Noticing Extraversion Effects Attention: How Robot and Participant Personality Affect Social Attention

Social robots with expressive gaze have positive effects on human-robot interaction. In particular, research suggests that when robots are programmed to express introverted or extraverted gaze behavior, individuals enjoy interacting more with robots that match their personality. However, how this affects social-cognitive performance during human-robot interactions has not been thoroughly examined yet. In the current paper, we examine whether the perceived match between human and robot personality positively affects the degree to which the robot's gaze is followed (i.e., *gaze cueing*, as a proxy for more complex social-cognitive behavior). While social attention has been examined extensively outside of human-robot interaction, recent research shows that a robot's gaze is attended to in a similar way as a human's gaze. While our results did not support the hypothesis that gaze cueing would be strongest when the participant's personality matched the robot's personality, we did find evidence that participants followed the gaze of introverted robots more strongly than the gaze of extroverted robots. This finding suggests that agent's displaying extraverted gaze behavior may hurt performance in human-robot interaction.

INTRODUCTION

Social robots as future cohabitants have become more and more our reality, and at present they are already used as social companions for elderly people or as therapeutical interventions for children with autism spectrum disorder or patients with sensorimotor impairments. Outside the clinical context, social robots foster collaboration in the workplace, or teach mathematics and science in the classroom. They also facilitate activities in daily lives as friendly assistants in supermarkets and airports. While a lot of progress has been made in terms of the technological realization of social robots, their ability to interact with humans in a truly social way is still quite limited. The biggest challenge is to determine how to design social robots that can adapt to the users' cognitive and technical abilities, but are also perceived as social companions that understand the needs, feelings, and intentions of their human partners.

Psychological research has contributed to solving these open questions by equipping social robots with the ability to send non-verbal cues, like changes in gaze direction, and measuring how attitudes and performance in human-robot interaction are impacted by robots exploiting these cues. Overall, it has been shown that robots displaying human-like social behaviors are rated more positively and are associated with better performance in human-robot interactions (Admoni & Scassellati, 2012; Özdem et al., 2017). For example, robots that display gestures by nodding or shrugging are evaluated more positively and trusted more than robots that behave mechanistically (Carter et al., 2014). Likewise, embodied robots are more anthropomorphized and engaging than robot-like agents presented on a computer screen (Kiesler et al., 2008). Furthermore, robots whose actions are perceived as socially relevant are attended to more and activate brain areas important for social interactions (Özdem et al., 2017).

Gaze cues have not only been shown to have a positive effect on the evaluation of social robots (Wiese et al., 2012; Wykowska et al., 2014), but to have a particularly positive effect on joint human-robot performance as they facilitate turn-taking in conversations (e.g. Bente et al., 2008). provide

information about a partner's intentions (Frith & Frith, 2006), and induce shifts of spatial attention to looked-at locations (Frischen et al., 2007), which can be used to guide an interaction partner's attention to relevant objects or events in the environment.

The extent to which gaze cues affect an interaction partner's attention has been extensively studied (outside the context of social robotics) using a gaze-cueing paradigm (e.g., Friesen & Kingstone, 1998). In the classical set up, a schematic face is presented centrally on a computer screen, first looking straight at the participant to establish mutual gaze, and then changing its gaze direction to look at either the left or right side of the screen. The change in gaze direction establishes the gaze cue and shifts the participant's attention to the gazed-at location. The gaze cue is followed by the appearance of a target item (either a dot or a letter) and participants are asked to detect, locate or discriminate the presented item as fast and accurately as possible by pressing an assigned response key. Critically, since observing the gaze cue initiates attentional orienting in the observer, targets presented at the gaze-cued location (i.e., valid trial) are responded to faster than targets presented opposite of the gazed-at location (i.e., invalid trial). The difference in reaction times between invalid and valid trials is called the *gaze-cueing effect*, and indicates how strongly another's gaze cues were followed.

