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FULL PAPER

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Assessing the effect of persuasive robots interactive social cues on users' psychological reactance, liking, trusting beliefs and compliance

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ABSTRACT

Research in the field of social robotics suggests that enhancing social cues in robots can elicit more social responses in users. It is however not clear how users respond socially to *persuasive social robots* and whether such reactions will be more pronounced when the robots feature more interactive social cues. In the current research, we examine social responses towards persuasive attempts provided by a robot featuring different numbers of interactive social cues. A laboratory experiment assessed participants' psychological reactance, liking, trusting beliefs and compliance toward a persuasive robot that either presented users with: no interactive social cues (random head movements and random social praises), low number of interactive social cues (head mimicry), or high number of interactive social cues (head mimicry and proper timing for social praise). Results show that a persuasive robot with the highest number of interactive social cues invoked lower reactance and was liked more than the robots in the other two conditions. Furthermore, results suggest that trusting beliefs towards persuasive robots can be enhanced by utilizing praise as presented by social robots in no interactive social cues and high number of interactive social cues conditions. However, interactive social cues did not contribute to higher compliance.

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Human-Robot interaction (HRI); persuasive robot; interactive social cues; social responses

1. Introduction

In the not too distant future, one could anticipate that humans will share tasks, interact and collaborate with robots. This will be so for diverse areas such as manufacturing to assist humans in production lines [1] or in education where robots will take more social roles such as that of teachers [2], or even in hospitals where we could soon get used to meet a robot waiting for us to welcome, examine, diagnose, treat, and prescribe medicine for us, instead of human health workers [3]. Crucially, in many of these roles, robots will need to be able to *persuade* humans. Accordingly, assistive robots have already been developed to serve as advisors in persuading people to practice healthy lifestyles (e.g. consume healthy foods and start exercising [4–6]), or in order to change their attitude and behavior [7] by showing some promising results, e.g. [8–10].

O'Keefe [11] argues that an act can be considered as persuasion when the 'persuadee' (the person to be persuaded) complies voluntarily (i.e. without being forced) to the persuasive attempt. Research into the nature of human responses to persuasive attempts by other humans (e.g. [12,13]) has shown that the way people react to persuasive attempts depends upon various factors, one of them is how they perceive the persuader. For example, the appearance of a salesperson may cause different buying decisions if the salesperson wears a suit instead of casual clothes.

However, when humans are subjected to persuasive attempts, they can respond to these attempts by showing both positive responses (liking, compliance) and negative responses (tantrum, reactance). Positive experiences include conformity to the robots by children [14], trustworthy to the robots with dissimilar gender with users [15] and increment of human performance facilitated by robot touch [16]. Indeed, powerful persuasive attempts can lead to psychological reactance [17] as highlighted earlier [18]. Since persuasive attempts potentially limit people's decisional freedom, they might trigger feelings of anger (towards the persuader), and cause people to host negative thoughts (about the persuader), and in some cases even motivate them to do the opposite to what

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they are asked to do [19,20]. Earlier research [20–22] has shown that psychological reactance can be measured using questionnaires.

The question arises whether people will respond in similar ways when *social robots* attempt to persuade them. In line with the Media Equations hypothesis [23], one could expect that artificial agents (in our case the persuasive robots) can elicit social responses even when these demonstrate only basic social behaviors towards humans like playing [24], smiling [25] and gazing [26]. This hypothesis has been supported by several studies [27,28]. Moreover, according to the Social Agency theory [29], human social responses should increase with the addition of social cues in robots. Earlier research has explored whether the Social Agency theory [20] and the Media Equation hypothesis [23] also apply to how much artificial social agents can evoke the above mentioned social responses in users. In a study by Roubroeks, Ham and Midden [30] showed that participants experienced more psychological reactance when a persuasive message was delivered by an agent represented as a still picture or as a moving human-like on-screen character, as compared to when the advice was provided as text-only.

However, only a few studies have investigated how people respond to persuasive attempts by social robots (see e.g. [31,32]). For example, Ghazali et al. [9,33] investigated the social responses caused by persuasive social robots and the social cues they displayed. They reported that a robot displaying minimal social cues (with a neutral face and blinking eyes) and enhanced social cues (with facial expressions, head movement, and emotional intonation in the voice) triggered lower levels of psychological reactance compared to when the same persuasive messages were presented as text-only with no robot present [9]. In another study [33], they reported that a persuasive robot with enhanced social cues triggered higher psychological reactance than a persuasive robot with minimal social cues.

Nevertheless, the aforementioned investigations [9,30,31] implemented what can be characterized as *static* or *non-interactive* social cues into persuasive social robots rather than *interactive* ones. Non-interactive social cues refer to the cues that are fixed and changeless while interactive social cues refer to the cues that can be changed according to the situations or needs [34]. We argue that it is crucial to study whether a persuasive social robot displaying more *interactive* social cues causes more or less social responses because most social cues in real life interactions between people are interactive, and robots will be more lifelike if interactive social cues are implemented onto the robots instead of non-interactive ones. Fong, Nourbakhsh and Dautenhahn [35] highlighted the importance of socially interactive robots in changing human behaviors [36,37]. Robots with non-interactive social cues execute pre-programed behaviors and dialogues, regardless of the reactions by humans [9]. Examples of such social cues are gender, facial expressions and pre-programed behaviors like head movement of a robot. On the other hand, interactive social cues are exhibited only when the robot social cues are in response to the users' behavior or give some context or situation-specific responses [38].

