# Toward Encouraging User Autonomy in Socially Assistive Human-Robot Interaction

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### I. INTRODUCTION

Many of the domains where socially assistive robotics (SAR) can aid people involve the mastery of actions that promote well-being, or *health behaviors*, by individuals with chronic conditions or disorders. In-home and in-classroom robots can teach new behaviors, encourage generalized learning, and promote patient autonomy that persists beyond the robot-aided intervention. For the near future, it is practical to develop methods and algorithms that anticipate the robot's limited time with the user, and incorporate it into models of social interactions that encourage user autonomy. The occupational therapy technique of graded cueing provides a framework for appropriately challenging feedback that can be incorporated into a SAR interaction.

### **II. COMPUTATIONAL CHALLENGES**

Computational challenges of encouraging user autonomy lie both in adaptation to changing behavior over time and in personalization to individuals with special and specific needs. To address these challenges, we must develop methods that can generate dynamic feedback from multi-modal, intermittent, and noisy human-robot interaction data.

Individuals with special needs often require treatments and therapies that are skills that must be developed over time. Adaptation algorithms must be able to account for two types of variation: between individuals in the presentation of symptoms and within individuals as their skills improve. For example, children with autism spectrum disorders (ASDs) exhibit a vast variety of symptoms and symptom severities, as well as variation of responses between therapy sessions due to a broad range of external and internal factors. Our methods must frequently evaluate internally modeled user state in order to capture and maintain each user's response to feedback and aim to decrease the need for feedback over time.

Additionally, the timescale for adaptation must be short because of the realities of human-robot interaction, which are limited by technological as well as human user logistics. One means of reducing the amount of real-time user adaptation is by bootstrapping the adaptation methods with profiles of personal (as well as medical, etc.) user information. User profiles track information that persists between interaction sessions, such as known medical conditions, learning style, and ability level achieved in each session, and can also be updated offline, between interaction sessions, based on a variety of data sources. Representing and integrating such asynchronous, intermittent, multi-modal user data is another well-recognized computational challenge.

## III. GRADED CUEING: A METHOD FOR AUTONOMY-ENCOURAGING FEEDBACK

The above computational challenges have been addressed in multiple studies where feedback was used to encourage user autonomy in performing a task. There is still much potential in future work to develop personalized, adaptive systems for increasing user task performance through robotmediated therapy and education.



Figure 1. Prompts used in the copy-cat implementation of graded cueing feedback.

We developed a computational model of graded cueing feedback using a probabilistic model of first prompt choice [3]. Graded cueing is an occupational therapy technique of giving the minimum required feedback during learning or practicing a task in order to promote patient autonomy and skill generalization [2]. The idea behind the process is to guide a patient through a task while only providing prompting when necessary. When the patient does need prompting, the therapist gives the patient a hint, encouraging them to remember and perform as much of the task autonomously as possible. In addition to encouraging autonomy, the therapist must also give the patient sufficient feedback to not frustrate them as they have to ask for help over and over. Thus, the challenge in using graded cueing is choosing the level of specificity of feedback that is the most appropriate for each patient. The implementation of the model was used to give feedback on imitation accuracy in a "copy-cat" game played between a Nao humanoid robot and a child with an ASD (high-functioning, aged 7-10). This game was chosen because children with autism often exhibit imitation and spatial reasoning difficulties [1]. The imitation task was simple to implement, consisting of only one step and having a single goal: correct imitation within an acceptable variance.

The computational representation of graded cueing is a series of increasingly specific prompts, the first of which is selected by a Bayesian model based on each user's previous performance. From there, if the user requires another prompt, the robot provides the next more specific prompt from the prompt list. If the user reaches the most specific prompt and still does not execute the task correctly, the robot then switches to another instantiation of the task (i.e., another movement example). In our implementation of the model, the task of arm pose imitation was broken down into four levels of prompt specificity, as shown in Figure 1. Domain-specific task feedback for each prompt was designed based on interviews with an autism therapy expert.

The graded cueing model was tested in a study with 12 children with ASDs aged 7-10 in an all-ASD special needs classroom environment. Participants were divided into two groups of six, one group receiving graded cueing feedback from the robot, and the other receiving the most specific feedback in every round. This comparison was chosen to test that a method of feedback that encouraged autonomy could do at least as well as a "hand-holding" feedback style that always gives the user the maximum amount of information to accomplish the task. Participants had five 10-minute sessions with the robot (10 rounds of imitation practice) over 2.5 weeks. Imitation accuracy was determined as the difference between a normalized-length version of the robot's joints and the user's joints as measured by the Microsoft Kinect.

The graded cueing condition was found to be the same or more effective than the control condition, implying that the autonomy-encouraging feedback caused no reduction in user ability and could be used instead of maximally specific feedback in future work. Participants in the graded cueing condition either saw a slight improvement in imitation accuracy or stayed the same, while the control group either saw no change or a slight decrease in accuracy, neither of which were statistically significant due to the small sample size. There were also fewer incidences of frustration (2 vs. 4) in the graded cueing condition. These trends are promising for future work.

We then expanded the graded cueing model as part of a larger study of long-term human-robot interaction in a nutrition education context with the DragonBot robot [4]. In that implementation, graded cueing was used to give feedback to children who were learning about nutrition. The children interacted one-on-one with the robot, choosing foods for the robot and placing them on a plate in front of the robot; the robot then gave feedback on the food choices. The foods included healthy (e.g., all-bran cereal, wheat bread, milk) and unhealthy (e.g., white bread, chocolate milk, doughnuts) choices. In this instantiation of the graded cueing model, during each round of interaction there were two goals to give feedback on: maximizing the number of healthy choices by the child and minimizing the number of unhealthy ones.

The first strategy to address the two goals was to treat them as a single goal, assuming the children would only add or remove one food item at a time. However, we observed that, after receiving feedback that some of their food choices were unhealthy, some children removed all food items from the plate and tried an entirely different combination. We revised the graded cueing implementation to use two goals treated as two separate instances of graded cueing, in order to accommodate multiple response with the same ratio of healthy to unhealthy choices. Future work will include an interaction monitor separate from each instance of graded cueing that will provide meta-feedback on the user's overall progress. Real-world health behavior tasks will have multiple goals and multiple steps toward each goal.

### IV. SUMMARY

Socially assistive robots have the potential to provide consistent, in-home and in-classroom therapy and education to special needs populations. The next step in increasing the complexity of interactions using the graded cueing framework is to further parameterize tasks/ lessons for increased personalization. Future work in the graded cueing project includes expanding the framework to include tasks with multiple steps and goals over many sessions with the robot. This expansion includes the representation of each user's knowledge and abilities as part of a larger ontological structure of domainspecific skills. These enhancements of the model will be evaluated in the context of a personalized health education framework with autonomy-encouraging feedback provided to special needs users having to manage one or more chronic conditions.

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