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How to Make Nonhumanoid Mobile Robots More Likable: Employing Kinesic Courtesy Cues to Promote Appreciation

Florian G. Kaiser and Karolin Glatte

Otto-von-Guericke University, Magdeburg, Germany

Mathis Lauckner

Robert Bosch GmbH, Stuttgart, Germany

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Correspondence concerning this article should be addressed to Florian G. Kaiser, Otto-von-Guericke University, Institute of Psychology, P.O. Box 4120, D-39016 Magdeburg, Germany; e-mail: florian.kaiser@ovgu.de

Abstract

Service robots that mimic human social behavior can appear polite. We tested the social and behavioral efficacy and legibility of two kinesic courtesy cues on people's approval of a service robot. In a repeated-measures design, 29 volunteers were randomly assigned to two test situations: A participant and the robot simultaneously approached a bottleneck either next to each other or from opposite ends. Nested within these two situations were three courtesy cue conditions: The robot moved without any explicit courtesy cues, stopped, or moved aside and then stopped. We found statistically significant effects of the courtesy cues on people's self-reported appreciation and the legibility of the robot's motion. Behavioral observations indicated that the robot exhibiting two courtesy cues was less disruptive to the human's own actions and was thus more behaviorally effective. This research demonstrates that kinesic politeness cues can be used effectively in the motion design of service robots.

Keywords: human-robot interaction; motion planning; autonomous agents; system design; social processes

Mobile assistive technologies (e.g., robots that autonomously transport documents and supplies within hospitals) are increasingly becoming part of people's everyday lives (e.g., Park, Fisk, & Rogers, 2010). The more humans share their environments with robots, the more critical the approval of these robots becomes, even more so with technology that has no immediate utility for the human counterpart, such as autonomously mobile robotic technologies in the service of others (e.g., patients or hospital staff). To bolster people's appreciation of nonhumanoid mobile robotic technology, robots' communication skills are expected to play an essential role (e.g., Dautenhahn, 2007).

Like people, machines can communicate nonverbally through posture, gestures, and movement (Birdwhistell, 1952, 1970), called body language in lay terms. As such, body language conveys social messages to others, but research has yet to determine whether body language has universal social significance (see Littlejohn & Foss, 2009). The existence of such universals is less disputed in other domains of nonverbal communication (e.g., facial expressions; e.g., Ekman & Friesen, 1971); that is, people all over the world largely comprehend the basic social meaning that is linked with facial expressions of particular emotions (e.g., sadness, fear). By contrast, little is known about universals in kinesics and other paralinguistic cues (see, e.g., Brown & Levinson, 1987; Culpeper, 2010).

Why is the existence of universals in kinesics, particularly in posture and movement, crucial for human-robot interaction? First, not all robots are humanoid (i.e., look human; e.g., have faces) or can communicate verbally. Second, only if such universals exist in kinesics can the motion design of robots draw on them to advance the legibility of robot movement and thereby optimize human-robot interaction (e.g., Brooks & Arkin, 2007; Dehais, Sisbot, Alami, & Causse, 2011; Lauckner, Kobiela, & Manzey, 2014; Sisbot, Marin-Urias, Broquere, Sidobre, & Alami, 2010).

In this research, we aim to demonstrate that two simple kinesic courtesy cues—presumed to fulfill a universal social function—can bolster people's generic approval of a service robot in action. First, our research contributes to the motion design of robotic technologies. Second, it can also help test the universal significance of kinesic cues. If humans even understand specific kinesic cues when communicated by robots, there is a fairly strong argument for the universality of the (a) social and behavioral efficacy and (b) legibility of these cues. Next, we will elaborate on what we already know about the features of robots people appreciate as such appreciation can subsequently lead to the approval and eventually to the acceptance of autonomously mobile robotic technologies.