A clear illustration of interactive social cues in human-human interaction is when Person A turns his head (the first example of interactive social cues) with a puzzled expression (the second example of interactive social cues) when suddenly Person B pats him on the shoulder from behind. Without a touch from Person B which triggers the reaction from Person A, most probably Person A such a behavior might not be triggered at all. Breazeal [39] suggested that what she called 'sociable robots' are pro-actively engaged with people to fulfill internal social aims such as sharing mutual emotions between humans and robots. Earlier research in human-robot interaction [38,40,41] demonstrated that people manifested positive responses (higher trusting beliefs, initiating joint attention, making eye contact and perceived friendliness) towards robots that exhibit interactive cues such as mimicry, interactive facial expressions, and social praise. Thus, we argue that persuasive robots should use interactive social cues such as mimicry and social praises in maintaining positive social relationships between humans and robots and thus enhance their effectiveness as well as how people experience interaction with a persuasive robot.

A related study on mimicry [42] claimed that social responses towards robots ignited if both parties (the mimicker and the mimickee) share the same emotional and cognitive states. Empirical studies had shown that when a mimicker (either robot or human) imitated the movements [43,44], accent [45], reciprocal [46] and facial expressions [47] of the mimickee, the positive responses for instance liking and trusting beliefs towards the mimicker increase. In this way, mimicry has been shown to be one of the most potent interactive social cue which can lead to positive impressions for such interaction. In line with similarity-attraction theory [48], earlier research in an automotive setting [32] has shown that mimicry of head movements by avatars can increase social responses in humans, such as trusting beliefs and liking towards the agents. However, we argue that this finding [32] was rather weak due to the mimicry of a 2D interaction by an on-screen partner and not a realistic 3D interaction as social robots could offer.

Mimicry is one of several interactive social cues by robots that have been assessed formerly in human-robot interaction. Another example pertains to interactive social cues is social praise. Experimental studies from neuroscientists show that social praise triggers the release of the neurotransmitter which is known as dopamine, that is associated with pleasure [49]. As suggested by the Media Equation hypothesis [23], several experimental studies attempted to identify how humans perceived social praise by robots. For example, a study by Kaptein et al. [38] showed that humans perceived social praise by an iCat robot as positive as in human-human interaction. Humans' motivation for learning, exercising for pleasure and rehabilitation [4,50,51] could be increased through the use of praise or encouragement by robots as well. Importantly, earlier study showed that timing in which the social praise was delivered has a significant bearing on its effectiveness [38]. However, no earlier study has yet examined the effect of interactive social praise, especially on psychological reactance by persuasive robots.

The current study extends the state of the art as described above, by investigating how interactive social cues impact interaction with persuasive robots. Specifically, this paper reports an experiment that examines the influence of the number of interactive social cues that the robot displays upon users' psychological reactance, liking, trusting beliefs and compliance towards the robotic persuader. The interactive social cues under investigation include head mimicry (off: a robot with random head's movement vs. on: a robot with head mimicry) and social praise (random timing vs. none vs. proper timing). Based on the Social Agency theory [29], it can be anticipated that responses towards persuasive robots with interactive social cues will be analogous to the responses towards the human-agent interaction. Thus, we expect that robots with interactive social cues: head mimicry [44] and social praise with proper timing [38] will evoke positive social responses including high liking and trusting beliefs towards the robot. However, we cannot predict how interactive social cues of robots will affect psychological reactance and compliance as earlier research has not yet examined them. The remainder of this paper outlines the methods and materials used and then describes the results of our study. We conclude this paper by providing implications for designing interactive social cues in persuasive robots.

1.1. The current study

This experiment investigates the influence of interactive social cues on persuasion activity upon psychological reactance, liking, trusting beliefs and compliance. Besides, this study also examines how psychological reactance experienced from the persuasive attempts influences liking, trusting beliefs and compliance towards the persuasive robot. We offer a higher level of social agency (a physical robot) as a mimicker compared to virtual agents used in earlier research [32]. In the current study, we used an embodied humanoid robotic agent called SociBot as a persuader in implementing the interactive social cues: head mimicry and social praise with proper timing (for brevity, we refer to proper timing for social praises simply as interactive social praise in the remainder of this manuscript.). SociBot is a robot developed by Engineering Arts Limited in the form of a stylized head of a human that can display social expressions by physically moving its head and back-projected facial expressions. The projected controllable features are blinking, perfectly synchronized facial expressions and lip movements with speech.

