, the robot replies saying the answer defined in the user rule (“Nice to see you, Eleonora”). In the user rule, a function to execute is called, which is an external method that is used to pass parameters or constants to the application.

4.2 Game Interaction and Implementation

The game is organised into three main states: introduction, play, results.

The starting state is the introduction. At this stage, it is possible to choose language, difficulty level, instructions. At first, Pepper greets the user and opens both arms over its head two times to simulate an invitation to interact with it. Then, the user vocally selects the preferred language between English or Italian. In this phase Pepper simulates some autonomous movements in order to show a social respond. After the language selection, Pepper asks the user's name and greets the user again. In this way, it demonstrates its emotional nearness to the user. In this phase of greeting, Pepper says to the user: “Hi! My name is Pepper and I’ll help you during the following game!”.

Simultaneously Pepper simulates a greeting with its right arm. After that, the caregiver can vocally select the difficulty level. Before the level selection, Pepper provides the game instructions. In particular, Pepper says "I’ll show you a recipe and you'll have to answer questions about the ingredients, their weight and type. You'll have 30, 20 or 15 seconds to answer according to the level of difficulty chosen”, and simultaneously it performs different gestures: twisting its torso, slightly opening its arms and hands, and placing its right hand on its hip and showing the open palm to the user. This animation is performed to simulate human behaviour and explain the instructions also moving its arms. The animation also aims to stimulate the user to focus on the game rules.

Then, the robot explains the steps to complete the recipes, providing information about the ingredients, their type and weight.

In addition, while explaining the cooking instructions, the robot expresses more emphasis on the elements that will be asked in the play state. To emphasise the ingredients more, we use the Speech Synthesis Markup Language (SSML). Its tags allow the programmers to customise the vocal parameters, such as voice, pitch, pauses, modify prosodic boundary and add prominence level (W3C, 2021). While rendering the recipe instructions, we used a combination of different SSML tags has been used, in particular, to emphasise the ingredients, their weight and type (using the tag \emph=2\ and \style=joyful\). The use of SSML provides the opportunity to highlight and give more emphasis and receive attention on the vocal elements pronounced by the robot that the user should remember.

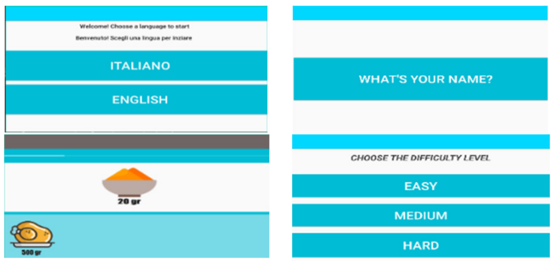

Figure 3: Introduction sub-states.

The play state is divided into two sub-states: questions and answers. In the question state, the robot displays and vocally renders the three types of questions. The upper right hand of the screen displays a timer showing the time remaining to answer. After the question has been presented, the countdown starts, and the possible answers are enabled. According to the difficulty level, four or more possible answers are proposed in the form of buttons showing the image of the ingredient or its weight or type. During the question time Pepper twists its torso and gently opens its hands. The user has three possibilities to answer the question.

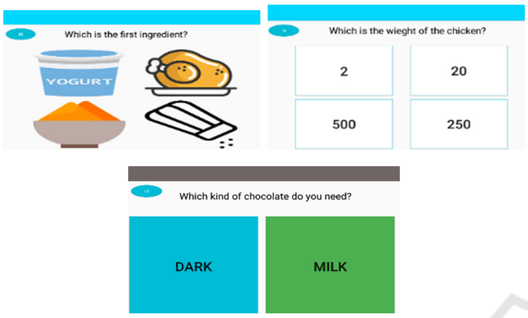

Figure 4: Play state 4a) question about sequence 4b) question about weight 4c) question about typology.

The answer state provides various reinforcement feedback to the user. The user interface changes according to the user's answers. If the answer given is wrong, the UI is highlighted with a red band and displays a thumbs down icon (see Figure 5). Additionally, reinforcing feedback is provided by the robot in the form of vocal feedback.