Acceptance of Autonomously Mobile Robotic Technologies

Technology acceptance research is typically grounded in social psychological attitude research and the assessment of people's personal approval. Conceptual notions of an attitude are governed by the idea that an attitude represents an unobservable, latent property that is manifested when a person professes more or less appreciation for an attitude object (e.g., mobile robotic technology; e.g., Eagly & Chaiken, 1993). With robots that have direct utility for the human counterpart in the interaction, the two prime factors that seem to control people's more or less favorable assessment of technology and, consequently, their acceptance of the technology are the technology's perceived usefulness and perceived ease of use (see, e.g., Davis, 1989).

For technology that has no immediate utility for a specific human (e.g., transportation robots in hospitals for a random visitor), people's acceptance of the technology is determined by other factors such as an appropriate interaction distance (e.g., Oestreicher, 2007) rather than usefulness or ease of use. Several heuristics have already been proposed to determine people's acceptance of autonomously mobile robots, one of which is “social competence” (e.g., Baddoura & Venture, 2015; Park et al., 2010). The general idea is that socially competent robots are better liked and are therefore more readily accepted than robots that show less or no social competence (e.g., Heerink, Kröse, Evers, & Wielinga, 2006, 2010). Thus, we conclude that the essential design question is: How can a robot competently (i.e., effectively) convey a specific social message when it cannot communicate either verbally or nonverbally through its facial expressions? Another question is: What kind of social message should the robot convey?

Motion Design of Robotic Technologies: Conveying Social Messages through Movement

The answer probably lies in the ability of robotic technology to imitate social behavior with movement and, in this manner, to convey nonverbal social messages (see von Zitzewitz, Boesch, Wolf, & Riener, 2013). To attain this goal, several conditions must be met. First, the robot must appear responsive to the presence of people through motion (Lasota, & Shah, 2015). Second, the motion of the robot must be legible and must have meaning for the human counterpart in the interaction (Sisbot, Marin-Urias, Alami, Siméon, 2007; Sisbot et al., 2010). Expectedly, this legibility increases with multiple cues rather than only single cues and, thus, with a redundant patterning of movements (see Arndt & Janney, 1987). Third, with robotic technology that does not look human (i.e., has no face) and cannot communicate verbally, one must almost exclusively draw on motion and, thus, universally meaningful (i.e., legible) kinesic cues. Fourth, a specific motion by the robotic technology can probably become a universally legible kinesic cue if this cue fulfills a particular generic social function, such as the consolidation of social affiliation among non-relatives (see e.g., Kenrick & Griskevicius, 2013).

Social affiliation among non-relatives is typically grounded in effective cooperation and, expectedly, in communicative acts of politeness that involve seemingly waiving a privilege for another's benefit, a circumstance that is captured in the German proverb "little presents preserve friendship." Kinesic cues that successfully promote social affiliation are recognizable in social consequences (e.g., expressions of liking and acceptance of others) but also in behavioral manifestations of social cohesion (i.e., an unobstructed, smooth social encounter). Both types of consequences, in turn, require the legibility of kinesic cues.

Service robots can mimic the social behavior of humans (e.g., in front of a bottleneck such as a doorway). Either by stopping or by simultaneously stopping and moving out of the way, they can apparently grant the human the privilege of first passage (see Figure 1). Accordingly, the robot's movements can be designed to communicate to the human counterpart a specific social message, for example: "I waive my privilege of first passage for your benefit." The autonomously mobile robot should, predictably, appear to the human to be exhibiting polite behavior, which in turn should be recognizable (i.e., legible) as such and lead to the implied social and behavioral consequences: more appreciation for the robotic technology and less disruption of the human counterpart's behavior.

Research Goals

In this research, we asked whether autonomously mobile robotic technology that mimicked human social behavior would be better liked and accepted than the same technology moving in a less human-like way. Specifically, we tested the generic legibility of two kinesic courtesy cues common in human interaction: stopping (i.e., supposedly granting the right of way or the first passage) and moving out of the way plus stopping (i.e., supposedly granting the right of way without disrupting the counterpart's movement). We expected that robots that were meant to act politely and were seemingly ready to waive privileges would not only be appreciated more but would simultaneously be recognized as more courteous by the human in the interaction. The interaction as such would, expectedly, also be more socially functional and, thus, less disruptive to the human counterpart.

