

Investigating Behavioral and Cognitive Changes Induced by Autonomous Delivery Robots in Incidentally Copresent Persons*

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Abstract— Autonomous delivery robots (ADRs) encounter incidentally copresent persons (InCoPs) during their delivery journeys. Despite the potential for ADRs' behavior to influence the behavior and cognition of InCoPs, there is limited research on the interaction between ADRs and InCoPs. Therefore, in this study, we conducted a within-participants experiment ($N=30$) with a 3 (confederate types: humans vs. high anthropomorphism robots vs. low anthropomorphism robots) x 2 (jaywalking status: jaywalking vs. not jaywalking) design to investigate the impact of ADRs on InCoPs' behavioral and cognitive changes induced by the social influence of ADRs. During the experiment, participants watched a video depicting interactions between ADRs and InCoPs at a crosswalk. Each participant was immersed in the video as an InCoP, instructed to make jaywalking decisions, and subsequently completed questionnaires. Results indicated that, behaviorally, participants displayed similar levels of conformity towards jaywalking behaviors across both the human and robot confederates. Cognitively, there were significant differences in morality based on the confederate types. Additionally, robots that refrained from jaywalking received more positive ratings in terms of morality and intention to use. This study confirms that ADRs have the capacity to induce conformity similar to humans and that the ethical behavior of ADRs can positively influence InCoPs' impressions and intention to use toward ADRs.

I. INTRODUCTION

Autonomous delivery robots (ADRs) offer several advantages in terms of cost and energy efficiency compared to other delivery systems, such as drones and conventional delivery methods [1]. This advantage has led to rapid growth in the ADRs market, which is anticipated to grow at an annual rate of 20.4%, reaching \$55 billion by 2026 [2]. Additionally, several companies like Uber Eats and FedEx has been utilizing ADRs for food and parcel delivery services.

A key distinction of ADRs from other service robots is their emphasis on 'mobility' in providing services. Unlike other

service robots, ADRs are primarily designed to move in order to provide delivery service. For instance, while information robots and robot vacuum cleaners also move around to provide services, they differ from delivery robots in that their primary functions are information delivery and cleaning, respectively. Due to their mobility, ADRs interact with people they encounter along their delivery routes, whether directly or indirectly. Previous research on ADRs has mainly focused on direct interactors, such as interaction between ADRs and orderers [3]. Since delivery robots primarily spend their time moving items among the three phases including item loading, moving, and unloading, it is crucial to investigate their indirect interactions with individuals encountered along their route. In this context, the concept of InCoPs (incidentally copresent persons), individuals who simply 'happen to be there,' was introduced [4, 5]. The most significant difference between typical human-robot interaction and InCoP-robot interaction is that, in most cases, their encounters are unintentional and unplanned. Despite such differences, research on HRI involving ADRs has primarily focused on interactions with intended users, with limited attention given to InCoPs.

Research on the interaction between InCoPs and ADRs has primarily relied on online surveys and exploratory studies, with limited experimentation in terms of methodology [4, 5, 6]. Moreover, studies have been predominantly confined to examining technology acceptance from the psychological perspective of InCoPs regarding the introduction of ADRs into public areas and investigating behavioral perspective in InCoPs based on the physical proximity between delivery robots and InCoPs [5, 6].

Given the potential social influence of ADRs on humans, we aim to investigate whether the behavior of ADRs influences behavioral and cognitive changes in InCoPs. In terms of behavior change, we seek to explore whether the behavior of ADRs induces conformity in InCoPs, akin to social influence observed in human-human interaction [7, 8]. Furthermore, in terms of cognitive change, we investigated InCoPs' perceived morality and intention to use, contingent upon the ethical behavior of the employed ADRs. In this study, to explore the effect of ADRs on behavioral and cognitive change in InCoPs, we utilized a jaywalking scenario. Therefore, the research question posed in this study is as follows: Can ADRs lead to behavioral and cognitive changes in InCoPs?

II. RELATED STUDIES

A. InCoP-ADRs Coexistence and Behavioral Changes: Conformity

Conformity, a social phenomenon studied in social psychology, refers to the tendency to align one's perceptions,

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opinions, or behaviors with group norms [9]. Peer-induced conformity, a significant aspect of social influence, has been extensively explored in human group [7]. Recent research has expanded this inquiry beyond human-human interactions to include human-robot interactions. Robots designed for social interaction can induce conformity in humans with whom they share decision-making processes [10]. Additionally, age-related differences in conformity using the Asch paradigm, reveal that children tend to conform to robotic collaborators while adults exhibit resistance [11].