Participants were asked to interact with the robot that was programed to have three conditions: no interactive social cues vs. low number of interactive social cues vs. high number of interactive social cues to answer the question whether a robot that has more interactive social cues will be perceived more positively than the robot with less interactive social cues. We implemented a robot that mimics participants' head movements (the first interactive social cue) and interactively praises the participants (the second interactive social cue). Specifically, the hypotheses for the current study are:

H1. Participants will experience lower psychological reactance when interacting with a persuasive robot featuring a higher number of interactive social cues than a persuasive robot with a lower number of interactive social cues

H2. Participants will like a persuasive robot with a higher number of interactive social cues than a persuasive robot with a lower number of interactive social cues

H3. Participants will have higher trusting beliefs towards a persuasive robot with a higher number of interactive social cues than a persuasive robot with a lower number of interactive social cues

H4. Participants will be more compliant towards a persuasive robot with a higher number of interactive social cues than a persuasive robot with a lower number of interactive social cues

H5. Psychological reactance has a negative correlation to liking, trusting beliefs and compliance

2. Methods and materials

2.1. Participants and design

We recruited twenty-one participants (9 male and 12 female) aged between 26 and 41 ($M = 30.9$, $SD = 4.00$). A 1×3 (number of interactive social cues: a robot with no interactive social cue vs. low number of interactive social

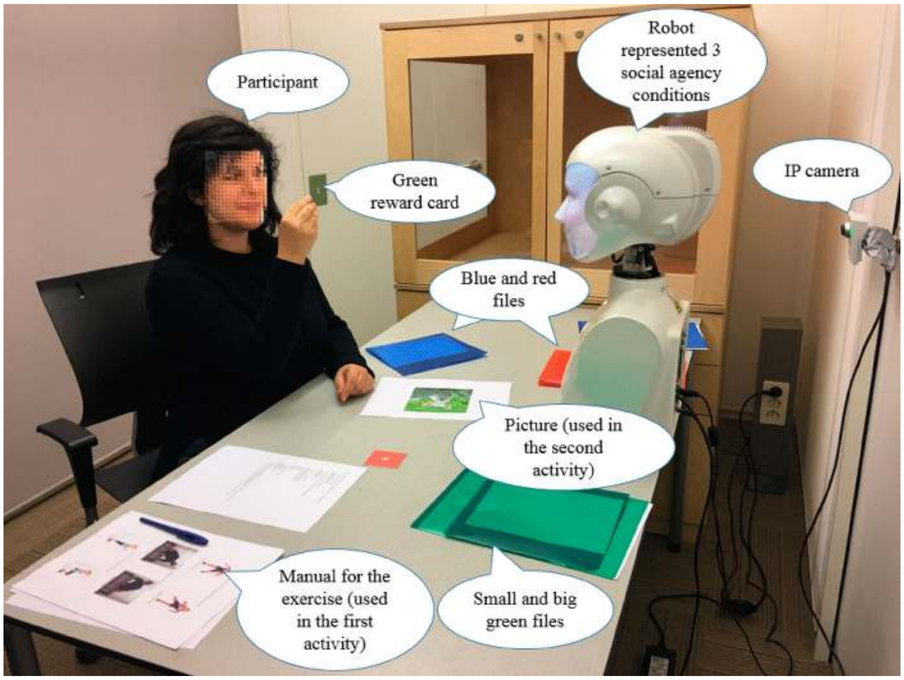

Figure 1. Experimental set ups.

cues vs. high number of interactive social cues) within-subjects experimental design was used. Experimental sessions lasted 45 min per participant for which participants were given a €7.5 voucher as a token of appreciation. All participants were employees of the Eindhoven University of Technology, Netherlands. The study was completely in line with the ethical research policies of the Department of Industrial Design for performing the experiment and rewarding the participants. All participants gave written informed consent in accordance with the Declaration of Helsinki.

To limit the 'carryover effects' of the within-subject experimental design [52], the order of the three interactive social cues conditions was randomized for each participant. For instance, some participants interacted with the robot showing no interactive social cue in their first session, followed by the robot showing a high number of interactive social cues in their second session, and a robot showing a low number of interactive social cues in their last session. For enhancing the study design and reducing carryover effects from the previous session, the robot's face and voice, type of exercises in the first activity, the theme of the pictures used in the second activity, the persuasive dialogues for both the first and the second persuasion attempts were also randomized.

2.2. Manipulation of interactive social cues

As mentioned earlier, we manipulated the number of interactive social cues implemented on the persuasive robot. In all three conditions, the SociBot was positioned on a desk in front of the participants and preprogrammed with verbal and nonverbal social cues (see Figure 1).

In the no interactive social cue condition, the robot interacted with the participant using random head movements (independent of the participant's head movement) and social praise delivered at random moments (independent of the participant's actions). In the low number of interactive social cues condition, the robot interacted with the participant while mimicking the participant's head movement. In the high number of interactive social cues condition, the robot mimicked the participant's head movement and also praised the participant at appropriate moments in the interaction. The robot praised the participant at random moments in time (e.g. which could also mean suddenly saying '*Good job*' before the participant had made any decision) in the no interactive social cue condition, but at appropriate moments in the interaction in the high number of interactive social cues condition (e.g. praised the participant by saying '*Good job*' only after the participant complied to the robot's advice). No social praise was given to participants in the low number of interactive social cues condition.

In all conditions, the robot was operated by the experimenter using a Wizard of Oz prototyping technique for choosing pre-selected dialogues at suitable moments during the interactions, including the social praise conveyed by the robot in the high number of interactive social cues condition. Additionally, the robot's head was preprogrammed to automatically mimic participants' head

Table 1. Manipulation of interactive social cues.