By testing the social significance of kinesic courtesy cues, our research contributes to the motion design of robotic technologies and the search for kinesic universals in human communication. If humans can understand robots that use specific kinesic cues, we will have an argument for the universality of the social significance of such cues.

Method

Participants

Participants came from a previously gathered pool of Robert Bosch GmbH employees who were willing to participate in empirical research; they were asked to volunteer in an experiment and consented to the specifically designated use of their data. As incentives, we offered a € 30 Amazon voucher as compensation. One volunteer was excluded because of some technical problems with the robot during the experimental trials. The final sample consisted of 29 Robert Bosch GmbH employees (14 male) from Schwieberdingen, Germany. In the final sample, the average age was 38.1 (*SD* = 10.2, Range: 21 to 56), and the majority (26; 89.7%) of them had previously seen the service robot "in person," in video footage, or in pictures.

Experimental Setup

The experiment took place in a secluded hallway-like space in the robotics lab at the Robert Bosch GmbH. Figure 1 provides details about the spatial features of the experimental setup. The numbers in Figure 1 reflect the respective distances in meters.

Participants were all randomly assigned to two test situations: Participants and the service robot approached a bottleneck in a hallway either next to each other or when moving from opposite ends (see Figure 1). After viewing a demonstration of the robot and its speed, participants were instructed to move forward at the robot’s pace and on its signal (i.e., an LED stripe that flashed green). Because they also knew that the robot shared their target (i.e., passing the bottleneck), both parties were confronted with a probable—head-on or from the side—collision at the bottleneck. Simultaneously, our participants had been informed that they were absolutely safe—which they were—because the robot would never collide with anyone or any object due to sensors that monitored its surroundings. With our instructions, we meant to make the robot appear smart. In reality, the robot moved on a preprogrammed trajectory. The experiment was videotaped, but we did not track the motions of the parties involved.

Nested within these two situations were three courtesy cue conditions: a control condition without any supposed courtesy cues in which the robot basically ignored the presence of the human counterpart, the Courtesy 1 condition in which the robot appeared to grant the right of way by pausing for 5 s at a distance of 0.8 m before the bottleneck, and the Courtesy 2 condition in which the robot not only appeared to grant the right of way but additionally moved out of the way. After a short pause of 3 s, the robot returned to its location in front of the bottleneck and resumed its predefined trajectory (see Figure 1).

The service robot that was used is a prototype of a transportation robot meant for hospitals. It was designed by Bosch’s Corporate Research Department. The prototype is a boxy 1.05-m tall, 0.46-m deep, and 0.73-m long object (total weight: 51 kg) that is equipped with an Omnidrive system (i.e., a cuboid-like mock-up body attached to a mobile platform), which allows the robot to engage in unrestricted movement in all directions without having to actually rotate its body. The robot recognizes its surroundings with two lasers that scan across an area of 270°. The Robot Operating System (ROS) software that we used runs on

LINUX and is controlled by an Apple tablet computer or a wireless Logitech gamepad. The robot typically runs at its maximum speed of 0.8 m/s.

Measures

In our research, we assessed the informational significance (i.e., the legibility) and the social and behavioral consequences of the presumed social message designed into the robot's motion with two distinct measures: (a) people's self-reported *appreciation* of the robot's motion (i.e., the social consequence), and (b) people's observed *resoluteness* in their behavioral responses to the robot's motion.

Appreciation. We gauged appreciation of the robot's behavior with evaluative statements collected with three distinct survey instruments: an Approval Scale based on items suggested by Heerink et al. (2009, 2010), a single item for perceived courtesy, and a specific courtesy control item for each of the six experimental conditions. Participants' approval, the robot's generic likability, was assessed with seven items: (a) "I would trust an autonomous assistant exhibiting such movement" and "The motion of the autonomous assistant is (b) good, (c) predictable, (d) surprising, (e) irritating, (f) strange, and (g) evokes unpleasant feelings." Whereas the first three items had a positive valence, the last four had a negative valence. Responses to these items were given on a 5-point Likert scale ranging from 1: *complete dissent* to 5: *complete consent.*