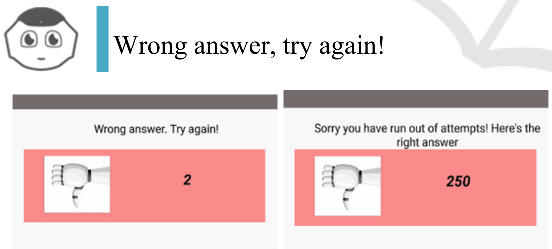

Figure 5: Visual and Vocal Feedback for a wrong answer and no answer given.

If the user does not provide the right answer after three possibilities, visual and vocal feedback is provided such as in Figure 5 right. Moreover, non-verbal feedback is combined with the verbal and visual feedback. In particular, in case of wrong answer, at the same time Pepper raises its right arm towards its face and simulates a negation by shaking its head to the left and right twice.

Figure 6: Animation for wrong answer.

Otherwise, if the answer given is correct, positive reinforcement feedback is provided such as "Really good job Eleonora! The answer is right! You are doing a great job!" and a thumb's up icon is showed on the screen over a green band (see Figure 8). Moreover, a nonverbal feedback is provided. The robot combines different gestures: at first it raises its arms to shoulder height, moves the forearm up and down, and nods its head twice.

Figure 7: Animation for positive answer.

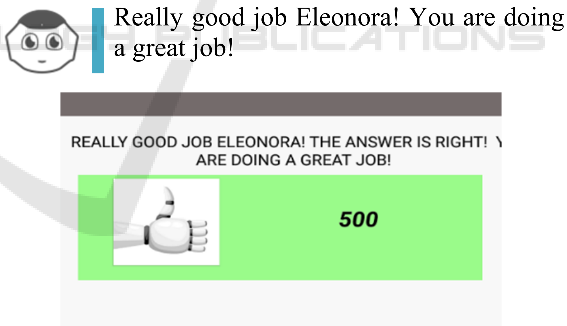

Figure 8: Visual and vocal feedback for right answer.

Additionally, the humanoid robot provides different feedback during the session using different modalities, such as head, arms, torso movements. If the user provides the right answer, Pepper performs one of the following three animations:

- Pepper raises the right arm and moves its elbow up and down, and simultaneously it nods its head twice (see Figure 7).
- It raises both arms over the head twice and expresses a sound of joy.

- It nods its head three times, and simultaneously raises the right elbow to its shoulder twice.

Otherwise, if the user provides a wrong answer or a timeout occurs, the robot performs one of the following animations:

- Pepper shakes its head twice to the right and left, and then raises its hands to its face (see Figure 6).
- The robot raises its right arm at the shoulder and shakes its head.
- Pepper moves the arms up and down, and then shakes its arms.

Finally, the result state is divided into final feedback and data results. In the final feedback state different visual, vocal and animation feedbacks are provided to the user.

According to the number of correct questions, different feedbacks are vocally synthesised. If the user provides less than four correct answers Pepper provides an encouragement feedback: "Good Job! See you next time to continue to improve!".

If the user gives between four and six correct answers, the following feedback is provided: "Congratulation! You answer at the majority of the questions! At next time!".

If the user provides more than six correct answers, the following feedback is provided: "Excellent! You did a great job!".

These vocal and visual feedbacks are provided to stimulate the user to continue the therapy and feel gratified by the interaction with the humanoid robot. In conclusion, a table displays a summary of the user performance during the game session (see Figure 9). Figure 9 shows, in particular, the number of correct answers within the three attempts, the number of correct answers on the first attempt, the number of incorrect answers, number of timeouts, number of correct answers for each question type. Such data are helpful to understand if there is an improvement in the memory domain.

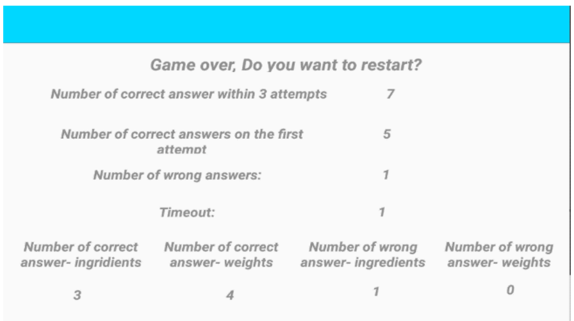

Figure 9: Example of session game results.