Previous studies on human-robot conformity have predominantly focused on indoor settings where robots and humans collaborate on shared tasks. Since the introduction of ADRs into public spaces has been anticipated, it is necessary to explore conformity with unfamiliar robots in public spaces where shared goals are absent. Specifically, since mere coexistence in human-human interactions can induce behavioral changes such as jaywalking [12], it is crucial to investigate whether similar phenomena would occur for InCoPs based on the behavior of ADRs.

H1. The InCoP will conform to robot confederates in the same way as they do to human confederates.

B. InCoP-ADRs Coexistence and Cognitive Changes: The Moral Impression and Intentions to Use

Morality, broadly understood as the capacity to discern right from wrong and act accordingly, has emerged as a significant focus within the realm of HRI [13]. Recent studies in this field have shed light on the moral dimensions of service robots, revealing that actions like privacy infringements and service exclusions can adversely impact user perceptions of robot morality [14, 15]. While existing research has predominantly explored the moral behavior of service robots interacting directly with humans, a notable gap exists concerning ADRs, which primarily navigate public spaces during delivery tasks and may encounter InCoPs without direct interaction. Recent findings indicate that the proximity of delivery robots to individuals in shared spaces can influence perceptions of robot capabilities [16]. In this research, we seek to examine whether the behavior of ADRs during public deliveries influences InCoPs' perceptions of robot morality. Moreover, it is essential to explore how perception of robot morality impact users' future intentions to utilize these robots [14]. Therefore, this study seeks to ascertain whether the ethical behavior of delivery robots affects InCoPs' perceived morality of ADRs and their inclination to use them.

H2a. The jaywalking behavior of robot confederates has a negative impact on the InCoP's ratings of the robots' morality.

H2b. The jaywalking behavior of robot confederates negatively influences the InCoP's intention to use of the robots.

III. METHODOLOGY

To assess the behavioral and cognitive impacts of delivery robots, we structured a within-subjects study with a 3 (confederate types: humans vs. high anthropomorphism robots vs. low anthropomorphism robots) X 2 (jaywalking status: jaywalking vs. not jaywalking) design. Additionally, a total of seven conditions were examined, incorporating one control condition to establish the baseline.

A. Participants

Thirty participants (15 males and 15 females) were recruited via webmail. The participants' ages ranged from 23 to 35 years ($M=27.53$; $SD=3.60$). Each participant received around \$12 USD for taking part in the experiment.

B. Robots

To manipulate the level of anthropomorphism, we employed two distinct types of robots. In the high anthropomorphism condition (Robot_AH), we utilized Temi, a personal assistant robot [17]. For the low anthropomorphism condition (Robot_AL), we modified a TurtleBot3 Waffle Pi by adding a delivery box mounted on top, resembling ADRs [18] (Fig. 1). Both ADRs were programmed to perform only the moving function for delivery, and their movement speed was standardized.

C. Experimental Stimuli

To simulate roads where jaywalking might occur, in the experimental scenario, a one-way road and a crosswalk which is 1 meter wide and 2 meter long were implemented (Fig. 2). Following the protocol established in prior research on robot coordination, the confederates were arranged in groups of three [7], as this configuration has been shown to be effective for coordination.

Each video sequence depicted a scenario where a man whom the participants was asked to immerse and confederates waited together. Subsequently, the confederates either jaywalked or refrained from doing so, followed by a close-up shot of the man's face. Each video had a total duration of approximately 20 seconds.

To create the experimental videos, we initially presented a scenario where participants were shown a red light situation. This scenario was edited to depict jaywalking by zooming in the video, effectively concealing the visibility of the traffic light. However, in reality, participants crossed the road only when the traffic light was green, ensuring safety. Zooming and transition editing were conducted using Adobe Premiere Pro.