The perceived courtesy of the service robot's motion and, thus, the legibility of the supposed courtesy cues was captured by participants' responses to the following statement: "The movement of the autonomous assistant is courteous." Again, the response options for this item could be chosen from a 5-point Likert scale ranging from 1: *complete dissent* to 5: *complete consent.* Specific courtesy control and, thus, the legibility of each of the six experimental conditions was assessed by asking "How did you perceive the movement of the autonomous assistant that (a) approached you or moved next to you and (b) stopped in front of you, sidestepped in front of you, or passed ahead of you?" The responses to these six distinct items were given on a 5-point Likert scale ranging from 1: *courteous* to 5: *discourteous.*

Discriminant validity information becomes obvious in the correlations between measures (see Campbell & Fiske, 1959). These correlations were all strong ($.70 < r < .80$; see Table 1) and reflected a lack of discriminant validity. To further explore the convergent and discriminant validity of the approval measure and the two legibility indicators, we performed an exploratory factor analysis using each of the six instances in which the 29 participants had filled out the three measures ($N = 174$), ignoring the fact that these measures were provided by the same individuals for this tentative exploration (i.e., the measures were dependent in a statistical sense). Note that this dependency was subsequently addressed by using a repeated-measures design to analyze the data.

Expectedly, a one-factor model accounted for 84.5% of the common variance in the three instruments meant to gauge people's appreciation of the robot's motion. All communalities were at least $h^2 = .65$, and all three measures had nontrivial loadings of a > .80 on the single factor (see Table 2). In other words, appreciation of the service robot was obviously substantially correlated with viewing its movement as comparatively more courteous. To reduce measurement error and to prevent artificial variance shrinkage, we estimated factor scores with the Bartlett method (Bartlett, 1937; see also Thompson, 2004) to gauge people's appreciation of the robot's motion and their inclination to comprehend the employed kinesic cues as expressions of courtesy.

Resoluteness. Robots exhibiting ambiguous social messages by way of illegible movements are expectedly socially dysfunctional and, thus, disruptive to human counterparts' actions. By contrast, socially functional robots exhibit comparatively unambiguous messages so human counterparts do not have to think about what the robot is doing. Ideally, humans do not even need to pay attention to the robot. In other words, socially functional robot motion does not cost human counterparts cognitive effort in deciding how to interact; thus, socially functional robot motion can be derived from the *resoluteness* or promptness of the human counterpart's behavior in the interaction.

On the basis of the video recordings of our experimental trials, we assessed the resoluteness with which our participants moved through the bottleneck. Two raters independently assessed the resoluteness of participants' behavior when encountering the service robot. Resoluteness was recognized irrespective of the type of action when the person's behavior did not show any sign of hesitation and appeared to be unwavering and prompt. If a person yielded signs of hesitation, slowed down, stopped, moved to the side, retreated, granted the robot the right of way, visually checked or even double checked the robot, moved first but tentatively, seemed somewhat forced by the robot to pass first, passed the bottleneck jointly with the robot, or they both got stuck in the bottleneck, the movement was pronounced as lacking resoluteness. The interrater correspondence in the 172 individual resoluteness decisions reported in Table 3 was 84.3%, which again translated into an acceptable Cohen's kappa of κ = .62.

Design and Procedure

All 29 participants were assigned to each of the six experimental conditions: three courtesy cue conditions (i.e., Control, Courtesy 1, Courtesy 2) and two test situations (i.e., alongside vs. opposite; see Figure 1). Both the conditions and situations were within-subjects factors as all participants were assigned to all six trials consecutively. Each of the participants experienced a unique trial sequence.

Each of the 29 runs of six trials took about 45 min. Before the trials began, participants received written instructions that informed them about the research topic and procedure; the service robot's motion was demonstrated to them, which allowed them to synchronize their own pace with the robot's; and they were asked to give their consent for videotaping. Subsequently, participants answered sociodemographic questions and questions concerning their familiarity with service robots. Each trial began with a brief oral explanation by a single experimenter (the second author). After each trial, appreciation for the robot's motion was assessed with the Approval Scale and the perceived courtesy item. After the entire experimental run, specific courtesy control was simultaneously explored for each of the six specific experimental conditions. Finally and upon request, participants were debriefed about the ultimate purpose of our research.