4.3 How the Robot Can Show Personalities

In addition, as introduced in the requirements section, during the users' interaction, it can be useful that the robot shows two different types of personality traits: introvert and extravert personality. In this section we describe how we plan to implement them in the game.

These personalities can be expressed by various cues. In particular, according with the literature we have identified different parameters to use in order to allow the robot to show these personalities (Tay, Jung, & Park, 2014).

Table 3 gives a brief description of the non-verbal and verbal parameters identified for the personalities modulation. The non-verbal parameters identified are: the robot's intonation with three values (neutral, joyful, and didactic); the variation of the speech rate, pitch, rhythm and volume; and a different set of feedbacks. The verbal cues identified are: a customized set of animations that can simulate different emotions, and combine complex gestures with different angles and speed; modulation of the movement's speed; association of movements with

Table 3: Personality parameters.

	Extravert	Introvert
Verbal		
Intonation	Joyful	Neutral
Pitch variation	pitch set at 150 [50-200]	pitch set as default 100
Volume rate	set 90 % maximum	set 70% maximum
Speak rate	170 words per minute	150 words per minute
Rhythms Variation	Variation rhythm set 2 [0-2]	Variation rhythm set 0
Set of feedback	reinforcement feedback	neutral feedbacks
No-verbal		
Gesture	both arms, head, torso movements with big angles, faster responses	one arm with small angles, slower response
Animations	animations that convey different emotions	neutral animations
Moving speed	40% faster than introvert movements	slower movements
Sound	movement associated with sounds and melody	no sounds or melody
Autonomous movements	autonomous movements	few autonomous movements

sounds; and the possibility to perform autonomous movements. Autonomous movements are natural movements that give the impression that the robot is alive (e.g. natural arms movements).

The robot can provide a different combination of verbal and non-verbal cues for each interaction with the users according to the personality performed. For example, in the extravert condition, the robot asks the questions with a joyful intonation and a high-pitched voice, and modulating its gesture such as moving both arms over its head. When the user provides the right answer the extravert robot provides reinforcement feedback and complex animations in association with a sound that expresses joy and increasing the speed of its animations. On the contrary, the introvert robot during the interaction will be neutral. For example, in the question state, the robot synthetizes the question with a neutral intonation and a slow animation. When the user provides the right answer the robot reacts with a neutral intonation and a low speech rate, providing a short feedback such as saying “Good”, and after a few seconds, it undulates the torso left and right twice. In summary, the extravert personality is shown through a more joyful and active interaction while the introvert with a more neutral and calm interaction.

We introduce possible ways to exhibit the two personalities because we want to investigate if these different personalities traits that can be activated depending on the users characteristics and interactions, can create an enjoyable interaction; engage more the user during the tasks; increase the user’s attention, and consequentially if can improve the user’s performance. The caregiver can select the personality according to the user personality trait identified before the cognitive training sessions.

4.4 Preliminary Evaluation

A preliminary evaluation with two experts on cognitive training and serious games was carried out in July 2021.

The evaluation was organized in two different steps: first of all, the experts interacted with the robot and the cooking game, and then a structured interview was performed using scripted questions in order to evaluate the game and the proposed requirements.

The experts interacted with the robot by performing the easy and hard difficulty levels. The two experts are both female with ages of 27 and 29. The interview was organized into six questions regarding general positive and negative feedback of the interaction with the robot and the game; information about the animations performed by the robot; whether it can be useful in cognitive stimulation and whether it can be improved, opinions on the tasks performed in the cognitive game, and the multimodal interaction, and finally a general remark about the sessions.