In human-human interaction, gaze-cueing effects can be found when gaze direction is predictive of target location (i.e., target appears in 80% of trials at valid locations), but also when it is non-predictive (i.e., target appears in 50% of trials at valid locations), or even counter-predictive (i.e., target appears in 20% of trials at valid locations; see (Frischen et al., 2007); for review) of target location. This strong tendency to follow gaze even when it is detrimental to performance is used as evidence for the reflexive bottom-up nature of gaze cueing. Indeed, a wealth of studies has demonstrated that attentional orienting to gaze cues is triggered by simple eye-like configurations (Quadflieg et al., 2004), is present in children as young as 3 months of age (Hood et al., 1998), and is unaffected by high workload which emphasizes that it does not require a high amount of cognitive resources (Hayward & Ristic.

2013). Additionally, gaze cueing seems to be uninfluenced by the gazer's emotional expression (Bayliss & Tipper, 2006), degree of animacy (Quadflieg et al., 2004) or familiarity to the observer (Frischen & Tipper, 2004).

Recently, however, an increasing number of studies have provided evidence that attentional orienting to gaze cues can be top-down controlled if the social relevance of the gaze cue is high enough (Abubshait & Wiese, 2017; Martini et al., 2015; Wiese et al., 2012; Wiese et al., 2013; Wykowska et al., 2014). Wiese and colleagues (2012), for instance, found that although the gaze of human agents is generally followed more strongly than the gaze of robot agents, attentional orienting in response to robot gaze cues is enhanced when participants believed that the robot's eyes were controlled by a human. Similar modulatory effects on gaze cueing were also observed when the gazer's human-likeness was manipulated via appearance (Martini et al., 2015) or motion cues (Wykowska et al., 2015). The tendency to follow others' gaze was also enhanced when gazers were believed to be part of the same social group as the participant (Liuzza et al., 2011) or when they were perceived to be similar to the observer (Hung & Hunt, 2012; Porciello et al., 2016). In addition to information that increases the social relevance of the gazer, individual differences in the observer have also been shown to modulate gaze cueing (Fox et al., 2007; Ponari et al., 2013). Fox and colleagues (2007), for instance, showed that highly anxious participants follow the gaze of fearful faces more strongly than participants with low trait-anxiety, and Ponari and colleagues (2013) showed that introverted participants followed gaze cues of faces with fearful or neutral, but not angry, facial expressions.

While most of the aforementioned studies have looked at gaze cueing and potential sources of top-down modulation thereof in human-human interaction, only a few studies have looked at the effects of gaze cues in human-robot interaction. Andrist and colleagues (2015), for instance, have used the embodied social robot platform Meka to examine whether the interaction between the participant's personality (Introvert vs. Extravert) and the robot's personality (Introvert vs. Extravert; manipulated via the robot's gaze behavior) had an effect on participants' motivation to engage in interactions with the robot. The results showed a perfect match between participant and robot personality, in the sense that extravert participants preferred interacting with the Meka robot displaying extraverted gaze behavior, and introverted participants preferring interactions with the introverted Meka. The effect this gazer-perceiver personality match had on gaze cueing, however, was not assessed. In contrast, Wiese and colleagues (under review) showed that Meka was perfectly able to induce gaze cueing effects that resemble those in human-human interactions, but without manipulating the robot's personality. The aim of the current experiment is to combine the latter two experiments and examine how the personalities of the participant (Introvert vs. Extravert) and robot (Introvert vs. Extravert) affect the degree to which robot gaze is followed. In line with Andrist and colleagues (2015), we expect extraverted participants to follow the gaze of an extraverted robot more strongly, and introverted participants to follow the gaze of an introverted robot more strongly.

METHODS AND MATERIALS

Participants

40 undergraduate students (age: $M = 20.18$, $SD = 2.31$; 30 females) from an American university participated in the experiment in exchange for course credit. Informed consent was obtained at the beginning of the experiment and the Office of Research Integrity and Assurance approved the experimental procedure. The experiment took about 40 minutes and participants were debriefed at the end of it.

Apparatus

The setup consisted of the Meka Robotics S2 humanoid robot head, two smart light bulbs that were network connected and controlled, and a user touch pad with which participants indicated their responses.