Results

We report our findings in two sections. First, we tested the effect of the two kinesic courtesy cues on self-reports of people's appreciation of a service robot in action with a repeated-measures ANOVA. Second, we compared the resoluteness of the human counterpart's behavior when interacting with the robot. Without courtesy cues, a robot's movement can be expected to be ambiguous and, thus, somewhat dysfunctional and therefore disruptive to a human counterpart's behavior, leading to noticeable hesitation (i.e., a lack of resoluteness) in the human's course of action.

Appreciation Effect

With a 3 (courtesy cue condition) by 2 (situation: alongside vs. opposite) repeated-measures ANOVA, we found a significant main effect of the courtesy cue condition on people's appreciation of the service robot, $F(2, 56) = 113.8$, $p < .001$, $\eta^2 = .80$. Neither the main effect of the situation, $F(1, 28) = 0.4$, $p = .56$, nor the interaction, $F(2, 56) = 0.7$, $p = .51$, was statistically significant. Irrespective of the situation—when approaching the bottleneck alongside each other or from opposite sides—robots displaying supposed kinesic courtesy cues were significantly better appreciated than robots that did not (see Figure 2).

Post hoc contrasts revealed that appreciation of the service robot was significantly lower in the control condition (M = -1.15, SD = 0.75) than in the Courtesy 1 (M = 0.54, SD = 0.59) or Courtesy 2 conditions (M = 0.61, SD = 0.54), $F(1, 28) = 59.1$, $p < .001$, $\eta^2 = .68$ and $F(1, 28) = 70.1$, $p < .001$, $\eta^2 = .72$. No statistically significant difference between the two courtesy conditions was identified. By using self-reflection on personal experiences, we found differences in approval only between the no-courtesy-cue condition and the apparently courteously acting robot irrespective of the number of courtesy cues. When confronted with a service robot that appeared to grant the right of way (a) by moving to the side and stopping or (b) only by stopping, the human counterpart's appreciation did not differ.

Resoluteness Effect

With a 3 (courtesy cue condition) by 2 (resoluteness: with or without hesitation) table, we explored whether differences in the robot's motion translated into observable differences in the promptness of a human counterpart's behavior. Overall, we found statistically significant differences in the observed and expected counts, $\chi^2(5) = 17.5$, $p < .005$, $\eta^2 = .09$. From a closer inspection of Table 3, we concluded that the brunt of the effect came from the Courtesy 2 condition. The observed frequencies in people's resoluteness significantly departed from a 50/50 chance of hesitating in their own course of action, $\chi^2(1) = 10.9$, $p < .001$, $\eta^2 = .09$.

When confronted with a robot that apparently granted the right of way by moving to the side and stopping, human counterparts hesitated significantly less in their own course of action, which could be seen again in the comparison between the Courtesy 1 and Courtesy 2 conditions, $\chi^2(1) = 10.7$, $p < .001$, $\eta^2 = .09$. Predictably, no such difference was found when comparing the Control condition with the Courtesy 1 condition, $\chi^2(1) = 0.54$, $p = .46$, $\eta^2 < .01$.

Discussion

In our research, we tested the legibility of two kinesic courtesy cues common in human interaction: apparently granting the right of way to another (a) by stopping or (b) by moving out of the way and stopping (see Figure 1). We found that an autonomously moving service robot that appeared to act politely was better appreciated by its human counterpart in an interaction regardless of which specific courtesy cue(s) the robot used (see Figure 2). In addition, we found that an autonomously mobile robot was not only appreciated more but was explicitly seen as more courteous when employing what we thought to be courtesy cues (i.e., stopping and moving out of the way; see Tables 1 and 2).

