Designing Dynamic Robot Characters to Improve Robot-Human Communications

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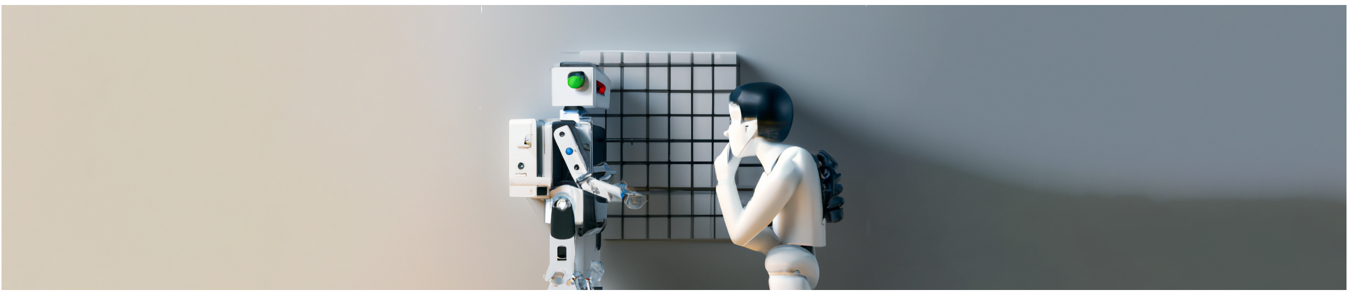

ABSTRACT

Socially Assistive Robots navigate highly sensible environments, which place high demands on safety and communication with users. The reasoning behind an SAR's actions must be transparent at any time to earn users' trust and acceptance. Although different communication modalities have been extensively studied, there is a lack of long-term studies investigating changes in users' communication needs over time. Considering two decades of research in Human-Robot Communication, we formulate the need to design dynamic robot personalities to unveil the full potential of SARs.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; • **Computer systems organization** → *Robotics.*

KEYWORDS

human computer interaction

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1 INTRODUCTION

While in 2005 Feil-Seifer and Mataric [14] still defined that they assist merely through social interaction, in 2021 Boada et al. [6] claimed that the application areas of Socially Assistive Robots (SARs) should also extend to robots that perform actions involving physical user contact. Working in domains with vulnerable users, e.g., in-home care for the elderly, differentiated education for children, or mental health [10], requires them to navigate both complex environments, social interaction [10], and obey social rules [2] to earn the users' acceptance and trust. This is crucial to use the robot's full potential.

To make a system predictable, it has to have consistent patterns, behavior, and characteristics - or: a personality - that can be learned by the user to determine future behavior. Prior research has shown that a robot's perceived personality can affect trust and acceptance [31, 41]. In general, the tendency of people to attribute human traits to inanimate objects - anthropomorphism - affects robots too. Depending on the robot's behavior and appearance, users will attribute a "mental" internal state to it, which will in turn influence how they anticipate the robot to act [37]. That means by consciously designing a robot's personality, the designer can help users to understand the robot's reasoning and build up trust.

However, implementing studies with automatic robots is still complex and costly. Thus, researchers often have to fall back to Wizard-of-Oz techniques combined with teleoperating robots. This makes it difficult to study the long-term effects of human-robot interaction, as in this case the robotic systems do not work autonomously and have to be manually controlled by an operator [7, 10]. Especially assistive robots, however, should be studied over longer periods of time to gain insights into the changing dynamics of human-robot relationships.

In sum, to clarify how trust and acceptance of a SAR can be achieved, we have to look at the combination of communication, personality, and relationship with the robot.

2 RELATED WORK

In the following, we will briefly summarize prior research on robot communication and transparency, robot embodiment, and types of robot-human relationships.

2.1 Reasoning and Communication

For users to accept and trust robotic systems, they must be able to understand the reasoning behind the robot's actions. Therefore, the robot must be able to communicate its internal state and intentions to the user [37]. Especially in collaborative tasks, non-verbal communication can remove the ambiguities of verbal exchange and increase task performance [7]. Furthermore, interactive social cues can help to achieve more social user responses [18], improve user experience [36] and also help shape the perception of robot personality and emotion [43].

While the right choice of words, voice, pitch and volume are crucial for verbal interaction, other audible queues can be used to indicate and support the robot's reasoning [28, 30, 44]. In the following, we will briefly touch on further non-verbal communication modalities.

Movement. During collaboration, especially object handovers, humans communicate intent and timing mainly through posture and limb movement. Based on these observations, Strabala et al. [34] derived crucial elements for robot handovers. The robot should have a "carrying posture" that is highly distinguishable from other poses, so the willingness to hand an object is clearly recognizable even if the user is not currently focusing on the robot. In this pose, object and limbs are held close to the robot. To signal the handover intent, the robot should move the object towards the torso of the user, ideally holding it sideways and tilting it towards the user.

Even when the robot is inactive, the user needs to know when it is operable. When the robot is not moving, there is no telling apart from being switched off or inactive. Breazeal et al. [7] introduced an idle movement to their robot to signal "aliveness", and Terzioğlu et al. [36] found that a "breathing" motion of their robotic arm is suitable to display its internal state and intent. In general, motions that are "human-like" are reported to have a positive notion and help users predict robot movements faster and more accurately compared to more direct or abstract movements [21, 34].

Gestures. Even robots with few movable extremities can achieve interpretable gestures (see R2-D2), like nodding or shaking for approval and refusal. Imitating the user's head movements can lead to more acceptance [18] and a "shrugging" gesture can signal the user that an input could not be interpreted [7]. Gestures accompanying verbal output by the robot can determine the level of its perceived extraversion [2] and therefore help shape its personality. While head gestures seem to have an engaging effect on users [20] and can convey emotional states like anger to the user [1], simply turning towards the user can signal attention [42].