Condition	Number of interactive cues	Cues used: *Head mimicry*	*Appropriate timing for praise*
No	0	No (random)	No (random)
Low	1	Yes	No
High	2	Yes	Yes

movements in X and Y axes for high and low number of interactive social cues conditions using integrated IR depth sensor embedded within the torso of the robot. Random head movements were presented during the interaction with the robot in no interactive social cue condition. Table 1 summarizes the manipulation of interactive social cues used in this study.

2.3. Task

The participants were asked to interact with a robot three times. In each of these three sessions, the SociBot displayed interactive social cues differently (fitting the manipulation of interactive social cues as described above). Each session was divided into two activities. In the first activity, participants were asked to do a simple three-minute exercise instructed by the robot. Participants were given a short, printed guideline leaflet describing the type of exercises and guidance on how to do these exercises step-by-step. Exercises for the first activity including standing on one leg, weight shifting, and sit-down, stand-up exercises. This activity was designed to increase the awareness of head mimicry by the robot (if any). As such, there were no persuasive attempts involved in the first activity.

The robot started the persuasive attempts in the second activity, in which the participants were asked to make choices in two tasks. The first task was a picture card selection task, where participants were asked to select which one of the two pictures the liked, and then to describe that picture to the robot in one minute. The second was a reward card selection task, where participants were asked to select one of three alphabet cards (card A, B or C) they liked as their reward. To ensure the fairness of the reward offered, the participants were given the same reward (the €7.5 voucher as mentioned earlier) at the end of the experiment, independent of the alphabetical reward card chosen. These two selection tasks each involved a persuasive attempt by the robot, in which the robot would persuade the participants to change their initial selection to another card (change the picture in the first attempt and change the reward card in the second attempt). The robot never agreed with any initial selections made by the participants, and it always tried to push the participants to change their selections.

Before these selection tasks, it had been emphasized by the experimenter that the participants could freely choose between two responses, i.e. keep their initial selections (ignore the advice), or change their mind and make other choices (follow the advice). Participants were also reminded several times that there were no absolute right or wrong answers in this game. During the persuasive attempts, the robot used forceful, high controlling language to increase the likelihood of compliance in accordance with the findings of an earlier study [9].

2.4. Procedure

The experiment was conducted at the Department of Industrial Design, Eindhoven University of Technology. The experimenter greeted participants upon arrival to a designated room and asked to take a seat against a table facing the robot that was placed on the table. Six plastic folders in three different colors (red, green and blue – one color for each session; and one small and one big folder for each color) were placed on the table. Each colored folder (big and small folders) represented different sessions. The three small folders contained two printed pictures of a theme (animals, vacation destinations and portraits) that would be used in the picture card selection task. Meanwhile, the three big folders contained alphabetical colored reward cards with three alphabetical-options (A, B and C) to be used in the reward card selection task and a set of questionnaires to be answered by the participants after the persuasive attempts at the end of each session. An Internet Protocol (IP) camera was placed near the robot to record the activities during the experimental session (see Figure 1).

Before filling in the demographic information, the participants were asked to read and sign a consent form containing the procedure of the experiment and agreement for video recording. In the consent form, participants were notified that their participation was entirely voluntary and that they had the right to withdraw their permission to use the data recorded by notifying the experimenter up to 24 h after the session. They could also refuse to participate in the experiment without any reasons and stop their participation at any time during the experimental session. The experimenter would leave the room after ensuring the participants were fit to undergo the exercise by asking the participants themselves and had no further questions.

The robot started the first session by greeting the participant to ensure that the participants were aware of the role and the identity (face and voice) of the robot. After that, the robot briefly explained all the activities that needed to be done by the participants in that specific session. The first activity involves exercise. After completing the first activity, the persuasive attempts took place as the robot started the second activity. Participants were required to participate in two task selections: picture card selection and reward card selection. After completing the second activity, the participants were asked to fill in the second questionnaire consisting of liking, trusting beliefs and psychological reactance items in evaluating the designated social agent. The following session would start after the participants would tell the robot '*I am done*' upon which the social agent would change its identity (face and voice).

The whole procedure was repeated in three consecutive sessions each featuring a different number of interactive social cues of a robot. The experimenter debriefed the participants and presented a voucher as a token of appreciation at the end of the experiment.

2.5. Measures

As there were three sessions of the experiment (led by the robot with a different number of interactive social cues), participants were asked to complete the questionnaires described below three times.

2.5.1. Psychological reactance

We measured psychological reactance by applying the intertwined model of psychological reactance [20]. This model conceptualizes psychological reactance as consisting in two self-reported components: feelings of anger and negative cognitions. 5-point Likert scales indicating the level of *irritation, angriness, annoyance,* and *aggravation* toward the robot were used to rate the feelings of anger, with levels ranging from completely disagree (1) to completely agree (5). From these four items, we were able to construct a reliable measure (Cronbach's $\alpha = 0.75$) of anger towards the persuasive robot. The participants were then asked to write down their thoughts after being persuaded by the robot and to label each thought as positive (P), neutral (Neu) or negative (N). Only negative cognitions were counted in calculating the psychological reactance score using the steps taken by Dillard and Shen (2005) [20] (see also [53]).