By asking people to report their personal experience (i.e., by collecting survey data), we unexpectedly found no difference in the generic appreciation of a courteously moving robot as long as the robot used some kind of courtesy cue. Autonomously mobile robotic technology that nonverbally mimicked politeness was appreciated more than the same technology moving seemingly less politely. Arguably, robots that do not look human and cannot communicate verbally can draw on universally meaningful motion and, thus, legible kinesic cues to promote appreciation (see, e.g., von Zitzewitz et al., 2013). Obviously, the movement of robots has the potential to convey social messages such as “I waive my privilege of first passage for you”; therefore, even robots that cannot communicate verbally can appear more or less socially competent by using nonverbal communication effectively.

When using behavioral observations, we even found that the specific courtesy cues that the service robot implemented in granting the right of way mattered (see Table 3).

Arguably, with a more redundant patterning of movements, courtesy cues are less ambiguous, and the social significance of the kinesic courtesy cues becomes more legible (see Arndt & Janney, 1987). Thus, socially functional robot motion is redundant and does not cost human counterparts cognitive effort to decide how to interact; therefore, socially functional robot motion is clear. This clarity becomes indirectly obvious when people's behavior does not show any sign of hesitation when encountering a service robot (i.e., when their behavior appears unwavering and prompt). As such, a robot's movement is less disruptive to a human counterpart's action. Thus, when confronted with a robot that appeared to act courteously only by stopping, the human counterpart's course of action showed more signs of hesitation than when confronted with a robot that appeared to act courteously by moving to the side and stopping.

Three limitations need to be kept in mind when appraising these results. One limitation involves the limited variability in our participants and in the situations that we tested (see Figure 1). The small size and the specific composition of our sample (i.e., highly skilled employees of the company that produced the technology used in this research) exposed to only two specific test situations challenge the generalizability of our findings across situations and the universality of our results across individuals. With a sample of 29, the current research provides, of course, only tentative evidence for the universal social significance of kinesic politeness cues in body movements; consequently, further empirical exploration is needed. However, with its exclusive academic focus, our research had no immediate commercial relevance. Therefore, we believe that our participants had at least no reason to intentionally display behavior that they thought might be in the best interests of the company.

Another limitation involves the selection of only two highly restrained test situations (see Figure 1). Less restrained conditions might predictably have resulted in less pronounced effect sizes but expectedly not in qualitatively distinct results. A third limitation involves the measurement of our two dependent variables. The precision of our overt behavior measure, the resoluteness measure (i.e., its interrater reliability), was acceptable (i.e., Cohen's κ = .62) by convention; however, it was not completely satisfactory. Our second measure, our robot motion-appreciation measure, by contrast, was highly dependable (i.e., Cronbach's α = .93); however, its behavioral relevance remains unresolved. This holds even though the measure is in line with conventional attitude measures (see, e.g., Eagly & Chaiken, 1993) and was based on previously established items from a generic approval scale (see Heerink et al., 2009, 2010).

Finally, our research was limited to the legibility and social and behavioral consequences of two cues (i.e., moving to the side and stopping) that we believe convey a social message to human counterparts when interacting with a robot. Our research did not aim to explore the human counterparts' personal interpretations of the two supposed courtesy cues, and thus we leave such an exploration to future studies.

Future research might also seek to explore other kinesic and paralinguistic courtesy cues than the ones included in this article. In addition, researchers might wish to explore whether it is indeed politeness and its reception rather than the predictability of a robot's movements as others have suggested (see, e.g., Böhme, 2001) that help to promote social affiliation with and, eventually, liking and acceptance of autonomously moving nonhumanoid service robots. Psychologists might be interested in finding out whether other than courtesy cues could be as effective at promoting liking and whether courteous behavior may even cause emotional attachment to an inanimate object like a robot (see, e.g., Kaiser & Fuhrer, 1996). Finally, nonhumanoid service robots will eventually rise to another level of interaction with humans when they become able to *autonomously* prioritize conflicting goals (e.g., identifying the most efficient execution of the robot's delivery vs. appearing courteous and likable while fulfilling its task) and choose different courtesy cues in response to different situational requirements (urgent vs. socially attentive task fulfillment).

