Multimodal Robot Feedback While Learning a Novel Cognitive Exercise From a Human Teacher

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***Abstract*— Socially-assistive robots could help their users in essential daily activities. However, teaching these tasks to a robot usually requires domain-specific robot programming, and hence substantial time investment. User-oriented methods for teaching robots can accelerate the learning process. The robot should disclose obtained knowledge and understanding of the new skill while learning it. Moreover, the robot should inform the teacher what additional instructions are necessary. This paper proposes adaptation of the robot feedback to a human teacher through the use of different robot modalities in the context of cognitive therapy.**

I. INTRODUCTION

Socially-assistive robotics has the potential to improve the quality of life for various groups of people [1]. For example, robots can provide cognitive therapy that slows down the cognitive decline of people with dementia. However, the interaction must feel natural and meet the expectations of the user. Otherwise, the robot does not serve its purpose. This paper outlines the use of robot modalities while a human is teaching it a new skill, and how to exploit the multimodal character of the interaction in this context. Moreover, the focus is on adapting the use of robot modalities when the robot provides feedback to lay users that are teaching it a new cognitive exercise.

People have different teaching styles [2]. Therefore, we should design robots that adapt to account for these differences. The robot should provide feedback to human teachers so that they can comprehend the robots understanding of the task. In this paper, the focus is on teaching robots new cognitive exercises because it is beneficial for people to perform diverse exercises since it minimizes their boredom due to repetition.

II. COGNITIVE THERAPY

Alzheimer's disease and other types of dementia affect an increasing number of people [4], and robots can assist in providing cognitive therapy [5]. One type of therapy are exercises that stimulate different parts of the brain. For instance, memory is trained using exercises of recalling objects from sequences (Fig. 1) that usually have minor differences among them. For example, the user needs to sort a set of objects in a predefined sequence. Performing the exercise multiple times with the same shapes can be boresome. Therefore, the exercises could engage more if different sets of shapes are used. However, the change of shapes requires reprogramming of the robot behavior, and

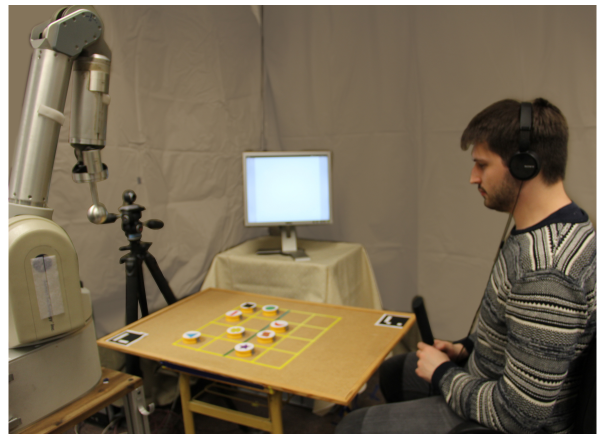

Fig. 1. Multimodal robotic system that supervises and assists its users in performing a memory exercise [3].

that process commonly requires the involvement of a robotics expert. Similarly, if the rules of sorting the sequence are modified, it would require additional programming by the expert.

III. USER-CENTERED ROBOT TEACHING

Multiple algorithms have been developed for teaching robots new skills and for robots to interactively learn [6]–[9]. Amershi et al. [10] show that human teachers improve the efficiency of learning algorithms and also create systems that are more adapted to the needs of its users.

The robot should track the state of the environment and the user when it receives instructions. Moreover, it should create a policy based on those instructions. The robot should disclose its perception of the environment, provided instructions, and the learned policy. However, the manner of interaction influences the teacher, and the robot should be careful not to provide feedback that can misguide the teacher. Therefore, the robot must provide relevant information in the manner most suitable for the particular teacher. The robot should track and estimate which types of interaction provide optimal teaching experience that is defined as successful, fast and enjoyable for the human teacher. Teaching is successful if the robot learns the desired policy, and it is enjoyable if the human labels it as enjoyable in post-task assessments. Moreover, the robot can use emotion recognition algorithms to detect and track the enjoyment of the teacher during the teaching process.