2.5.2. Liking

The liking rate of the robot was rated using 9-point semantic differentials from the Godspeed Questionaire [54] indicating that '*Please rate your impression of David* (e.g. name of the social agent) *on these scales*': *dislike/ like, unfriendly/ friendly, unkind/ kind, unpleasant/ pleasant* and *awful/ nice.* This liking rate was assessed after the persuasive attempts by the agents at the end of each session. Cronbach's α for the five liking items of a persuasive robot was 0.81.

2.5.3. Trusting beliefs

To assess how high the associated number of interactive social cues on trusting beliefs, we used the questionnaires developed by Heerink et al. (2009) [55] and Tay et al. (2014) [56]. To estimate the trusting beliefs, three statements were used: '*I will trust Robin if he gives me advice again in the future*', '*I trust that Robin can provide me with good suggestions*', and '*I will follow the advice Robin gives me*' in 5 point-Likert scales with level ranging from completely disagree (1) to completely agree (5). The trusting beliefs measurement was found to be highly reliable (Cronbach's $\alpha = 0.85$).

2.5.4. Compliance

We assessed the compliance to the robot as follows: If the initial and final selections were inconsistent, the participants would be awarded 1-point for each selection [9,57,58]. For example, if a particular participant changed his/her choice of a picture and reward-card as asked by the robot, then the participant would be given the compliance score of 2. However, if the participant changed only the initial picture or only the initial reward card, then they would be given a score of 1. If participants would ignore the advice and keep to their initial selections, they would be given a score of 0.

3. Results

All statistical analyses for this study used the Statistical Package for the Social Sciences (SPSS) version 23. The sequence of the manipulated interactive social cues conditions by the agents was used as a covariate (and not as an independent variable) in all analyses. In the hypothesis testing section below, we first described the effects of the number of interactive social cues by the robot on psychological reactance, liking, trusting beliefs and compliance, as well as correlations between these dependent variables.

3.1. Hypothesis 1: psychological reactance

In analyzing the effect of the number of interactive social cues on psychological reactance, a repeated measure Analysis of Covariance (ANCOVA) test was run by comparing the scores of 3 (number of interactive social cues: no vs low vs high)×2 (elements of psychological reactance: feelings of anger and negative cognitions). Results indicated a significant main effect of the number of interactive social cues, $F(2, 18) = 7.62$, $p = 0.004$, partial $\eta^2 = 0.46$ for which hypothesis 1 was accepted. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated in this

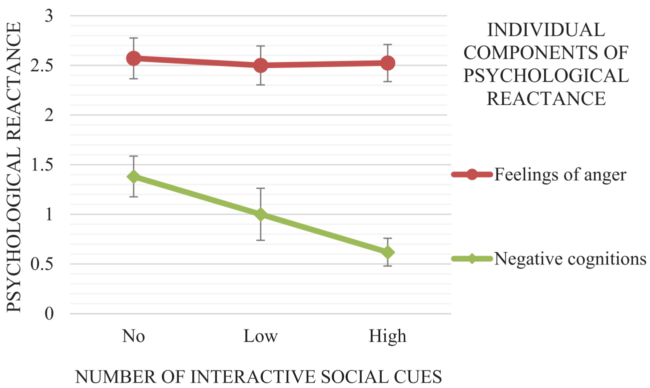

Figure 2. Mean and standard error of individual components of psychological reactance: feelings of anger and negative cognitions) on persuasive robot scores by the number of interactive social cues. Participants reported the highest reactance on the robot in no interactive social cue condition and the lowest reactance for the robot in high number of interactive social cues condition. The lowest feelings of anger scores were recorded by the robot in low number of interactive social cues condition.

test, $\chi^2(2) = 0.81$, $p = 0.14$. The linear test of within-subjects contrasts also demonstrated a significant relation between the independent and dependent variables, $F(1, 19) = 14.70$, $p = 0.001$, partial $\eta^2 = 0.44$. In line with our hypothesis, this main effect showed that participants reported the highest reactance towards the persuasive robot in no interactive social cues condition ($M = 1.98$, $SD = 0.84$), followed by the robot in low number of interactive social cues condition ($M = 1.75$, $SD = 0.94$) and the lowest reactance when interacting with the robot in high number of interactive social cues condition ($M = 1.57$, $SD = 0.62$).

A repeated measure one-way ANCOVA test was performed to examine the individual components of psychological reactance scores (feelings of anger and negative cognitions as two separate dependent variables) resulting from the manipulations of the number of interactive social cues (see Figure 2).

Several main results related to the individual components of psychological reactance measured were found. First, there was a significant main effect of the number of interactive social cues on feelings of anger, $F(2,18) = 10.44$, $p = 0.001$, partial $\eta^2 = 0.54$. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated in this test, $\chi^2(2) = 0.92$, $p = 0.63$. The linear test of within-subjects contrasts also demonstrated a significant relation between the independent, dependent and covariate variables, $F(1, 19) = 22.93, p < 0.001$, partial $\eta^2 = 0.55$. Results showed participants experienced the highest feelings of anger interacted with the robot in no interactive social cue condition ($M = 2.57$, $SD = 0.94$), followed by the robot in high number of interactive social cues condition ($M = 2.52$, $SD = 0.86$) and the lowest feeling of anger was recorded in low number of interactive social cues condition ($M = 2.50$, $SD = 0.90$).

