Analyzing Cognitive Flexibility in Older Adults Through Playing with Robotic Cubes

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Abstract. Cognitive flexibility is an important ability to adapt to changing situations. We consider the evolution of technologies in the digital era as a changing situation requiring the individuals to maintain a certain cognitive flexibility. Across the lifespan, cognitive flexibility is an essential ability to adapt to a continuous evolution of human-computer interactions (HCI). In this study, we observe older adults in a playful robotic task aiming to observe their cognitive flexibility in order to consider if older adults shows an adequate level of cognitive flexibility to solve a problem solving task with unknown robotic cubes. The playful robotic task engages the participants individually in problem solving a puzzle-based challenge with modular robotics.

Keywords: Cognitive flexibility · Robotics · Lifelong learning · Human-computer interactions · Problem solving

1 Introduction

The evolution of technologies in the digital era engages the citizens in a never-ending situation of novelty which requires a certain degree of cognitive flexibility to adapt to new or changing technologies and their interfaces. Human-computer interaction (HCI) has changed along the evolution of the different forms of technologies that has been developed in the last decades. The changes in the technologies requires citizens to maintain a certain cognitive flexibility in their ability to adapt to a continuous evolution of HCI. While elderly oriented screen based applications are often designed according the important corpus of knowledge in the HCI field [1, 2] we lack of a so extensive corpus when we consider robotic technologies. Robotic technologies have evolved into a wide diversity of forms and when we use the term robot we should consider an important diversity of devices that corresponds to the definition of what is a robot. While some robots are human shaped and integrate vocal based interactions like the Nao robotic robot in which the user can engage in turn-taking like in human-to-human interactions [3], other robots such the Cubelets kit [4] are composed of basic robotic cubes with basic interaction capacities. In the case of this robotic kits, the user can just manipulate and assemble the cubes to create a robot capable of very basic interactions. The diversity in robotic technologies should be considered when analyzing the type of Human Robot Interactions (HRI). In this study we focus on the use of the Cubelets modular robots to understand the

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cognitive flexibility that could be observed among elderly engaged in the interactions with this robotic technology when solving a puzzle-based task.

2 Diversity Within Human Robot Interactions (HRI)

Robots are defined as “an autonomous system existing in the physical world that can detect the environment and take action to achieve the goal” [5]. They have a physical existence including the sensors to detect different signals from the environment but also processing units to take actions through the actuators. Thereby, from a technological perspective, Munich, Ostrowski and Pirjanian [6] define a robot “as a system that has a number of sensors, processing units (e.g., computer), and actuators”. The type of technologies responding to these characteristics is very diverse, but the social representation of robots is not based in these features but on the representation influenced by science fiction and robots highlighted in mass media, most of them, having a humanoid form. But humanoid robots are only a type of robotic technologies. A wide diversity of robotic technologies has smaller and more abstract features than the humanistic ones. The robotic technologies embedded in our lives could not easily recognized by the user as robots because of the gap between the metal representation of a robot, often associated to a humanoid robot, and the robotic technologies that could be small and very diversity shaped (Fig. 1).

Fig. 1. Poppy humanoid robot.

Humanoid robots have an anthropomorphic appearance that corresponds to the social representation of robots. When people are interacting with humanoid robots, some of their characteristics such the head’s dimension and the number of facial features influences the humanness perception of the robot [7]. Within the educational robots, Nao and Poppy are two popular robots that has been designed to have a humanoid look and feel. Poppy humanoid robot [8, 9] has multiple sensors, a complex software being able to create different types of reactions according to the programs integrated in the Poppy robot. Finally, the actuators make Poppy able to move in different ways and generate sounds and images.

Fig. 2. Robot created with Cubelets modular robotic cubes.

Users with no knowledge in robotic technologies does not perceive not humanoid robots as robots. When facing robotic solutions such the Cubelets [4], they consider them as electronic toys without considering them as robots [10]. In Fig. 2, the robot is created by the user by assembling a sensor (a light sensor integrated in the black cube), a battery making the system able to react, and a wheel which serves as actuator when the light signal is transformed into a signal for the motor moving the wheels. All the components of a robot are present but the look and feel and the simplicity of the system makes the users perceive it as an electronic toy instead of a robot.