Figure 1. ADRs used based on anthropomorphism level

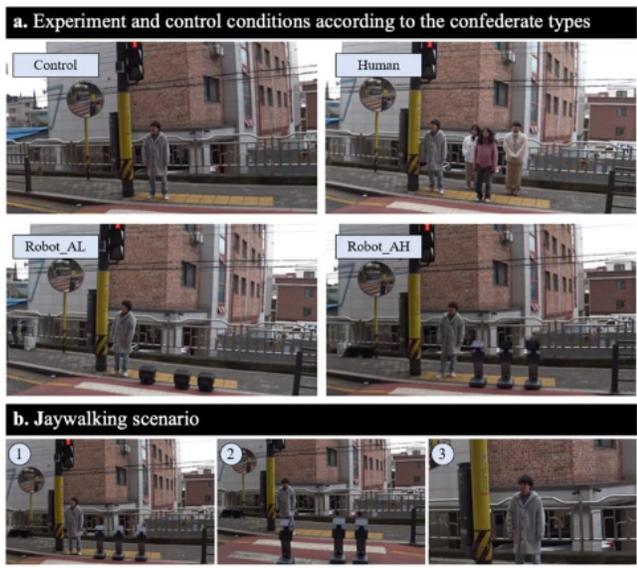


Figure 2. Experiment stimuli

To enhance the validity of jaywalking decisions, each participant was asked to immerse the video environment. To be specific, each participant was asked to imagine themselves as the man in the video. Each participant was briefed about the study, completed an informed consent form, and engaged in seven sessions in a randomized order. Each session involved watching a video, deliberating on whether to jaywalk, and subsequently completing an online questionnaire.

Given that the videos were filmed outdoors, we had limited control over traffic conditions. Therefore, each participant was encouraged to make decisions and responses to questionnaire items without considering traffic density.

E. Measures

In this study, we utilized the morality and appropriateness scales to assess the cognitive changes of an InCoP in response to the robot's behavior. Additionally, the malfunction and dependency scales were included to ensure whether behavioral and cognitive *changes* in each participant attribute malfunction and dependency rather than the robot's moral behavior. Furthermore, the human likeness scale was employed to gauge the impact of manipulated anthropomorphism. Thus, a total of 25 items across six scales were used: morality [19], malfunction [20], dependency [19], appropriateness [21], intention to use [22], and human likeness [23]. During the sessions, the participant completed the morality scale comprising 5 items when the confederates were humans. The participants rated all survey scales composed of 25 items when the confederates were robots (Table 1). All items were assessed using a 7-point Likert scale, where 1 represents "strongly disagree" and 7 represents "strongly agree."

IV. RESULTS

To assess the effectiveness of anthropomorphism manipulation, a paired sample t-test was conducted on the human likeness scale. The analysis revealed a significant difference in human likeness between the Robot_AH Questionnaire condition and the Robot_AL condition

TABLE I. QUESTIONNAIRE

Category (Cronbach's α)	Items
Morality ($\alpha=0.993$)	This [X] has a sense for what is right and wrong.
	This [X] can think through whether an action is moral.
	This [X] might feel obligated to behave in a moral way
	This [X] is capable of being rational about good and evil.
	This [X] behaves according to moral rules.
Malfunction ($\alpha=0.927$)	This robot looks malfunctioning.
	This robot looks like making a mistake.
Dependency ($\alpha=0.884$)	This [X] can only behave how it is programmed to behave.
	This [X]'s actions are the result of its programming.
	This [X] can only do what humans tell it to do.
Appropriateness ($\alpha=0.982$)	This [X] would never do anything it was not programmed to do.
	Please rate your impressions of the robot/robots on these scales:
	Inappropriate-Appropriate
	Wrong for Task-Right for Task
	Ill-Suited-Well-Suited
Intention to Use (1 item)	If the robot was available, I would use it.
Human Likeness ($\alpha=0.865$)	Improper-Proper
	Mismatched-Matched to Task
	To What extent does the robot have human-like attribute?
	To What extent does the robot look like a machine or mechanical device?
	To What extent does the robot have characteristics that you would expect of a human?
To What extent does the robot have machine-like attributes?	
To What extent does the robot act like a person?	
To What extent does the robot act like a machine?	

[$t(29)=-0.630, p<0.05$]. The human likeness in the Robot_AH condition ($M = 3.238, SD = 0.195$) was found to be higher than that in the Robot_AL condition ($M = 2.919, SD = 0.168$), confirming the manipulation of anthropomorphism levels (Fig. 3).

To analyze participants' jaywalking decision, a chi-square test was conducted. Morality was analyzed using a 3 (confederate types) X 2 (jaywalking status) repeated measures ANOVA, with the human confederates' condition included. For other items not measured against human condition, the human condition was excluded, and comparisons were made between robots. Therefore, malfunction, dependency, human likeness, appropriateness, and intention to use were analyzed using a 2 (level of

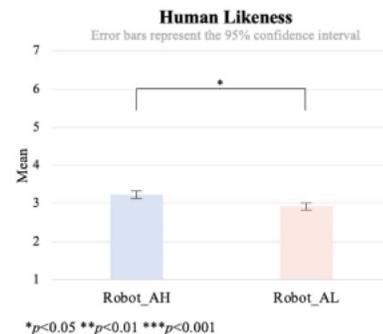


Figure 3. Manipulation check of anthropomorphism

anthropomorphism) x 2 (jaywalking status) repeated measures ANOVA. Bonferroni post hoc tests were employed to determine significant differences among confederate types and jaywalking status. All analyses were conducted using IBM SPSS Statistics V26.0.