A person's appreciation for robotic technology predictably depends on the robot's communication skills (e.g., Dautenhahn, 2007), particularly when robots have no immediate utility for individuals, such as when they are delivering medication or transporting files in a hospital. Even nonhumanoid machines (i.e., robots that do not look human and cannot communicate verbally) can communicate nonverbally with movement as we have demonstrated. On the one hand, our research speaks of the existence and the universal legibility of paralinguistic, kinesic politeness cues in human communication. On the other hand, it speaks of the utility of kinesic courtesy cues for bolstering the generic acceptance of autonomously moving robotic technologies and, thus, their utility for promoting the appreciation of service robots in action. Accordingly, motion design can draw on socially functional kinesic cues when aiming to further the approval of robots (e.g., Brooks & Arkin, 2007; Lauckner et al., 2014; Sisbot et al., 2010). The motion design of autonomously moving nonhumanoid service robots in particular can draw on kinesic politeness cues when aiming to improve human-robot interactions and to make robotic transportation aids more likable.

Compliance with Ethical Standards

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Table 1

Descriptive Statistics and Bivariate Correlations of Appreciation of the Service Robot's Motion, Generic Approval, Perceived Courtesy, and Specific Courtesy Control

	N	*M*	*SD*	Appre-ciation	Generic approval	Perceived courtesy
Appreciation of motion	174	0.00	1.03	.93[C]	-	-
Generic approval (w/o courtesy items)	174	3.45	1.03	.86**	.92[C]	-
Perceived courtesy	174	3.32	1.43	.99**	.80**	N/A
Specific courtesy control	174	3.47	1.53	.86**	.70**	.80**

[C] In the section to the right of the *SD*s, the numbers in the diagonal cells indicate internal consistency estimates (i.e., Cronbach's α). Internal consistencies could not be estimated for perceived courtesy and courtesy control because they were single-item measures.
**$p < .001$.

Table 2

Principal Axis Factor Analysis of the Generic Approval, Perceived Courtesy, and Specific Courtesy Control Measures

	Appreciation of service robot's motion	h^2
Generic approval (w/o courtesy)	.81	.65
Perceived courtesy	.87	.76
Specific courtesy control	.81	.65
Eigenvalue	2.54	
Proportion of variance explained	84.52%	

Note. N = 174.

Table 3

Observable Signs of Resoluteness in the Human Counterpart's Behavior while Encountering a Service Robot in the Control (i.e., no courtesy cues), Courtesy 1 (i.e., appearing to grant the right of way by stopping), and Courtesy 2 (i.e., appearing to grant the right of way by stopping and moving out of the way) Conditions

		Experimental condition		
		Control	Courtesy 1	Courtesy 2
Resoluteness	Without hesitation	*25* (14.5%) **33.4** (19.4%)	*28* (16.3%) **32.2** (18.7%)	*46* (26.7%) **33.7** (19.6%)
	With hesitation	*33* (19.2%) **24.6** (14.3%)	*28* (16.3%) **23.8** (13.8%)	*12* (7.0%) **24.6** (14.3%)

Note. In all six cells, *observed counts* and **expected counts** are given. Relative frequencies are presented in parentheses.

