ABSTRACT
We suggest that adding social cues to IoT devices can lead to a more natural user experience and improve user’s understanding of autonomous IoT internal state. We base this assumption on two studies demonstrating that minimal movement of an abstract robotic object is perceived by participants as non-verbal social cues. In the first study, we showed that interaction with an abstract robotic object can be perceived as a social experience. In the second study, we showed that the social interpretation given to the robotic object’s minimal gestures is an implicit automatic process, meaning people can not avoid perceiving the object’s movement as a social cue. Interaction designers can leverage this implicit automatic process, by adding minimal movement to IoT devices as a form of social interaction, improving user’s interaction with an IoT-infused environment.

KEYWORDS
IoT; Social interaction; Gestures; Social cues; Social robots; robotic objects

INTRODUCTION
Interaction designers of IoT devices are typically limited to screen-based or audio-based interfaces. As IoT devices are becoming more autonomous, it becomes harder for designers to communicate the device’s internal state in a natural, effective, and non-intrusive manner. One possible approach for
addressing this challenge is by leveraging people's tendency to anthropomorphize inanimate objects [3], and adding social cues to the interaction with IoT devices.

This approach was already utilized by robot designers, who enhance the interaction with humanoid robots by designing both verbal and non-verbal social cues leading to a social experience [3, 9]. Implementing a social aspect into the interaction with a robot is thought to increase the robot's acceptance, to enhance understanding of the information conveyed by the robot, and to lead to a more natural interaction in general [2, 3].

Prior work demonstrated that social aspects can also be integrated into to the interaction with non-humanoid robots, including everyday objects such as a trash-barrel and automatic doors [6, 12]. These studies showed that the object’s movement was perceived as social cues, indicating willingness or unwillingness for interaction.

The possibility of designing social interactions with non-humanoid robots and everyday objects implies that non-verbal social cues are sufficient for creating a social experience, and that human-like appearance or verbal cues are not essential. This social interaction with robotic objects suggests that we can leverage social cues in the IoT domain. Empirical findings indicating that people automatically perceive the world through a social lens [11] further support this possibility. For example, Heider and Simmel (1994) showed that when participants were asked to explain the behavior of animated geometric shapes presented in a short video, they consistently interpreted the movement of the shapes as social interaction [5]. The participants associated intention, emotions, and even personas to the abstract geometrical shapes in the animated video.

Based on this previous literature, we evaluated the extent to which minimal movement performed by an autonomous abstract object (i.e. robotic object) is perceived as social cues. Our findings suggest that participants consistently attributed social interpretation to the robotic object’s movement. Moreover, this interpretation is automatic to the extent that it cannot be avoided, implying that attributing social intent to abstract objects does not require cognitive processing effort and is a natural aspect of the interaction.

ONGOING RESEARCH

Study 1: Social interpretation of minimal movement performed by an abstract robotic object

In this study (published in RO-MAN 2018, presented at September 2018), we set out to evaluate the possibility of designing gestures for an abstract robotic object, that will be consistently perceived by participants as social cues, even though the gestures cannot be directly mapped to human behavior.
We chose opening encounters as the social context of the interaction, as they play a significant role in the initiation of any social interaction, and shape the nature of the interaction that follows [7]. As such, opening encounters are predicted to be relevant for a wide range of applications.

We designed an abstract robotic object in the form of a small ball rolling on a larger dome, with a mechanical design that supports a variety of minimal movements (see figure 1). This abstract design allowed to assess the social interpretation of the movement regardless of any specific association to everyday functions and independently of human-like appearance or human-like behavior.

The gesture design process was not a trivial design process, as prior work on robots in the context of opening encounters focused on humanoid robots that mostly mimic human greeting gestures. We therefore consulted with four movement experts that guided us in the gesture design process: an animator, a puppeteer, a choreographer, and a comic artist. We created a low-fidelity prototype of the robotic object as a passive puppet, on which the movement experts could demonstrate the gestures they imagine as appropriate for opening encounters. Based on the brainstorming session with the experts, we defined two main gesture classes: Approach (back-to-front) and Avoid (front-to-back). For each gesture class, we designed two types of movement paths: Straight (direct point-to-point) and Animated (indirect, with curves and turns). Finally, we designed half of the gestures with the small ball always visible in the participant’s field of view, and half with the small ball starting or ending the movement at a hidden area at the back of the object. The result was a set of eight gestures: four Approach and four Avoid gestures. Four gestures were Straight and four Animated. In four gestures the small ball was always visible and in four it was sometimes hidden (see figure 2). The different gestures in each class allowed to evaluate two movement categories instead of two specific movements. We used these eight gestures in a qualitative evaluation study designed to assess participants’ perception of the gestures. Participants experienced brief interactions with the robotic object, which performed a single gesture during each interaction. They were then asked to describe the experience.

Findings revealed that participants consistently perceived the minimal movement of the abstract robotic object as either positive or negative social interaction in the context of opening encounters. They described the interaction using socially-related terminology, and attributed a wide variety of relevant social expressions to the robotic object’s gestures. Participants perceived the interaction with the robotic object as an emotional and social experience indicating that minimal movement of an extremely abstract robotic object is sufficient for providing social cues in a human-robot interaction. These social cues can be as meaningful as signaling to participants if they are suitable for interaction [1].
Study 2: Automatic social interpretation for minimal movements performed by an abstract robotic object

In the second study (initial results accepted to CHI2019 as Late Breaking Work), we tested the possibility that the social interpretation of minimal movement is an automatic process, activated without explicit intent, that cannot be avoided even when it conflicts with another intentionally performed task [10]. An automatic perception of minimal movement as social cues suggests that adding social features to the interaction with the object does not require additional processing effort by the users. Social features, thus, may enhance the interaction without leading to additional cognitive load. In addition, automatic processing will indicate that social cues are basic, natural features of an interaction and may be strong candidates for supporting and enhancing the interaction with IoT devices.

In order to evaluate if the robotic object’s gestures are automatically interpreted as social cues, participants performed an adaptation of the Implicit Association Test (IAT) [8]. The updated paradigm was designed to identify automatic implicit associations between the minimal gestures and their social interpretation, by measuring reaction-time. The test involved word and gesture classification tasks. The gesture classification task required classification of videos presenting the robotic object’s gestures according to the direction of the movement (the small ball moving from the back to the front of the dome vs. from the front to the back of the dome). The word classification task required classification of words according to their social valence (Willingness vs. Unwillingness for social interaction). Notably, the gestures were presented as physical movement to specific directions and participants had no motivation to attribute social interpretation to the robot’s gestures. The classification tasks shared the same response keys, allowing to evaluate the influence of the compatibility between the words’ social valence and the gestures’ social interpretation.

Our findings revealed that the social interpretation of an abstract robotic object’s gestures is an automatic cognitive process that cannot be avoided. We believe that this effect is related to Theory of Mind (ToM) [4] defined as humans’ ability to attribute a mental state to others in order to explain and anticipate their behavior. As ToM is thought to be an automatic process in human-human interaction, it is possible that people automatically applied ToM to the interaction with the robotic object. This explanation further supports our hypothesis that (if designed properly) adding social features to the interaction with IoT devices may improve users’ understanding of IoT internal state and enhance the interaction.

CONCLUSION

We suggest that user experience with IoT devices can be enhanced by adding social aspects to the interaction. Our ongoing research in the field of robotic objects indicates that minimal movement of a
non-humanoid, abstract object is automatically perceived as social cues, leading to a social experience. We conclude that interaction designers can include minimal movement as an additional non-verbal communication channel for IoT devices, leveraging it to enhance the interaction by enriching it with social aspects.

REFERENCES


