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Perception of *own* and *robot* engagement in human–robot interactions and their dependence on robotics knowledge

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HIGHLIGHTS

- Engagement with robots was measured while participants gave simple instructions.
- Perceived robot engagement and understanding was dependent on its nonverbal gesture.
- Nodding was the most effective nonverbal gesture and increased liking of the robot.
- Implications for increasing liking and trustworthiness of robots are discussed.
- Greater familiarity with robotics may help to maximise positive HRI experiences.

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ABSTRACT

Communication between socially assistive robots and humans might be facilitated by intuitively understandable mechanisms. To investigate the effects of some key nonverbal gestures on a human's own engagement and robot engagement experienced by humans, participants read a series of instructions to a robot that responded with nods, blinks, changes in gaze direction, or a combination of these. Unbeknown to the participants, the robot had no form of speech processing or gesture recognition, but simply measured speech volume levels, responding with gestures whenever a lull in sound was detected. As measured by visual analogue scales, engagement of participants was not differentially affected by the different responses of the robot. However, their perception of the robot's engagement in the task, its likability and its understanding of the instructions depended on the gesture presented, with nodding being the most effective response. Participants who self-reported greater robotics knowledge reported higher overall engagement and greater success at developing a relationship with the robot. However, self-reported robotics knowledge did not differentially affect the impact of robot gestures. This suggests that greater familiarity with robotics may help to maximise positive experiences for humans involved in human–robot interactions without affecting the impact of the type of signal sent by the robot.

1. Introduction

The rapid progress of robotics means that machines are now capable of fulfilling many roles that have been previously carried out by humans alone. As a result, the potential applications of robot use have widened dramatically. Many of these new applications will require robots to work in much closer proximity to humans than has previously been the case, and so the ability to interact socially with humans is likely to prove an important factor. A case in point is the current drive to develop autonomous social robots designed to enter the home and play assistive roles for individuals such as the elderly; scenarios in which humans are unlikely to have much previous experience of robots. To render interactions both smooth and intuitive, autonomous assistive robots should thus be designed to exploit human-like communication strategies (see e.g. [1,2]).

One method previously employed in robotics research to exploit human-like communication strategies involved verbal face-to-face conversations between humans and robots, with each taking turns to talk and listen [3,4]. This type of social human–robot interaction (HRI) was primarily used to optimise the learning environment of the robot by allowing it to explore which of its actions

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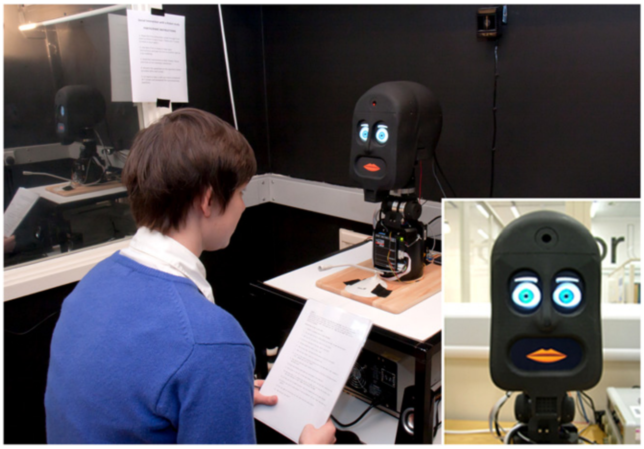

Fig. 1. Interacting with BERT. *Inset:* Close-up of the BERT head.

provoked specific behavioural responses in humans. In later interactions, nonverbal communication gestures such as nodding [5,6] and emotional expressions [7] were shown to facilitate robot learning as they enhanced not only verbal communication, but also the experience of the human in the interaction (e.g. [8]; see also [9] for a direct comparison of conversational gestures with emotional expressions). Surprisingly little is known, however, about how nonverbal robot communication gestures are subjectively experienced or interpreted by humans.

The experiment described here was intended as a first step in addressing this gap in our knowledge. We used the expressive head from our humanoid robot torso, called BERT (see inset in Fig. 1, referred to as BERT from now on for brevity), to set up social HRI through which we were able to examine the subjective experiences of the human participants. Participants read a series of instructions to BERT, who performed the role of a 'listener' and responded by using different combinations of nonverbal gestures. Within this context, we investigated how the different nonverbal gestures (and their combinations) influenced both individuals' engagement in the interaction and their perception of the robot's engagement in the HRI.