Stimuli

The Meka head has eight degrees of freedom. Four degrees of freedom are in the neck; in a kinematic chain from the bottom of the neck up these are: pitch, roll, yaw, pitch. Additionally, there are two degrees of freedom (pitch, yaw) in each eye, which are attached to the face at the top of the neck's kinematic chain. Furthermore, the Meka head was raised 5.5 inches in order to be level with participant's gaze and subtended a visual angle of approximately $27.5^\circ \times 30^\circ$. Two a19 smart light bulbs, which could be turned on and off with millisecond precision, were used as targets. Light bulbs were $4.2 \times 2.4 \times 2.4$ inches and were placed 12 inches to the left and right of Meka. Gaze cues were created with pre-programmed head and eye movements to either the left or right light bulb.

Task

Each trial in the gaze cueing task required participants to respond to the side of the table at which a target event happened (i.e., color change of light bulb) by pressing the corresponding side of a touchpad in front of them. Before the color change, Meka looked either to the side where the target event was about to happen (i.e., valid trial) or to the opposite side (i.e., invalid trial) by moving its eyes and head. Left and right side of the table were equally frequently gazed-at. Meka was positioned centrally with respect to participants during the entire task and began a trial by facing participants (i.e., mutual gaze).

Procedure

Participants were introduced to the gaze cueing task via written instructions informing them they would perform a perceptual task in which they would look at Meka while reacting to changes in the color of light bulbs positioned to the right and left of Meka by pressing one of two keys on the touch pad in front of them. They were instructed to respond as fast and accurately as possible and to press the side of the touch pad that corresponded to the side of the light bulb that changed colors. Participants were also told that before the color change

Figure 1. Trial sequence: Meka faced the participant at the beginning of the trial, after which she looked at either the right or left light. Afterwards, the light at the gazed-cued or uncued location changed its color. Participants responded to the side a target appeared on by pressing the corresponding side of a touchpad in front of them. At the end of a trial, Meka returned to her original position.

of one of the light bulbs Meka would make an eye movement to either the left or the right side of the table.

Participants first gave informed consent, and then completed the Big Five Inventory (BFI; John & Srivastava, 1999). Based on the obtained BFI score, participants were informed whether they had more an introverted or extraverted personality (i.e., median split: participants with less than 3 points were categorized as introverted, and those scoring 3 points or higher were categorized as extraverted). Participants then read gaze-cueing instructions and were informed that the robot was programmed to have either an introverted or extraverted personality (assignments to either the extraverted or introverted robot condition were counterbalanced). In reality, the robot was not programmed to show specific introverted or extraverted behaviors and behaved similarly in both conditions.

Figure 1 illustrates the sequence of events on gaze cueing trials. A trial began with Meka facing the participant for 250 ms, after which Meka looked at either the right or left light. After a stimulus-onset asynchrony of 200 ms, the light at the gazed-cued or uncued location changed its color. Meka did not change its posture until participants made a response or 5000 ms passed, whichever occurred first. At the end of the trial, Meka returned to its original position. The experiment was composed of 80 trials: 40 of which were valid and 40 invalid. Gaze direction (left or right) and target location (left or right) were selected pseudo-randomly with the constraint that every combination occurred with equal frequency. A trial was considered valid if Meka gazed in the same direction as the target (e.g., gaze left, target left), and invalid if it gazed in the opposite direction (e.g., gaze left, target right).

Analysis

Reaction time data was analyzed using R 3.2.4. Missed and incorrect responses, as well as reaction times deviating by more than ± 2.5 standard deviations from the individual participants means were removed prior to analyses. Difference scores were then calculated by subtracting mean reaction time

of valid from invalid trials, providing a measure of gaze cueing.

With the remaining data we examined the impact of the personality of the *Participant* (Introverted vs. Extraverted) and of *Meka's* believed personality (Introverted vs. Extraverted) on gaze cueing effects using a 2 x 2 between-participants ANOVA. Specifically, we expected interaction effect between the personality of the participant and Meka's personality (i.e., stronger gaze cueing when participant and robot matched in personality as opposed to when they did not match).