Second, the number of interactive social cues manipulation resulted in a significant main effect for negative cognitions towards the robot, $F(2, 18) = 3.93, p = 0.038$, partial $\eta^2 = 0.30$. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated in this test, $\chi^2(2) = 4.95$, $p = 0.08$. The linear test of within-subjects contrasts also demonstrated a significant relation between the independent, dependent and covariate variables, $F(1, 19) = 13.46$, $p = 0.002$, partial $\eta^2 = 0.42$. As anticipated, the negative cognitions decreased as the number of interactive social cues increased. These results demonstrate that the lowest negative cognitions were experienced by participants in the high number of interactive social cues condition ($M = 0.62$, $SD = 0.64$), followed by the interaction in low number of interactive social cues condition ($M = 1.00$, $SD = 1.20$) and the highest negative cognitions was recorded in no interactive social cue condition ($M = 1.38$, $SD = 1.15$). Using the Bonferroni correction, pairwise comparisons revealed a significant difference in the mean negative cognitions scores only in the high number of interactive social cues and no interactive social cue conditions, $p = 0.02$. The score was 0.76 points lower for the robot in high number of interactive social cues condition than the robot in no interactive social cue condition, with a 95% confidence interval [−1.36 −0.16]. However, no evidence of the effect of the number of interactive social cues on negative cognitions for other pairs were significantly differed (no interactive social cue vs low number of interactive social cues, mean difference of 0.38, $p = 0.26$) and (low number of interactive social cues vs high number of interactive social cues: mean difference of 0.38, $p = 0.08$).

In summary, psychological reactance, and specifically the measure of negative cognitions was found to be lower when the robot has more interactive social cues.

3.2. *Hypothesis 2: liking*

We run a repeated measure ANCOVA with the number of interactive social cues of the robot as the independent variable, and liking score as the dependent variable. Results showed that a significant main effect of the number of interactive social cues on liking, $F(2, 18) = 8.88$, $p = 0.002$, partial $\eta^2 = 0.50$ for which hypothesis 2 was accepted. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 1.74$, $p = 0.42$. Confirming

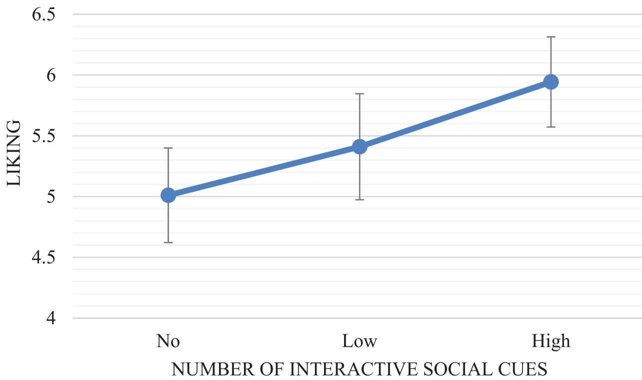

Figure 3. Mean and standard error of liking scores by the number of interactive social cues. Participants reported the highest liking score on the persuasive robot in high number of interactive social cues condition and the lowest liking score for the persuasive robot in no interactive social cue condition.

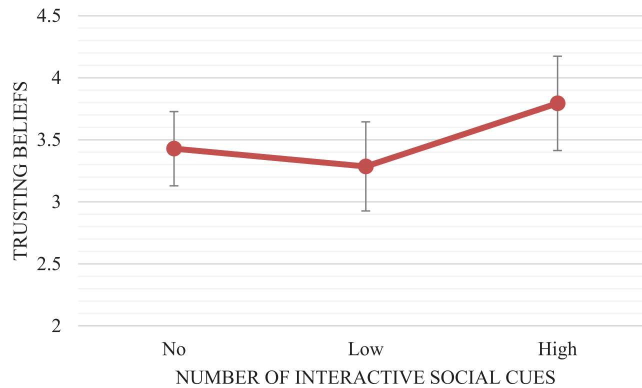

Figure 4. Mean and standard error trusting beliefs on persuasive robot scores by the number of interactive social cues. Participants reported the highest trusting beliefs on the persuasive robot in high number of interactive social cues condition and the lowest trusting beliefs for the persuasive robot in low number of interactive social cues condition.

our hypothesis, the linear test of within-subjects contrasts also showed a significant relationship between the independent, dependent and covariate variables, $F(1, 19) = 16.61$, $p = 0.001$, partial $\eta^2 = 0.47$.

As shown in Figure 3, results indicated that participants rated the robot in the high number of interactive social cues condition with the highest liking rate score ($M = 5.94$, $SD = 1.70$), followed by the robot in low number of interactive social cues condition ($M = 5.41$, $SD = 2.00$) and robot in no interactive social cues condition ($M = 5.01$, $SD = 1.78$). Using the Bonferroni correction, the pairwise comparisons for the liking score for the robot in high number of interactive social cues and the robot in no interactive social cue conditions was significant, $p = 0.05$. The score was 0.93 points higher for the robot in high number of interactive social cues than for the robot in no interactive social cue, with a 95% confidence interval [−0.07, 1.88]. However, no evidence of the effect of the number of interactive social cues on liking rate for other pairs were significantly differed (low number of interactive social cues vs. no interactive social cue, mean difference of 0.40, $p = 0.51$) and (high number of interactive social cues vs low number of interactive social cues: mean difference of 0.53, $p = 0.31$).