Gaze. Gaze cues help communicate the robot's internal state and intent [36]. In collaborative tasks, gaze can help establish grounding, disambiguation of spoken information, joint attention that signals understanding, and turn-taking [25]. Moon et al. [27] found that handovers are significantly faster if the robot gazed toward the anticipated handover location. One might think this only applies to robots with face-like or even just eye-like features (like, e.g., [7]). However, in their work, Terzioğlu et al. [36] demonstrate how gaze and posture cues can be easily achieved, even with a non-humanoid robot. In their studies, they used a robotic arm with a two-finger end effector and achieved sufficient cues by attaching a pair of glasses on top of it while pointing the fingers at the object in question.

2.2 Personality and Embodiment

According to Deng et al. [12], the physical embodiment of robots "includes the internal and external mechanical structures, embedded sensors, and motors that allow them to interact with the world around them". Compared to virtual representations, embodied robots affect user performance and perception of an interaction [39]: it increases compliance [3], social engagement and enjoyment [4, 22, 40], improves cognitive learning [23] and motor skills [17], and increases user engagement in social [16], educational [38] and clinical [8] context.

Designing a robotic assistant does not stop at the visual appearance, number and functionality of extremities, level of human-likeness, size, color, and shape. Considering the strong impact assistant embodiment has, profound thought has to go into the "how" of the robot's actions: How and when does the robot move? How fast should it move, and how close should it approach the human? Are the movements abstract or more human-like? How are movements linked to other communication channels?

Deng et al. [12] propose a process for designing robot embodiment that considers the desired context. They suggest starting from the task a robotic assistant is to fulfill. According to Mcgrath [24], collaborative tasks can be classified by four task natures: Generate, Choose, Negotiate, and Execute. Based on the task, decide which relation (or role) the assistant should have to the user (see Section 2.3). The assistant's role falls between abstract (metaphorical) and literal (or realistic). The levels of abstractedness, task nature, and the chosen role later influence the level of autonomy and intelligence the users expect from the assistant.

2.3 Relation and Habituation

An assistant's relation with the user falls between subordinate and superior [10, 12]. A *subordinate* role can signal that the assistant wants to learn from or be instructed by the user and is the least complex to implement. It can encourage empathy [33] and self-efficacy [5, 15]. The *peer* meets the user on equal footing. It can learn from and correct the users and successfully engage them in cognitive competition [12]. The role which is most difficult to implement is the *superior* [16]. It can be used to increase user compliance and achieves higher reliability and competence [19] and therefore is suitable, e.g., for coaching purposes.

When the user first uses the system, there is, of course, a novelty effect. The user is yet to learn, understand and trust the robot. In this phase, transparency has to be high, and parameters, like, e.g. action speed, have to be low. After a while, when the user has built up trust in the system and gained knowledge about its capabilities, reasoning can be dialed down, and speeds can be increased. Nevertheless, these are not the only parameters that have to be adapted over time. A study by Salter et al. [32] has shown that the engaging functions of a robot can deteriorate over time, especially when used in the wild.

3 CREATING DYNAMIC ROBOT PERSONALITIES

We learned that adequate communication is necessary for a robotic system and that the robot's personality can shape the quality of communication. A well-defined robot personality can help users understand the robot's reasoning. Mimicking human behaviors helps engagement and trust but does not have to be exact [42]. Even abstract behavioral cues are sufficient to distinguish between different robot personalities [13]. What personality should a robot have? Studies indicate that the preferred personality amplifies the user's traits [42]. Extroverts, for example, using more vivid and more frequent gestures during a conversation, also accept robots approaching closer during interaction [29]. However, other studies have found participants to prefer a character opposite to theirs [9]. In their study Mileounis et al. [26] confirm that a robot's personality design directly affects its perceived intelligence and, more importantly, social intelligence. Asserting social intelligence is crucial for users to believe the robot is capable of making reasonable decisions.

How should robot personalities be designed? Whittaker et al. [42] suggest using classic persona design [11]. Starting from a persona, designers can combine personality traits that make robot behavior more predictable. In general, users seem to react better to extrovert robot personalities [35] and perceive it as more socially intelligent [26]. However, as mentioned earlier, most robot studies are short-term and are conducted in controlled environments. Given a short time frame, an extrovert character leaves a better and more memorable impression than an introvert one could. We assume that a robot companion with exclusively extravert behavior would be draining over a more extended period.

This is where the dynamic aspect of robot personality comes into play: We propose a more open personality emphasizing invitation and transparency for the first interaction phase ("getting-to-know"). After that, facets of extraversion and communication frequency, as well as an excessive amount of gestures, should be toned down, as well as explanations that serve transparency (e.g., explaining each time for repetitious tasks why the SAR reaches a particular stance in a decision-making process). The result should be a smooth transition from the novelty phase, shaped by amazement considering the unknown functionalities, to the phase of habituation, in which the novelty effect is depleted, and users value a robust, reliable system.

In our view, one big challenge that this approach of dynamic personality poses is again rooted in anthropomorphism: We, as humans, value consistent personalities in other humans and are deterred by personality fluctuations. Changes in behavior or personality traits can hint at impostors - a link we do not want in the context of trust-building. Therefore, personality changes must be fine-tuned to fly under the radar - otherwise, we would change one drawback for another.

4 CONCLUSION

We argue that during the design of SARs these vital must be taken into account to achieve transparent and trustful SARs: a coherent robot personality, that reflects in coherent behavior, movement, verbal and non-verbal communication as well as changing factors in human-robot relationship dynamics. More long-term studies have to be conducted that focus on the change of requirements to derive best practices on how the user can implicitly or explicitly control the amount of reasoning by the robot which, given the rapid development in AI techniques over the last years, is now more likely to happen than ever.

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