RESULTS

Reaction times as a function of validity, Meka's personality and the participant's personality are reported in **Table 1**. Difference scores as a function of Meka's personality and participants' personality are reported in **Figure 2**.

Table 1. Mean reaction times (and standard errors) by validity, Meka's believed personality, and participant personality

	Meka			
	Extravert		Introvert	
Participant	Valid	Invalid	Valid	Invalid
Extravert	562.84 (54.40)	562.37 (55.60)	516.02 (18.41)	540.80 (23.42)
Introvert	525.38 (15.03)	532.27 (18.89)	572.32 (31.27)	583.70 (31.01)

The analysis of gaze cueing data showed that participants were highly accurate in their performance ($M = 99.75\%$, $SE = 0.16\%$). Collapsing across participant's personality and Meka's personality, a paired t-test revealed participants respond-

ed significantly faster on valid ($M = 544.14$ ms, $SE = 16.56$) than invalid trials ($M = 554.78$, $SE = 17.21$), $t(39) = 2.91$, $p = .006$.

The ANOVA of the difference scores revealed a significant main effect of *Meka*'s personality ($F(1,36) = 4.55$, $p = .039$), indicating a larger cueing effect when *Meka* was an introvert ($M = 18.08$ ms, $SE = 4.77$) than when they when it was an extravert ($M = 3.21$ ms, $SE = 5.13$). There was no main effect of *participant* personality ($F(1,36) = 0.19$, $p = .667$), indicating that gaze-cueing performance did not depend on whether participants were introverted or extraverted. Furthermore, the interaction between *Meka*'s believed personality and participant personality was not significant ($F(1,36) = 2.21$, $p = .145$), indicating that gaze cueing performance with an introverted or extraverted *Meka* did not depend on the participant's personality, and more importantly that gaze cueing was not stronger when participant and robot matched in personality.

Figure 2. Difference scores (gaze cueing effects) by *Meka*'s believed personality (Extraverted vs. Introverted), and the participant's personality (Extraverted vs. Introverted)

DISCUSSION

The goal of our experiment was to examine how the participants' (Introvert vs. Extravert) and robot's (Introvert vs. Extravert) personalities impact the degree to which a robot's

gaze is followed. Specifically, we predicted that extraverted participants would follow the gaze of an extraverted robot more strongly, and that introverted participants would follow the gaze of an introverted robot more strongly. Interestingly, we did not find evidence for stronger gaze cueing when the participant's personality was matched with the robot's personality. Instead, our central finding was significant stronger gaze cueing when *Meka* was believed to be introverted rather than extraverted. This finding aligns with a number of previous studies showing that attentional orienting to gaze can be modulated by top-down information (Abubshait & Wiese, 2017; Liuzza et al., 2011; Ponari et al., 2013; Wiese et al., 2012, 2013), while showing for the first time that an embodied agent's personality impacts gaze cueing. We believe participants may have been more comfortable in the presence of a perceived introvert robot due the balance of social power (Li, Ju, & Nass, 2015). Indeed, the strongest gaze cueing effect occurred when extraverted participants were interacting with the introverted robot. It is also possible that the observation that stronger gaze cueing occurred with the introverted *Meka* means that an introvert's gaze is be interpreted as being more meaningful or helpful than extravert's gaze, and thus is followed more strongly. Future studies should examine this possibility, and determine the underlying cause for stronger gaze cueing effects when interacting with an introverted robot.

While these results are interesting and point towards a systematic relationship between robot gazer and human observer personalities, the current findings have to be interpreted with caution. First and foremost, the sample size is too small ($N = 40$) to draw reliable conclusions about the relationship between robot and human personality. We will continue data collection until a sample size of about 128 participants has been reached (according to a G*Power a-prior power analysis this number of participants is needed to have an 80% chance to detect a moderate effect size). Furthermore, since the manipulation of robot personality was instructional, it is difficult to know for sure if it had to intended impact on participants (i.e., did participants really perceive it as extroverted vs. introverted). Future studies should examine this by programming robots to express extraverted or introverted gaze.