A chi-square test was performed to examine the relationship between confederate types and the participant's jaywalking decisions, as well as confederates' jaywalking status and the participant's jaywalking decisions (Table 2). When analyzing the combination of confederate types and jaywalking status, a significant difference in the decision to jaywalk was observed [$X^2(5, N=180)=55.379, p<0.001$]. Specifically, the highest proportion of participants chose not to jaywalk when the human confederates refrained from jaywalking (16.1%), while the highest proportion of participants chose not to jaywalk when the Robot_AH confederates did not jaywalk (14.4%). Additionally, the following percentages were observed: jaywalking proportion of participants when human confederates jaywalked (13.3%), not jaywalking proportion of participants when Robot_AL confederates refrained from jaywalking (12.2%), jaywalking proportion of participants when Robot_AH confederates jaywalked (10.0%).

The analysis revealed that there was no significant relationship between confederate types and jaywalking decision [$X^2(2, N=180)=0.326, p=0.850$]. However, there was significant relationship between confederate behavior and jaywalking decision [$X^2(1, N=180)=47.099, p<0.001$].

The two-way repeated measures ANOVA results showed significant differences based on the confederate types and jaywalking status. Specifically, the main effect of confederate types was significant for morality [$F(2,58)=31.576, p<0.001$] (Fig. 4). However, the main effect of confederate types showed no significant difference for the following scales: malfunction [$F(1,29)=0.969, p=0.333$], dependency [$F(1,29)=0.345, p=0.561$] (Fig.5), appropriateness [$F(1,29)=2.747, p=0.108$], and intention to use [$F(1,29)=1.875, p=0.166$] (Fig. 6). A Bonferroni post hoc test revealed that morality was significantly higher in the human confederates condition compared to the Robot_AH confederates condition (95% CI [0.905, 2.170], $p<0.001$) the

TABLE II. THE RESULT OF CHI-SQUARE TEST FOR JAYWALKING DECISION BY THE CONFEDERATE TYPES AND JAYWALKING STATUS

	Jaywalking Decision (%)		X^2	p
	Jaywalking	Not Jaywalking		
Confederate Types			0.326	0.850
Human	25(13.9)	35(19.4)		
Robot AH	22(12.2)	38(21.1)		
Robot AL	24(13.3)	36(20.0)		
Jaywalking Status			47.009	<0.001
Jaywalking	58(32.2)	32(17.8)		
Not Jaywalking	13(7.2)	77(42.8)		
Confederate Types X Jaywalking Status			55.379	<0.001
Jaywalking	Human	24(13.3)	6(3.3)	
	Robot AH	18(10.0)	12(6.7)	
	Robot AL	16(8.9)	14(7.8)	
Not Jaywalking	Human	1(0.6)	29(16.1)	
	Robot AH	4(4.4)	26(14.4)	
	Robot AL	8(2.2)	22(12.2)	