We focussed on three different nonverbal response modes thought to be highly important in human–human interaction: nodding, change of gaze direction and eye blinks, all of which had also been used in the above-mentioned earlier HRI studies. Nodding is a well-studied behaviour in human–human conversation that serves to establish common ground, i.e. shared knowledge between conversational participants [10]. Nodding signals encouragement and affirmation between speaker and listener [11]. Eye gaze, specifically averting and reengaging, is used to indicate turn taking in dyadic conversation and to garner attention from the listener [12]. Gaze aversion with successive reengagement of gaze is most often observed in cognitively demanding situations [13] where it is likely interpreted by the observer as an indication that the performer is 'thinking'. Furthermore, aversion of gaze is thought to facilitate remembering [14]. Blink rate can also play a role in communications. The average spontaneous blink rate of a human is about 20 times a minute during conversation [15]. In tasks in which a person is particularly attentive, memorises information or is thinking, the blink rate might drop considerably [16–19]. Though largely necessary to protect the cornea (e.g. [20]), eye blinks contain an important social component: very infrequent blinking (i.e. staring) is rated as unfriendly [21,22], and reduced blink rate might be linked to deception [23,24]; it is this social component of eye blinks that is thought to be the reason our brain registers each individual eye blink made by a person we look at [25]. We predicted that each of the three tested robot response modes in isolation might facilitate human engagement in HRI to some degree, but that in combination they would show the biggest effects, that is, the highest levels of reported engagement.

Humans can be expected to differ quite substantially in their theoretical knowledge of and practical experience with robotics. A participant's intimate knowledge of the state-of-the-art in robotics might potentially confound our experiments, affecting the extent to which this participant believes that the robot understands their instructions. This, in turn, might affect how nonverbal gestures are experienced by the participant. We therefore predicted that participants with little knowledge of robotics were more likely to interpret gestures, such as, e.g. head nodding, as a direct confirmation that the robot indeed understood what participants said; participants with more knowledge of robotics, in contrast, might be more likely to consider the gestures to be what they were, namely preprogrammed responses, rather than a method of conscious and autonomous communication and interaction. To account for such a possibility, we asked participants to rate the degree of their knowledge about recent advances in robotics. If the degree of knowledge of robotics mattered, then we would predict that the robot response modes should have a greater effect on human engagement in HRI for participants with less rather than more previous knowledge of robotics. Further, we examined the possibility that participants with a greater knowledge of robotics might engage less with the robot overall, might like the robot less overall, might be less likely to perceive the robot as comprehending their instructions, and, as a consequence, might be less likely to develop a relationship with the robot.

Some of these results were presented earlier as a conference presentation [26].

2. Methods

2.1. Robot

The head of the social robot BERT (see inset of Fig. 1), designed at the Bristol Robotics Laboratory, UK, was mounted atop a neck containing 2 degrees of freedom, allowing for basic head nodding and shaking gestures. The head consists of a 3D printed mask with eye and mouth holes. A monitor is mounted behind the face to display eyes, eye brows, and mouth through the holes in the mask. This setup allows the animation of the eyes, eye brows and mouth whilst the rest of the head remains static. The robot's "face" contains 13 degrees of freedom: left eyebrow angle, right eyebrow angle, left eyebrow vertical height, right eyebrow vertical height, left eyelid openness, right eyelid openness, eye vergence, eye pitch and eye yaw, mouth corner vertical height, mouth width, top lip openness, and bottom lip openness. The face is controlled by sending a simple string of commands, using *udp*, to a program that deals with all animation. The neck is controlled by an Epos CAN system.

Ten expressions were used to animate parts of the face at random times throughout the experiment as a kind of "baseline animation"; these expressions consisted of movements of the eyebrows and the mouth, constantly modulating between a more neutral expression and slight smiles. Expression cycles were variable in length and independent of nonverbal response modes.

2.2. Control design

The robot had two forms of input: a microphone placed in front of the robot and a camera mounted in the forehead. Using *opencv*, the camera encoded participants' faces and guided BERT's head and eyes to directly "gaze" at these as if establishing eye contact. The microphone encoded sound (here the participant's speech).

BERT detected pauses in the participant's speech. These pauses caused the robot to send a non-verbal response signal. Pause detection was based on a simple algorithm: First, the robot would