In the diversity of Human Robot Interactions (HRI), Yanco and Drury [11] develops a taxonomy for considering the different types of interactions humans can develop individually or in team when engaged with a robot. In the updated taxonomy later by Yanco and Drury [12] they expand the categories for classifying HRI to integrate the social nature of the task by considering the different types of human and the human-robot proximity. The taxonomy could fit the HRI for the use of robots in the professional field, but should be expanded to consider the design, the programming and the building phase of educational robots. In education, robots are not only pre-existing technologies to be interacted, but could be also be a set to build engaging the learner in a designing, programming and building process through the robot creation such in the case of Cubelets modular robotic kit [10].

3 Robotic Technologies for the Elderly

Robots for the elders has been designed in the field of service, in some cases with a focus on healthcare and in other cases on social interaction [13–15]. Most of the uses has been developed in the domestic arena by introducing robots at elderly's home. The importance of technology acceptance in a healthcare relationship has led to consider humanoid robotics as key aspect in the design of robotic technologies for the elderly. Human robot interaction (HRI) for the elders has also focus strongly on humanoid robotic systems aiming to mimic socio-emotional traits of humans. In elderly care robotic systems, the appearance of humanoid robots has an influence in their acceptance, but also can cause some confusion among elderly with cognitive decline [13]. The use of not humanoid robots with the elderly has been less explored, except for robotic pets which pretends, as humanoid robots, be as close as possible of the pets they represent such in the case of the AIBO robotic dog [16, 17]. Beyond humanoid robots and robotic pets, the use of other robotic technologies has been rarely studied or just proposed to the elders as final users without engaging them in the robotic design [18]. In this study we engage elders not in the role of robotic technologies consumers, but as robot designers with educational robotic solutions. For this objective, we engage them in the CreaCube task, in which they should analyse the use of the robotic cubes and create a robot.

4 CreaCube Task, a Playful Robotic Activity for All the Lifespan

Modular robotics engages the users in assembling a set of robotic components into a robot. Among the most known robotic kits, LEGO Mindstorms engages the player in creating, building and programming a robot [18, 19]. In order to analyse the cognitive flexibility, we designed the CreaCube task [10, 20] in which the player should create a robot able to go from a point to another in an autonomous way. Cubelets are modular robotic cubes which are not initially recognized as robotic technologies, neither as a robot [10]. In this study we focus on elders' exploration of these robotic technologies which are unknown for them. For succeeding in the CreaCube task the participants are proposed to use four Cubelets robotic modular cubes to solve a robot creation challenge in which they should build a vehicle able to move from an initial red point to a final black point (Fig. 3).

Fig. 3. Participant exploring the cubes.

The CreaCube task requires the participant to explore the robotic cubes in order to figure out the way the behave. This initial exploration is required before engaging in a building activity requiring an important cognitive flexibility to adjust the intermediate solutions to achieve the solution. The novelty of the task and the technology manipulated by the participants could impact their cognitive flexibility in the problem solving CreaCube task. Cognitive flexibility, understood as the human ability to adapt cognitive processing strategies to face new and unexpected conditions, has pointed as intrinsically linked to attentional processes in problem solving tasks [21].

We observe older adults in a playful robotic task aiming to observe their cognitive flexibility. The playful robotic task engages the participants individually in problem solving a puzzle-based challenge with modular robotics. Modular robotics are an unknown technology for most of the participants; in particular older ones which has not played with this type of technologies [22]; older adults does not associate it to the electronic games younger participants evoke when interacting with the robotic cubes. Elderly engaged in the CreaCube task observes the cubes and grasp them to touch the metallic parts. Once they observe the cubes are magnetic and could be assembled, the participants engage in a, reflexive analysis of the errors and cognitive flexibility is required to change the different building solutions until finding a correct solution. CreaCube is an ill-defined robotic task in which the initial complexity engages the participant in a series of unsuccessful prototypes. When observing the problems appearing in each prototype the participant has the possibility to understand the features of each robotic cube and be potentially able to acquir3e the enough knowledge to complete the CreaCube task. Cognitive flexibility is therefore important to be able to develop different solutions with the robotic cubes and analyze the errors in each of the phases. In each prototype testing, we can observe cognitive flexibility as how the person changes its solution "selectively in response to appropriate environmental stimuli" [23]. In a similar way, cognitive flexibility is for Krems [24] the "person's ability to adjust his or her problem solving as task demands are modified" (p. 202), a set of modifications which in the CreaCube appears at each new combination of the robotic cubes.

