The Power of Suggestion: Teaching Sequences Through Assistive Robot Motions

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ABSTRACT
We present a preliminary implementation of a robot within the context of social skills intervention. The robot engages a human user in an interactive and adaptive game-playing session that emphasizes a specific sequence of movements over time. Such games highlight joint attention and encourage forms of interaction that are useful within various assistive domains. Noteworthy robot activities include those that could be used to promote social cues in children with autism, sequences that maintain or improve memory in Alzheimer's patients, and movements that encourage exercises to increase range of motion in post-stroke rehabilitation.

Categories and Subject Descriptors
I.2.9 [**Artificial Intelligence**]: Robotics.

General Terms
Experimentation, Human Factors, Measurement, Performance.

Keywords
Human-robot interaction, socially assistive robotics.

1. INTRODUCTION
Facial expressions, eye gaze, head movement, posture, gestures, and other nonverbal cues play a crucial role in what can be considered "typical" social interactions. These sometimes-subtle cues are learned and eventually imitated at an early age by typically developing children. However, there are some populations of children and adults whose circumstances impair such social development. For example, children with autism spectrum disorder tend to avoid eye contact and, thus, often miss intentions and emotions expressed in the face and body; the early-to-moderate stages of Alzheimer's disease often limit a patient's vocabulary and hinder his ability to form coherent sentences; post-stroke rehabilitation patients frequently have reduced motor activity, thus limiting social expressiveness.

Interactive and engaging tools that explicitly promote motions that are common in social cues are useful for assisting such populations. Clinical studies have demonstrated the effectiveness of social skills training programs in groups with special needs, and have proposed methods to enhance intervention strategies for different populations (Rao *et al.* 2008). Contemporary research suggests that physically embodied robotic systems can be used to improve social activity, in particular through the use of instructional games that involve training through imitation (Rogers & Williams 2006; Tapus *et al.* 2007).

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2. APPROACH AND METHODS
The purpose of this project is to develop a framework for a humanoid robot to engage in an interactive and adaptive game-playing session—that emphasizes potentially exaggerated robot movements that adapt over time—with a human. Specifically, these games place participants in situations where the goals are not immediately or explicitly clear, but, rather, must be inferred from referential robot gestures and/or movements within the context of a particular domain. Reliance on observing the robot could promote social cues in children with autism. Sequencing games could maintain or improve memory in Alzheimer's disease patients. Finally, movements could increase range of motion in post-stroke rehabilitation patients.

A single task-oriented motion is used to *shape* the user's behavior. Preliminary research in our lab suggests that a robot can shape the behavior of a typically developed person to better recall an order of events; however, simple behavior shaping will likely not suffice for special-needs populations. Connecting multiple shaping movements in a sequence results in *behavior chaining*. This introduces context into the motion, playing a key role in a social environment. Using these chaining strategies, the robot can direct an interaction by performing a series of motions that help link actions to be carried out in a particular order.

A sequencing game was chosen to demonstrate the feasibility of a robotic system capable of shaping and chaining human behavior. For the purposes of this study, a sequence is defined as a series of button presses in a particular order; however, to make the game challenging and to better provide opportunities for interaction, the user is not told the sequence and, thus, he or she is presented with two choices: 1) determine the sequence by exploring different button combinations or 2) elicit help and guidance from the robot to determine the sequence. The sequence is initially short and simple, but increases in difficulty over time—as the user gets deeper in the sequence, remembering all preceding button presses becomes quite a challenge. At any point, if the user requests assistance [from the robot], the robot engages in motions and behaviors that reference physical entities (e.g., using eye gaze, head orientation, and/or nodding to refer to the user or a button).

3. ROBOT PLATFORM

The system was implemented on the Bandit III platform available in the Interaction Lab at the University of Southern California (http://robotics.usc.edu/interaction/?l=Laboratory:Facilities#humanoid). Bandit is a humanoid torso robot with 17 degrees of freedom (DOF). These DOF allow the robot to be highly expressive by using individual and combined motions of the head, face, and arms. The robot is more to scale with respect to human users than many other humanoid platforms; mounted atop a Pioneer P2 base, the entire robot stands at one meter tall, making it well suited for interaction (especially with children). An overhead camera facilitated robot and human-user tracking.

4. CONTROL AND INTERACTION

A *three-layer architecture* was used for robot control (Gat 1998).

In the *reactive layer*, the robot is constantly responding to the relative position of the user, panning and tilting its head to maintain eye contact. The height of the participant is used to determine the proper amount of head tilt.