The experts indicated as a positive aspect the multimodal interaction that simplifies the interaction and offers elements that can stimulate more attention from the user. They found that the multimodal interaction is the optimal interaction mode for the target identified because the vocal interaction is immediate and easy to use and the touch interaction with the robot’s sensor requires, on the one hand, more attention and, the other hand, engages and offers the possibility to interact with the robot through physical interaction. They stressed the effectiveness of the multimodal interaction as the optimal solution with elders compared to the touch interaction with a tablet. The experts highlighted how the touch interaction with the robot’s screen may cause some issues. Another element highlighted was the importance of emphasising the ingredients that will be asked about later in the quizzes. Some negative feedback concerned the weights shown during the recipe instructions presentation on the screen, which were considered too small and difficult to read. One expert stressed as positive element that during most of the game the vocal feedback provided by the robot is shown also on screen, in this way the user has double reinforcement feedbacks. As negative element both experts indicated the instruction state. The experts advised providing specific instructions for each level after selecting it. Another element, is to provide more vocal prompt about the instructions during the interaction. For example, when the touch sensor interaction is required, the robot could provide a vocal prompt in which it explains that at that time the touch interaction is required. The experts reported the necessity to provide an additional vocal feedback when the robot does not understand the answer given by the user. Concerning the animations, they reported some issues regarding one animation shown when the user answers correctly. They indicated that the animation shown in Figure 7 does not effectively convey the message of the right answer, and could be modified by simulating a victory animation. The other animations were found immediate and coherent. One expert stressed the importance of animations because they create more engagement and provide a feeling of gratification in the user. Regarding the animations, one expert highlighted how they could create more engagement and stimulate attention in the user. The game seemed well organized with the different interaction modes and the different levels.

One expert suggested a possible change in the type of question regarding the weight of the cooking technique required in the recipe because she believes that remembering weight information is a difficult task. The other expert reported the utility of the multimodal interaction in the cognitive context because it improves the engagement and the attention of the user. Overall the game was found a helpful tool because it stimulates multiple cognitive domains. The animations are important elements and provide more engagement and additional reinforcement feedback. As far as the multimodal interaction is concerned, both experts highlighted its usefulness and immediacy, and reported that it is the optimal interaction model for older adults with cognitive impairments. One expert suggested the possibility to physically interact with the robot not only with the hands but also with the head of the robot.

4.5 Data Visualization for Caregivers

In addition, a Web application has been developed to provide the caregivers the possibility to access the user's performance data regarding the interaction with games and the robot.

The robot is provided with a Wi-Fi connection that allows storing the collected data into an external server. The data collected are: user id, total right answers, total wrong answer, right answer and wrong answer for each question typology, the total number of questions the number of timeouts performed during the session and reaction time.

Such data are collected to analyse the evolution of users while playing the game and then to evaluate if there is an improvement in the cognitive level, in particular on working memory, on the reaction time and the attention.

The Web application shows a game report with general information such as the number of users that are involved in the training, the total numbers of sessions completed, and a graph regarding the total numbers of errors and success rate over time. At the top of the UI, the caregiver can select the data performance of a specific user. Figure 10 shows the interface and provides the information about the user's session. The top of the page reports general information about the user: the total number of sessions performed, the total hours taken, graphs regarding the success and error rates. At the end of the page a table collects the information about the user's performance: the number of correct answers within the three attempts, the number of correct answers on the first attempt, the numbers of incorrect answers, number of timeouts, number of the correct answers for each question type. The Web application is an additional tool offered to the caregivers, which may be useful to monitor the user's cognitive improvement over time.

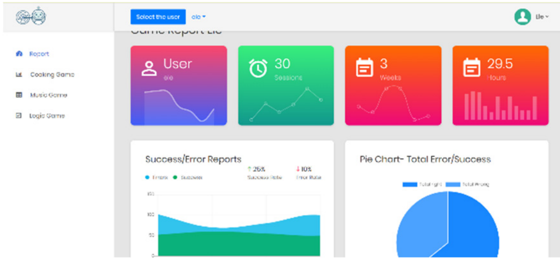

Figure 10: Web application showing data for the caregivers.

5 CONCLUSIONS AND FUTURE WORK

This paper presents the design and implementation of a cognitive serious game for older adults with cognitive impairments proposed through multimodal interaction with a humanoid robot. We describe the current state of the application prototype, and also how two robot personalities can be added to it. Moreover, we report on some preliminary feedback from two experts in cognitive training with serious games.

As future work we intend to complete the implementation of the support for the two personalities, and test the application with older adults with mild cognitive impairments. Furthermore, we want to offer the caregivers the possibility of customising some game features to provide a better personalization for each user. We also plan to investigate the impact of different robot personalities on older adults, and how their use should consider the user personality.

Finally, after validating the proposed game we plan to derive a set of guidelines that can be generally useful for serious games played through humanoid robots.

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