In summary, these analyses demonstrate clearly that liking on persuasive robot increased with the increment of the number of interactive social cues.

3.3. Hypothesis 3: trusting beliefs

A repeated measure of ANCOVA test showed the influence of the number of interactive social cues was not significant on trusting beliefs, $F(2, 18) = 3.22$, $p = 0.06$, partial $\eta^2 = 0.26$. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 0.20$, $p = 0.90$. Confirming our hypothesis, the linear test of within-subjects contrasts also showed a significant relationship between the independent, dependent and covariate variables, $F(1,19) = 5.51$, $p = 0.03$, partial $\eta^2 = 0.23$. This linear relationship indicates that when participants interacted with the robot without social praises as the interactive social cues (in low number of interactive social cues condition), trusting beliefs were lower ($M = 3.29$, $SD = 7.38$) compared to the interaction with the robot that expressed social praises (in no interactive social cue: $M = 3.43$, $SD = 6.87$). As demonstrated in Figure 4, the highest trusting beliefs were reported in high number of interactive social cues condition, $M = 3.79$, $SD = 7.94$.

In summary, these analyses reveal that persuasive robot with social praise enhances trusting beliefs towards the agent.

3.4. Hypothesis 4: compliance

We run Friedman Test because the measure of compliance was an interval variable that could have the value of either 0, 1 or 2. As results, we found that there was no statistically significant difference in compliance depending on the number of interactive social cues, $\chi^2(2) = 0.55$, $p = 0.76$. Thus, no conclusion can be made for the manipulation of the number of interactive social cues on compliance towards the persuasive robot.

3.5. Hypothesis 5: correlation between the dependent variables

With respect to the number of interactive social cues, Spearman's rho correlation coefficients were computed to

Table 2. Correlations test based on the number of interactive social cues.

No		Low		High	
r_{no}	p_{no}	r_{low}	p_{low}	r_{high}	p_{high}
Between psychological reactance and liking					
−0.90	< 0.001	−0.91	< 0.001	−0.72	< 0.001
Between psychological reactance and trusting beliefs					
0.63	0.002	−0.45	0.04	−0.23	0.32
Between liking and trusting beliefs					
0.50	0.02	0.48	0.03	0.51	0.02

assess the relationship between the dependent variables (psychological reactance, liking and trusting beliefs) that were used in the previous hypotheses. Correlation of compliance on other dependent variables was not reported since we found no significant main effect of the number of interactive social cues on compliance. As shown in Table 2, 2-tailed correlation test results demonstrate strong negative correlations between psychological reactance and liking, moderate negative correlations between psychological reactance and trusting beliefs, and moderate positive correlations between liking and trusting beliefs, concerning the number of interactive social cues.

In summary, an increase in psychological reactance towards the persuasive robot was correlated with lower liking and lower trusting beliefs.

4. Discussion

In this study, we showed that interactive social cues that persuasive robot display influenced positive social responses in humans which is in line with Social Agency theory [29]. Findings from this study improve our understanding in designing social cues for persuasive robots so that humans will positively perceive the persuasive attempts by the robots. This study also extends earlier research [38] in social psychology showing that interactive social cues [32,59] have profound positive effects on humans in human-agent interactions. Importantly, the current research is the first investigation of the effects of the number of interactive social cues by persuasive robots on psychological reactance, trusting beliefs and compliance in the context of the human-robot interaction.

Providing evidence for the first hypothesis, results showed that interactive social cues decreased the amount of psychological reactance experienced by the participants in persuasive attempts. Participants felt less reactance (and less negative cognitions) when interacting with the robot that mimicked their head's movements and interactively praised them in high number of interactive social cues condition. Participants also reported the highest reactance when the robot displayed random head movements and random social praises during the interaction in no interactive social cue condition. A potential explanation might be that the participants perceived the persuasive messages from the robot in high number of interactive social cues condition as the advice from a friend that wants them to change their initial choices for the participants' benefit, instead of as an order from a stranger. Earlier research has indeed shown that proper timing of social praises enhanced the perception of the friendliness of a robot [38] while mimicry increased the social attractiveness of the mimicker [45] and facilitated negotiations [60] in human-human interaction. Thus, less psychological reactance reported against the robot's persuasion in high number of interactive social cues condition compared to the robot that had random head movements and random social praises (vs low number of interactive social cues with head mimicry only). Finding in the first hypothesis indicates that the number of interactive social cues that a robot has is essential in designing persuasive robots so that the persuasion activity will invoke low reactance.