Our results have implications for the design of social robots. If people pay less attention to extraverted than introverted robots designing robots that trigger perceptions of extraversion could have negative effects on joint action performance in human-robot interaction. For example, a robot tour guide at a museum that expresses an extraverted personality may have negative consequences on attention given to an exhibition during a tour. In particular, it is possible that if individuals do not follow its gaze sufficiently they might be less capable to make connections between what the robot is explaining about pieces of art and the actual details the robot is referring to. Although the effect of extraversion on gaze cueing was not extreme, it is noticeable enough that the lack of gaze following in response to extroverted robot agents might lead to an accumulation of missed information in the long run. Future studies should examine the effect of extroverted robots on performance in long-term human-robot interactions and identify situations in which gaze signals of extroverted robots might be advantageous and followed more strongly.

References

- Abubshait, A., & Wiese, E. (2017). You Look Human, But Act Like a Machine: Agent Appearance and Behavior Modulate Different Aspects of Human–Robot Interaction. *Frontiers in Psychology*, 8. <https://doi.org/10.3389/fpsyg.2017.01393>
- Admoni, H., & Scassellati, B. (2012). Robot Gaze Is Different From Human Gaze: Evidence that robot gaze does not cue reflexive attention. In *Proceedings of the “Gaze in Human-Robot Interaction” Workshop at HRI*.
- Andrist, S., Mutlu, B., & Tapus, A. (2015). Look Like Me: Matching Robot Personality via Gaze to Increase Motivation (pp. 3603–3612). ACM Press. <https://doi.org/10.1145/2702123.2702592>
- Bayliss, A. P., & Tipper, S. P. (2006). Predictive Gaze Cues and Personality Judgments. *Psychological Science*, 17(6), 514–520. <https://doi.org/10.1111/j.1467-9280.2006.01737.x>
- Bente, G., Rüggenberg, S., Krämer, N. C., & Eschenburg, F. (2008). Avatar-mediated networking: Increasing social presence and interpersonal trust in net-based collaborations. *Human Communication Research*, 34(2), 287–318. <https://doi.org/10.1111/j.1468-2958.2008.00322.x>
- Carter, E. J., Mistry, M. N., Carr, G. P. K., Kelly, B. A., & Hodgins, J. K. (2014). Playing catch with robots: Incorporating social gestures into physical interactions. In *Robot and Human Interactive Communication, 2014 RO-MAN: The 23rd IEEE International Symposium on* (pp. 231–236). IEEE.
- Fox, E., Calder, A. J., Mathews, A., & Yiend, J. (2007). Anxiety and Sensitivity to Gaze Direction in Emotionally Expressive Faces. *Emotion (Washington, D.C.)*, 7(3), 478–486. <https://doi.org/10.1037/1528-3542.7.3.478>
- Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, 5(3), 490–495.
- Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze Cueing of Attention. *Psychological Bulletin*, 133(4), 694–724. <https://doi.org/10.1037/0033-2909.133.4.694>
- Frischen, A., & Tipper, S. P. (2004). Orienting Attention Via Observed Gaze Shift Evokes Longer Term Inhibitory Effects: Implications for Social Interactions, Attention, and Memory. *Journal of Experimental Psychology: General*, 133(4), 516–533. <https://doi.org/10.1037/0096-3445.133.4.516>
- Frith, C. D., & Frith, U. (2006). The neural basis of mentalizing. *Neuron*, 50(4), 531–534. <https://doi.org/10.1016/j.neuron.2006.05.001>