4.1 Cognitive Flexibility

When engaged in problem solving activities, the participants should be able to generate different ideas in order to explore the best solution for the problem. Within this context, cognitive flexibility is a key executive function to generate and decide the best idea. Cognitive flexibility is part of the important executive functions making possible to the individuals to understand a problem, generate hypotheses to solve it and evaluate the relevance of each of these hypotheses to find the most appropriate solution. If the first hypothesis tested is not the right one, then it will be necessary to be able to disengage from this solution to seek a new and more suitable resolution mode [25].

Cognitive flexibility is expected to be better developed in adulthood [26] when the prefrontal cortex is already mature [27]. From the observations we have started to develop through the CreaCube task we observe kids younger than 10 years to have difficulties to keep in mind the task objective, while older kids and adults are able to keep in mind the objectives. Among older adults, cognitive flexibility could decline [28], which could be explained with a reduction of dopamine levels [29]. Through the CreaCube task we observe cognitive flexibility in relation to the iterative prototypes proposed to solve the task.

5 Results

Four older adults were voluntarily engaged in the CreaCube task within a community center environment in a peripherical neighbourhood of a small city. Participants engaged in the CreaCube tasks are healthy and socially active older adults, but they self-declare themselves as less knowledgeable than other adults which could be analysed as a low self-steem in relation to academic tasks. We analyse cognitive flexibility in relation to the different shapes and cubes moves made during the CreaCube tasks.

We can observe all the four adults to focus on a single shape for the construction instead of creating different shapes. The shape used by the older adults is the "train", which combine the four cubes in a row (Fig. 4).

Fig. 4. Participant assembling the cubes in a "train" shape.

Adults and younger participants created different shapes during their problem-solving activity demonstrating a higher cognitive flexibility in terms of shapes imagined solving the CreaCube task (Fig. 5).

Fig. 5. Adult participant assembling the cubes in a "S" shape.

The problems faced by the older participants during the CreaCube task are also informative about their difficulties within this task.

In Fig. 6, we observe the difficulties of an elderly participant along the CreaCube task. The elderly engages in the task 9:30 min. Until 9:15, the participant fails to make move the robot, and thereafter the sense of advancements of the robot is inversed. The duration of these problems could be analysed as a difficulty to propose other solutions which can overcome the problem.

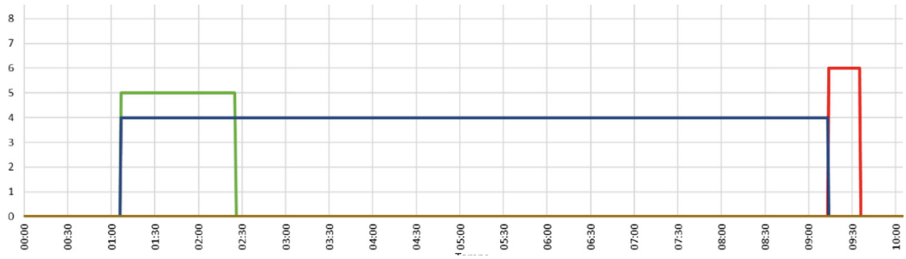

Fig. 6. Elderly participant problems during the CreaCube task.

6 Conclusion, Limitations and Implications

Older participants appear to be less cognitive flexible in the CreaCube task. The task is characterized by its novelty and its ill-definition. Elderly focus on a single shape for the solution despite the persistence of the problems when they test their solution. Younger participants react with a higher cognitive flexibility to problems appearing during the CreaCube task. The error tolerance of participants facing the assembling problems during the process of solving the CreaCube task is invoked by the activity [30]. When facing a problem, the participants with higher cognitive flexibility considers an array of different solutions that could be tested to verify the hypothesis generated during the problem-solving process.

We should consider the possibility that the context of the task could have led to frustration in a context where the older adults are not familiar with the researchers engaging them in the CreaCube task and they feel evaluated. Additional tests of the CreaCube tasks would consider the social connection with the researchers to consider the possibility that creating a more relaxed condition for the CreaCube test could help the older participants to better cope with the frustrations generated by the errors in the intermediate solutions. Another possibility to better manage the stress of the task developed in individual settings is the possibility to evaluate the collaborative problem-solving processes when participants are engaged in same-age groups or intergenerational teams. In addition to better managing the situation, the CreaCube task should be developed with a higher number of participants in order to analyse the standardised ways of solving the task and better situate each of the participants within a certain level of cognitive flexibility. The advancement on this research axes is integrated in the ANR CreaMaker project which will finish in 2022 with the early results on the collaborative problem-solving favors and cons.

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