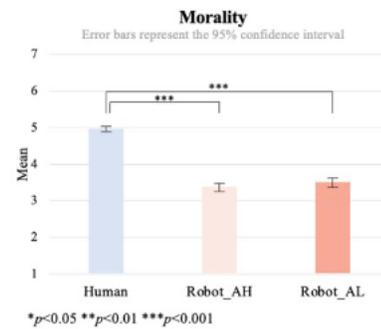


Figure 4. Results of confederates types: morality

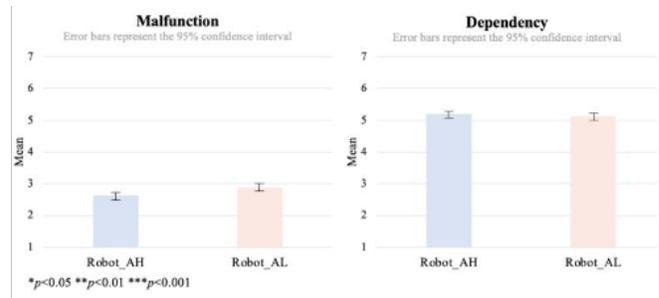


Figure 5. Results of confederates types: malfunction, dependency

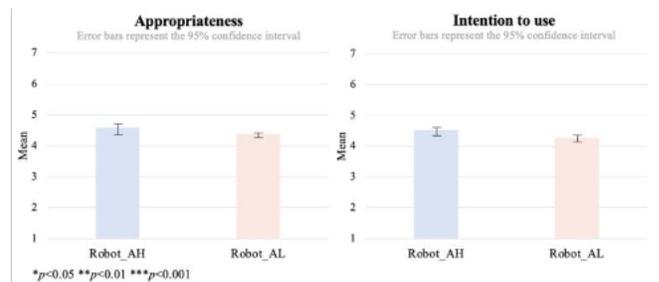


Figure 6. Results of confederates types: appropriateness, intention to use

Robot_AL confederates condition (95% CI [0.893, 2.160], $p<0.001$).

Additionally, the main effect of the jaywalking status was significant for various scales: morality [$F(1,29)=74.437, p<0.001$] (Fig. 7), malfunction [$F(1,29)=24.613, p<0.001$], dependency [$F(1,29)=14.457, p<0.001$] (Fig. 8), appropriateness [$F(1,29)=56.033, p<0.01$], and intention to use [$F(1,29)=25.208, p<0.05$] (Fig. 9). A Bonferroni post hoc

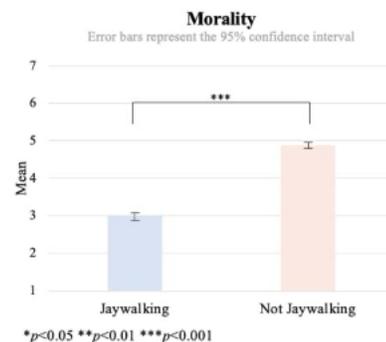


Figure 7. Results of jaywalking status: morality

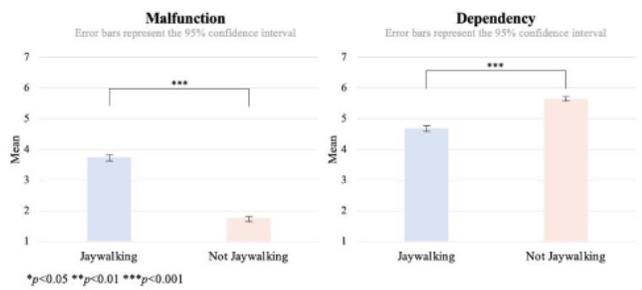


Figure 8. Results of jaywalking status: malfunction, dependency

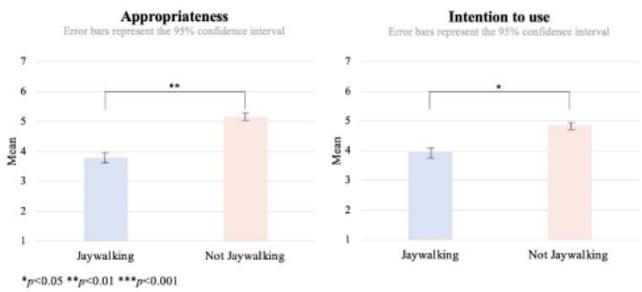


Figure 9. Results of jaywalking status: appropriateness, intention to use

test revealed that morality (95% CI [1.426, 2.312], $p < 0.001$), appropriateness (95% CI [0.436, 2.297], $p < 0.01$), and intention to use (95% CI [0.016, 1.817], $p < 0.05$) were significantly higher when confederates did not jaywalk compared to when they did. However, malfunction (95% CI [1.156, 2.777], $p < 0.001$) and dependency (95% CI [0.437, 1.455], $p < 0.001$) were significantly higher when confederates jaywalked compared to when they did not.

A significant interaction effect was found between $F(1,29)=2.581$, $p < 0.05$ and intention to use $F(1,29)=4.408$, $p < 0.05$ (Fig. 10).