As expected in the second hypothesis, interactive social cues have a significant effect on liking towards the persuasive robot. This study shows that participants reported liking more the robot with the head mimicry and interactive social praises than the robot with the head mimicry only. They reported liking the least the robot with random head mimicry and random social praise. It can be suggested that the presence (no interactive social cues vs. low number of interactive social cues) and the amount (low number of interactive social cues vs. high number of interactive social cues) are essential for persuasive robots to be liked by humans. Regarding head mimicry, this result is partly in line with research in social value orientation on the mimicry-liking link [42], which suggested that people with prosocial value orientation (people who take the well-being of others in considerations and seek for alternatives that maximize their own and other's well-being [61]) like to be mimicked than not being mimicked in human-human interaction. Liking the interaction partner, however, did not differ either being mimicked or not being mimicked for proself (people that oriented to maximize one's own well-being, either for competitors or for the individualists [61]). Although the current research did not take into account participants' social value orientation, our study showed that head mimicry by the robot generally leads to liking, as was found in earlier studies [32,43]. Our result also can be explained by the findings highlighted in the earlier study [62, 63], in which perceived similarity is a strong predictor of liking. Humans like more robots that mimic them (see [64]). Concerning interactive social praise, this experiment found positive effects of interactive social praise on liking which is similar to earlier findings [65]. Participants liked to interact with the robot that has interactive social praises compared to the agent with random social praise. A possible explanation for this result could be that some participants reported they felt strange when the robot uttered random praise, and they claimed that the compliments delivered by the robot were insincere and not genuine. This negative thought leads to liking the least the robot offering random praises in no interactive social cue condition than the robot with interactive praises in high number of interactive social cues condition. Replicating the findings in hypothesis 1, testing hypothesis 2 also showed that head mimicry and interactive social praise strengthened the effect of liking the robot as shown in high interactive social cues condition [38].

In support of hypothesis 3, our results demonstrated the expected influence of interactive social cues on trusting beliefs only partly. That is, participants did not report higher trusting beliefs for the robot that mimicked their head movements (in low number of interactive social cues condition) than the robot that moves its head randomly and praises the participants at random moments (in no interactive social cue condition). However, as expected, the participants reported higher trusting beliefs on the robot with head mimicry and interactive social praise (in high number of interactive social cues condition) than the robot with both random head's movement and social praises (in no interactive social cue condition). These findings demonstrated that the participants had higher trusting beliefs towards the robot supporting social praise. Although the robot in no interactive social cue condition randomly praises the participants and some of the participants labeled them as a 'weird agent', people still choose to trust the 'weird' robot than the robot without any social praise like in the low number of interactive social cues condition. Thus, our study provides evidence that trusting belief in persuasive robots can be developed using social praise. This finding is in line with an earlier study [66] that showed trusting beliefs was influenced positively by casual praise feedback in online product reviews. Apart from building trust using social praise, this study also showed that trusting beliefs towards the robot could be enhanced by combining social praise with head mimicry as used in high number of interactive social cues condition. This finding is in agreement with an earlier experimental study evaluating the effect of a similar head mimicry [32] an automotive setting using a non-embodied agent. Specifically, participants in that study trusted a 2D virtual agent more in the mimicked condition than the agent in the non-mimicked condition.

Related to Hypothesis 4, unfortunately, we found no evidence of the effect of interactive social cues on compliance. We expect that this is due to a limited number of choices given to the participants during the persuasive attempts (two choices in the first task selection and three choices in the second task selection) that which does not appear to be enough to influence the participants to comply with the persuasive robot. An earlier study provides evidence that compliance towards persuasive agent can be enhanced by extending to the number of choices given in each task [31].

4.1. Design implications

This study provides insights into how to design interactive social cues for persuasive robots so that the persuasion activity will positively affect humans. We have demonstrated that psychological reactance towards persuasive robots is strongly and negatively correlated with liking (Hypothesis 5). By combining these results, we infer that it is crucial for designers to model likable interactive social cues on persuasive robots so that people will experience lower psychological reactance during persuasive attempts. This can be done by implementing head mimicry and interactive social praise. We also learned that social praises, even combined with random head movement, lead to higher trusting beliefs.

4.2. Future work

Future research might investigate the effect of interactive social cues on human responses using humanoid-type robots (i.e. robots that have two arms for displaying social gestures) with different appearances and sizes. Another exciting avenue for future researches might be to investigate the effects of other interactive social cues such as mimicry of rhythmic gestures and facial emotional resemblance on humans' social responses for example engagement level and perceived friendliness. Future research might also explore the effect of interactive social cues on compliance by using non-dichotomous activities such as offering more than one alternative options to the participants and doing that for many tasks in order to enhance the chances of successful persuasive attempts. Moreover, future research could explore the effect of culture and gender of the participants on social responses like psychological reactance.

5. Conclusions

This article contributes to the scientific literature by extending our knowledge regarding the effects of the number of interactive social cues on persuasive robotics:

(1) we have shown how head mimicry of a persuasive robot can lower psychological reactance and induce liking (2) we have illustrated how well-timed social praise can lower psychological reactance and enhance liking (3) we have found that social praise even in random moments can increase trusting beliefs and (4) we have demonstrated how increasing the number of interactive social cues on a persuasive robot can lead to lower psychological reactance and higher liking. Finally (5) we have shown that low psychological reactance towards an agent was correlated with high liking and high trusting beliefs. From a practical standpoint, our results demonstrate how designing the persuasive robots with interactive social cues for example head mimicry and interactive social praises can lead to more positively perceived persuasion.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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