The *deliberative layer* was used to maintain the states of both the user and the robot over time. This allowed the robot to produce output behaviors that were appropriate to the skill levels of individual users. To make the interaction more natural and unobtrusive, a social robot should offer an appropriate amount of assistance based on the feedback and preferences of the user; however, a social robot should not appear completely inanimate when it is not directly or actively engaged with the user (the latter of these two concepts is handled by the reactive layer).

A task-oriented *behavioral layer* was implemented to facilitate robot feedback and action based on inputs from the user. Behaviors include *tracking user* (default; defers to the reactive layer), *correct/incorrect button pressed* (provides smooth transitions between the current action and the corresponding button response behavior), *responding to correct/incorrect button press* (indicates user success or failure with a head nod or shake, respectively), *request for assistance* (provides smooth transition between the current action and the assistance response behavior), and *responding to request for assistance*. The last behavior produces the majority of the robot's activity; it becomes active once motor preconditions have been met following a user's request for assistance. The behavior responds based on the level of assistance needed.

At the lowest level of assistance, the robot simply looks at the button directly in front of the user and either 1) nods its head if the button is, indeed, the next button to press in the sequence or 2) shakes its head if the button is not the next button to press in the sequence. This is useful in eliminating possible solutions, and is often used if the user is simply unsure of one of the buttons he or she has previously pressed.

If more assistance is required, the robot tries to guide the user in the direction of the next button in the sequence. This is done by the robot looking at the user and then having the head follow a trajectory from the position of the user to the correct button. This is useful in further narrowing down where the next button is.

At the next level of assistance, the robot attempts to be more explicit in its help—it looks directly at the correct button for a few seconds. This type of assistance makes the goal significantly more clear to typical users.

Any subsequent requests for assistance result in the robot looking directly at the correct button as before, and then nodding at it. The number and "weight" of the nods (i.e., how much of a sweeping motion the head makes) are based on the number of requests.

5. PRELIMINARY STUDY RESULTS

We preformed the following preliminary experiment. The robot provided scripted instruction to the user regarding the task. The task was as follows: the user was to press one of five buttons (in this implementation, each button was a Wiimote and button presses were communicated via Bluetooth), each atop a 1.1-meter pedestal, in an unknown sequence. If an incorrect button was pressed, the user had to restart the sequence from the beginning; thus, the cost of an incorrect button press was high, especially as the user progressed farther into the sequence. The goal was to press as many buttons in the sequence in a five-minute time limit.

The experiment was done over two trials. In the first trial, the user had to rely completely on exploration to determine the sequence and memory to remember the sequence when incorrect buttons were pressed. In the second trial, the user was given a Wiimote and could elicit help from the robot by pressing one of its buttons; the more requests for assistance the user made, the more helpful the robot was.

The experiment was conducted with 11 participants in both the non-assistive and assistive conditions. Preliminary results suggest that users that elicited help from the robot were able to progress further in and faster through the sequence than those who did not. The number of requests for assistance varied across participants; further experiments will be conducted to determine the level of user interaction with the robot, as well as the potential for behavior chaining strategies to improve user performance.

6. FUTURE WORK

Possible considerations for future work include multimodal assistance (communicating the correct button using arm gestures), a reward structure for success (promoting interaction with the robot), and learning based on user patterns of assistance requests.

7. REFERENCES

[1] Gat, E. (1998). "On Three-Layer Architectures". In Artificial Intelligence and Mobile Robotics, Kortenkamp, D., Bonnasso, R.P., & Murphy, R., eds., AAAI Press, pp. 195-210.

[2] Ramesh, A. & Matarić, M.J. (2002) "Learning movement sequences from demonstration". In *Proceedings of the International Conference on Development and Learning*, pp. 203-208.

[3] Rao, P.A., Beidel, D.C., & Murray, M.J. (2008). "Social Skills Interventions for Children with Asperger's Syndrome or High-Functioning Autism: A Review and Recommendations". *Jrnl. of Autism and Developmental Disorders*, 38(2), pp. 353-361.

[4] Rogers, S.J. & Williams, J.H.G. (2006). Imitation and the Social Mind: Autism and Typical Development. New York, NY: The Guilford Press.

[5] Tapus, A., Matarić, M.J., & Scassellati, B. (2007). "The Grand Challenges in Socially Assistive Robotics". *IEEE Robotics and Automation Magazine*, 14(1), pp. 35-42.