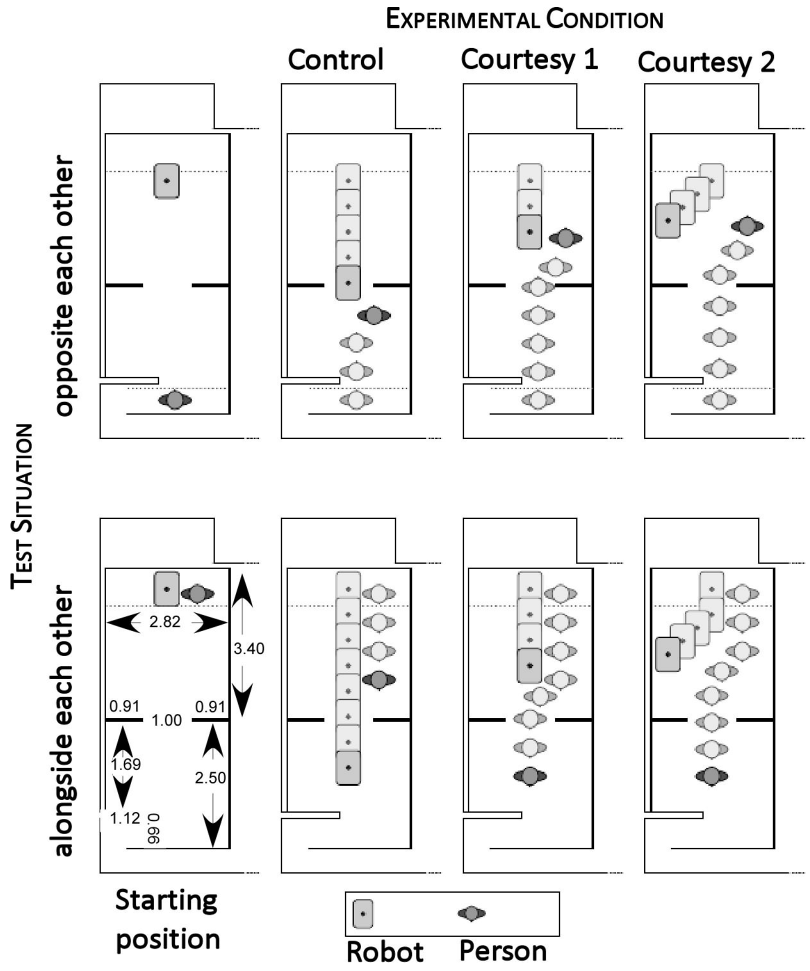

Figure 1. Test situations: (a) Control condition (i.e., no courtesy cues), (b) Courtesy 1 condition (i.e., appearing to grant the right of way by stopping), and (c) Courtesy 2 condition (i.e., appearing to grant the right of way by stopping and moving out of the way). Numbers reflect the spatial distances in meters.

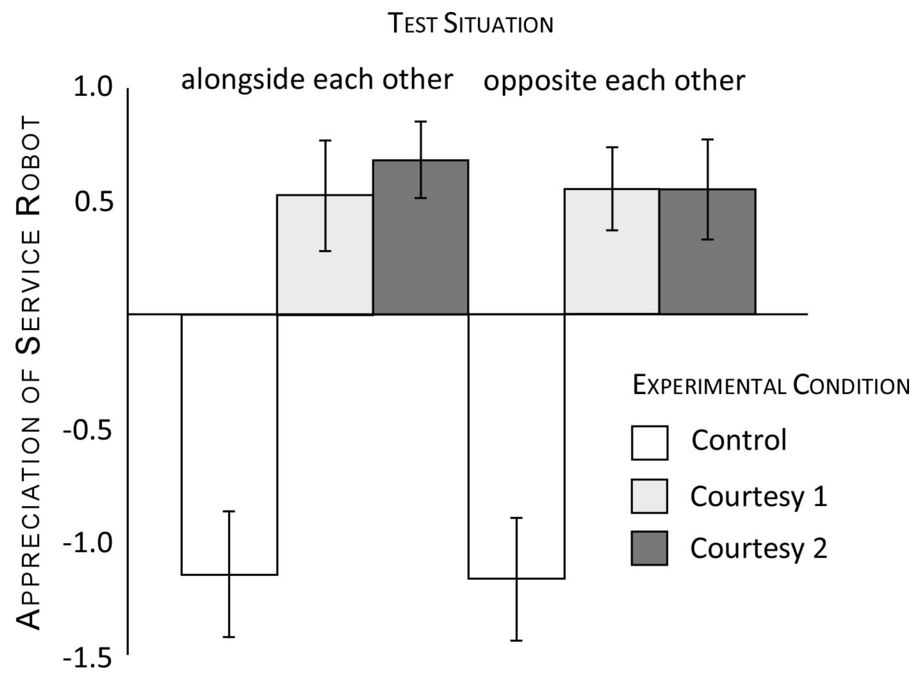

Figure 2. Appreciation of a service robot (in mean z-values and 95% confidence intervals) that exhibits no courtesy cues (i.e., Control condition), that appears to grant the right of way by stopping (i.e., Courtesy 1 condition), or that appears to grant the right of way by stopping and moving out of the way (i.e., Courtesy 2 condition).