Post hoc analysis of the interaction effect between the confederate types and jaywalking status on appropriateness revealed that, when jaywalking, the Robot_AH condition was evaluated as more appropriate than the Robot_AL condition (95% CI [0.149, 0.864], $p < 0.01$). However, there was no significant difference in appropriateness based on anthropomorphism level in the non-jaywalking condition (95% CI [-0.261, 0.421], $p = 0.635$). Similarly, a post hoc analysis of the interaction effect between the confederate types and jaywalking status on intention to use showed that, when confederates jaywalked, participants displayed a higher intention to use toward the Robot_AH condition than the Robot_AL condition (95% CI [0.158, 1.109], $p < 0.05$). On the other hand, there was no significant difference in intention to use based on anthropomorphism level under the

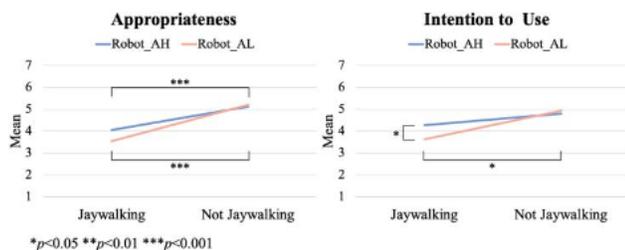


Figure 10. Questionnaire results of interaction effect

non-jaywalking condition (95% CI [-0.392, 0.659], $p = 0.608$).

V. DISCUSSIONS

This study investigated the impact of ADRs' behavior on behavioral and cognitive changes in InCoPs. The findings revealed that InCoPs conform to robot confederates in a manner similar to human confederates, indicating a significant social influence of ADRs. Additionally, it was observed that robot confederates' unauthorized jaywalking behavior negatively influenced participants' perceptions and intentions to use of the ADRs.

In the field of HRI, studies on conformity have primarily focused on direct interactions, such as shared goals between participants and confederates, or indoor settings [10, 11]. However, as products with agency, such as IoT devices and robots, continue to emerge, it becomes imperative to investigate whether indirect interactions with them also impact individuals. We confirmed that robots can induce conformity in humans who do not engage in direct interaction, through social influence. This expands conformity research within the HRI domain from direct interaction to indirect interaction. In addition, the study results imply that the social impact of robotic mobility systems, including ADRs, needs to be considered when designing robotic mobility systems within a vehicle-to-everything (V2X) environment.

Additionally, there was a greater conformity tendency when confederates did not jaywalk compared to when confederates jaywalked. These results are consistent with prior studies demonstrating how social robot can induce individuals to conform to social norms [8]. This implies that robots can act as social norm inducers [24]. This suggests that the mere presence of a group of robots may prompt socially normative behavior.

From a cognitive perspective, there were partial differences observed based on the type of confederate and their jaywalking status. Morality ratings were higher for human confederates compared to robot confederates. However, no differences were observed in malfunction, appropriateness, or intention to use based on the degree of robot anthropomorphism. Participants reported higher scores in morality, dependence, appropriateness, and intention to use when the confederates refrained from jaywalking compared to when they jaywalked. This aligns with previous research indicating that behaviors conflicting with moral norms are associated with lower perceived morality [14, 15]. Moreover, participants perceived ADRs to be more dependent and appropriate when they adhered to social norms. Additionally, the robot was assessed as more appropriate, and participants expressed a greater desire to use it when ADRs refrained from jaywalking, consistent with the positive influence of morality on intention to use [14, 15]. Moreover, regardless of the degree of ADRs' anthropomorphism, participants evaluated robots more negatively when they jaywalking compared to when they adhered to pedestrian norms. Furthermore, when robots engaged in jaywalking, participants expressed a higher intention to use high anthropomorphism robots than low anthropomorphism robots. Conversely, for robots with low anthropomorphism, participants' intention to use varied based on jaywalking behavior. This indicates that the significant impact of robot behavior on user's intention to use [25].

Furthermore, consistent with previous research showing that participants' preference depends on the social behavior of the delivery robot [16], the results showed that the moral behavior exhibited by ADRs during delivery can evoke positive impressions from InCoPs. It highlights the potential for behavior design of ADRs during item moving phase as a marketing tool, aimed at fostering brand loyalty and encouraging future usage.

C. Limitations and Future Work

This study has several limitations. In this study, whether conformity was induced or not was examined based on the decision to jaywalk rather than the actual act of jaywalking. Since there is a difference between decision-making and the actual behavior, relying solely on decisions to determine conformity may not fully capture the dynamics of social influence in real-world scenarios [26].

Additionally, another limitation is the gender bias present in the experimental stimuli, as the individual depicted in the video, in which participants were instructed to immerse themselves, was male. This gender bias might have influenced the level of presence by participants and could introduce confounding variables into the study results [27].

Therefore, future studies should address these limitations by considering examining whether conformity behavior manifests similarly in real-world settings. Additionally, investigating whether ADRs effectively induce conformity in InCoPs across different contexts and demographics would offer important guidance for the development and application of ADR technology.

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