- Hayward, D. A., & Ristic, J. (2013). Measuring attention using the Posner cuing paradigm: the role of across and within trial target probabilities. *Frontiers in Human Neuroscience*, 7. <https://doi.org/10.3389/fnhum.2013.00205>
- Hood, B. M., Willen, J. D., & Driver, J. (1998). Adult’s eyes trigger shifts of visual attention in human infants. *Psychological Science*, 9(2), 131–134.
- Kiesler, S., Powers, A., Fussell, S. R., & Torrey, C. (2008). Anthropomorphic Interactions with a Robot and Robot-like Agent. *Social Cognition*, 26(2), 169–181. <https://doi.org/10.1521/soco.2008.26.2.169>
- Li, J., Ju, W., & Nass, C. (2015). Observer Perception of Dominance and Mirroring Behavior in Human-robot Relationships. *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, 133–140.
- Liuzza, M. T., Cazzato, V., Vecchione, M., Crostella, F., Caprara, G. V., & Aglioti, S. M. (2011). Follow My Eyes: The Gaze of Politicians Reflexively Captures the Gaze of Ingroup Voters. *PLOS ONE*, 6(9), e25117. <https://doi.org/10.1371/journal.pone.0025117>
- Looser, C. E., & Wheatley, T. (2010). The Tipping Point of Animacy: How, When, and Where We Perceive Life in a Face. *Psychological Science*, 21(12), 1854–1862. <https://doi.org/10.1177/0956797610388044>
- Martini, M. C., Buzzell, G. A., & Wiese, E. (2015). Agent Appearance Modulates Mind Attribution and Social Attention in Human-Robot Interaction. In *Social Robotics* (pp. 431–439). Springer, Cham. https://doi.org/10.1007/978-3-319-25554-5_43
- Özdem, C., Wiese, E., Wykowska, A., Müller, H., Brass, M., & Van Overwalle, F. (2017). Believing androids – fMRI activation in the right temporo-parietal junction is modulated by ascribing intentions to non-human agents. *Social Neuroscience*, 12(5), 582–593. <https://doi.org/10.1080/17470919.2016.1207702>
- Ponari, M., Trojano, L., Grossi, D., & Conson, M. (2013). “Avoiding or approaching eyes”? Introversion/extraversion affects the gaze-cueing effect. *Cognitive Processing*, 14(3), 293–299. <https://doi.org/10.1007/s10339-013-0559-z>
- Porciello, G., Liuzza, M. T., Minio-Paluello, I., Caprara, G. V., & Aglioti, S. M. (2016). Fortunes and misfortunes of political leaders reflected in the eyes of their electors. *Experimental Brain Research: Heidelberg*, 234(3), 733–740. <http://dx.doi.org/10.1007/s00221-015-4496-1>
- Quadflieg, S., Mason, M. F., & Macrae, C. N. (2004). The owl and the pussycat: Gaze cues and visuospatial orienting. *Psychonomic Bulletin & Review*, 11(5), 826–831.
- Wiese, E., Weis, P. P., & Lofaro, D. M. (n.d.). Embodied Social Robots Trigger Gaze Following in Real-Time HRI. *Under Review*.
- Wiese, E., Wykowska, A., Zwickel, J., & Müller, H. J. (2012). I See What You Mean: How Attentional Selection Is Shaped by Ascribing Intentions to Others. *PLOS ONE*, 7(9), e45391. <https://doi.org/10.1371/journal.pone.0045391>
- Wiese, E., Zwickel, J., & Müller, H. J. (2013). The importance of context information for the spatial specificity of gaze cueing. *Attention, Perception, & Psychophysics*, 75(5), 967–982. <https://doi.org/10.3758/s13414-013-0444-y>
- Wykowska, A., Kajopoulos, J., Obando-Leitón, M., Chauhan, S. S., Cabibihan, J.-J., & Cheng, G. (2015). Humans are Well Tuned to Detecting Agents Among Non-agents: Examining the Sensitivity of Human Perception to Behavioral Characteristics of Intentional Systems. *International Journal of Social Robotics*, 7(5), 767–781. <https://doi.org/10.1007/s12369-015-0299-6>
- Wykowska, A., Wiese, E., Prosser, A., & Müller, H. J. (2014). Beliefs about the Minds of Others Influence How We Process Sensory Information. *PLOS ONE*, 9(4), e94339. <https://doi.org/10.1371/journal.pone.0094339>