Interaction can be unsuccessful because the teacher misunderstood feedback from the robot. This situation is detected

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if robot's perspective about the task is unchanged after the repeated teacher's explanation. In this case, the robot should provide feedback in another manner, using different modalities. Moreover, the failure of the former feedback should influence modality choices in the future by labeling those modalities as less preferable.

The robot may misunderstand the instruction of the teacher. After additional explanations, the robot obtains the correct description of the tasks. Moreover, if possible, the robot should disclose how it came to the wrong conclusion. This can be accomplished by evaluating previous instructions, and if any of the instructions does not fit the new perception of the task, the robot should inform the teacher.

Robots interact using different modalities. Depending on the situation and the user, some are more appropriate than others [3]. If the robot detects strong ambient noise, it should not rely on verbal communication. Similarly, if the user has a hearing impairment the verbal interaction is not suitable. While robots can have diverse modalities, most common are speech, visual, and gestures.

Verbal communication is common among humans; however, the intricacies of languages are challenging for machines to understand, and hence act upon. Therefore, providing adequate feedback minimizes the ambiguity on both sides of the interaction. Several commercially available robots, including Pepper [1] and Baxter [2] , have a built-in display. Through this type of devices, the robot can provide rich visual information —e.g., a picture of a relevant object in a cognitive exercise. Gestures are another modality that can convey information, and they are especially suitable for providing spatial information because the robot can divert user attention towards an object of interest using pointing gestures. In some situations, a gesture augmented with a verbal command can provide a better quality of interaction than the unimodal interaction with only one of those modalities.

IV. TEACHING A COGNITIVE EXERCISE

In this paper, an example of a sequential memory exercise (Fig. 1) is used to illustrate the process of teaching the robot a cognitive exercise. The user is initially informed about a sequence of objects (e.g., the robot says object names), that need to be sorted in the same order. This exercise should stimulate the memory recall. In the example in Fig. 1 the objects are round tokens with different shapes printed on their top side. This robotic system can speak, perform gestures with its robotic arm, and show visual information on its display. A similar version of the aforementioned exercise requires that the user sorts the objects in the reversed order, by first selecting the last objects from the initial sequence, etc.

The teacher can explain the rules interactively. Depending on the exercise stage, the teacher can give some information, and ask the robot to perform a part of the exercise. Another way is performing one or more complete exercises correctly and then asking the robot to repeat. The robot generates a policy based on those demonstrations. While the robot is performing the exercise, the teacher gives feedback that guides the robot towards the correct policy.

If the robot is unsure as to which object the teacher is referring, it can point towards possible objects, or say a relative description. The choice of a modality the robot uses can depend on the modality that the teacher used. For example, if the ambiguity is because the robot was not capable of discerning towards which object the teacher was pointing, it can also use gestures. However, the robot could show the pictures of the possible objects, and ask the teacher to select the correct one. The current state of the environment and the users must be considered. For example, if the teacher is not looking towards the robotic arm, the robot may not want to influence the teacher to divert her or his gaze, hence the robot should avoid using this modality under the mentioned circumstances. Furthermore, the history of previous interactions should be a key factor when deciding which modality to use.

V. CONCLUSION AND FUTURE WORK

Modality adaptation is an important aspect of human-robot interaction. During robot teaching, the goal is to enable the human teachers to instruct the robot in a manner most natural to them while the robot provides them adequate feedback about its reasonings. This is important for having a high-quality learning process. In this paper, the adaptation of modality use when providing feedback is outlined.

In future work, user-centered robot teaching will be implemented and evaluated with user-studies with caregivers as teachers. The focus of the evaluation will be on the usefulness of the system and the quality of the interaction [11]. Furthermore, the teaching methods should also be evaluated on other use-cases that could improve the quality of life for older adults, in the line of the goals of the SOCRATES project.

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