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Non-Verbal Cues on Robot-Group Persuasion

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Abstract— **When integrating robots into human daily life, persuasive power can be essential. However, there are often group dynamics which can complicate persuasion. This study focuses on how non-verbal cues, specifically gaze and hand gestures, affect the persuasiveness of a social robot. We have designed a protocol to include non-verbal cues in the social robot Vizzy (head and eye gaze, hand gestures) and test them in a series of experiments using the paradigm of the "Desert Survival Challenge". The goal of the robot is to persuade the participants of the game into changing their answers whilst avoiding negative feelings. It is hypothesized that the non-verbal cues will help avoid psychological reactance without diminishing compliance to the verbal requests issued by the robot. This phenomenon has been verified before for single person persuasion, but it is yet to be tested on groups. Thus, the goal of this project is to verify the effect of non-verbal cues in group persuasion by a robot and comparing it to single person persuasion. The results showed that the robot's gestures increased compliance by the group and the gaze behaviour decreased psychological reactance.**

I. INTRODUCTION

Persuasion can be defined as an attempt to influence the thoughts, opinions, or actions of others through communication. This skill can be particularly useful when attempting to achieve a successful inclusion of autonomous robots in human daily life, such as in the classroom as teachers or assistants, in healthcare settings like in hospitals, or even as team members at work. Indeed, research on persuasion has been carried out in various settings: in [1] there was a focus on persuasion in healthcare, in [3] robot persuasion on children was studied, which can be useful for robots' integration into classrooms, and in [4] there was research into people's reaction to repeated persuasion in an office setting. However, one thing all of these studies did not consider is that, in many situations, persuasion will happen towards a group and not a single person, such as in the classroom [5] and in the service industry [14].

Group interaction is quite different from a psychological view point from an interaction between only two people or, in this case, a robot and a person. In group persuasion, there are some new concepts which must be taken into account such as group belonging, and social influence, which none of the previous studies on single person persuasion can take into consideration.

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As a result, we have conducted a user study that attempts to measure the effects of non-verbal cues on robot-group persuasion and compare it to individual persuasion in a hypothetical game scenario. The metric used to evaluate the success of persuasion was the compliance achieved. This compliance was measured as the number of requests accepted by the participants out of the total of nine requests always made by the robot. To evaluate the participants' feelings during the interaction, psychological reactance was obtained from a post-experiment questionnaire. Psychological reactance [7] is a psychological phenomenon that can happen when a person feels that their freedom is being limited. It can occur during persuasion if the interaction is too controlling, and it can result in increased resistance.

The results show that the robot's gestures can improve compliance by the group, and the gaze behaviour can decrease psychological reactance. When comparing the individual and group behaviours, we observe that groups are less likely to comply with the robot's suggestions and are more prone to experiencing high levels of psychological reactance. Overall, this study opens up new avenues for research on the impact of non-verbal cues on group persuasion and highlights the difference between individual and group interactions when integrating robots into human daily life.

The remainder of this paper is organized as follows. In Section II we discuss several works that focus on human-robot persuasion, group persuasion in human-human interaction, and social influence in both human and human-robot groups. In section III we formulate our hypotheses. Our user study is described in Section IV. We then analyse the results in Section V. In Section VI we discuss the results, study limitations, and ideas for future work. Section VII presents the final conclusions.

II. RELATED WORK

A. Robot-Human Persuasion

When using robots for persuasion, the use of direct language seems to be favoured as shown in [2] [3]. However, strategies must be employed to mitigate the psychological reaction which may arise from this type of interaction. A commonly employed technique is the use of social cues by the robot. In [8] and [9], it is demonstrated that it is possible to improve people's perception of the interaction and reduce reactance towards the persuasive robot by using interactive social cues like head mimicry and social praises without affecting user compliance. In [10], it was even found that non-verbal cues, like gaze and gesturing increased compliance.

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All of the previously mentioned studies focused on individual persuasion. This results in a significant gap in our knowledge of robot persuasion as most daily interactions occur in group settings. This is the gap we are hoping to bridge with this experimental study, which focuses on non-verbal cues on robot-group persuasion.

B. Group Persuasion versus Social Influence

One must consider how group persuasion has some new challenges which were not faced in single person persuasion. One of these challenges is the social influence exerted by the people in the group. In [11], it was shown that people tend to be influenced by the majority in a group. Furthermore, [12] has shown that if a single individual disagrees with the group, it can lead to negative perceptions of said individual. Thus, when only one member tries to persuade a disagreeing group, it is expected that there will be a higher resistance than when trying to persuade only one disagreeing individual. This can lead to a lower compliance rate and potentially to worse perception of this member by the group.

Let us first establish the difference between persuasion and influence. In persuasion there is a conscious attempt on the source's part to actively influence its targets' behaviours, thoughts, or actions. When persuasion is successful and the targets' attitudes are changed, it is because the source used good arguments which convinced the targets. Contrarily, influence is often exerted unbeknownst to the source and no arguments or persuasive power are necessary. During influence, the targets' attitudes are changed due to two main reasons: fear of rejection or an acceptance of the source's opinions as fact, without a persuasive attempt being necessary. There have been many research efforts into robot's influence over groups, as described in the next paragraph. However, robot persuasion of groups is a much more unexplored field. As such, our goal with this paper is to provide a new line of research in group persuasion.

There have been studies showing that robots may be able to cause social influence in humans [13][14]. However, these studies were done in extremely controlled interactions: in [13] participants performed their tasks on an individual user-interface and were separated into cubicles, having no communication between them and in [14] the influence was once again conducted virtually through the use of videos. When similar studies are performed in-person with only one participant being influenced by a group of robots, the results are not as linear, with [16] reporting successful robot influence, but [17] showing none. It is hypothesized in [18] that influence by robots only happens when the task is not objective. Indeed, many of the previous studies focused on robots' social influence on objective tasks since they recreated social influence experiments previously carried out for human-human interaction such as [11]. This means that whilst humans have social influence both on objective and subjective tasks, robots seem to only have it for subjective tasks. Furthermore, many of these experiments explored a somewhat rare paradigm, multiple robots interacting with a single individual. The most common interaction scenarios happen between one robot and multiple people. This is an unfavourable scenario for robot influence since, according to [15], conformity is more likely to happen when more robots are used.

Our experiment consists of a subjective ranking, which means the robot does have a chance of promoting social influence. However, it is only one robot whilst the participants will be in a group of three. Thus, it has to compete with the social influence caused by humans, which, from the limitations of the previous studies, does seem to overpower that of the robot. This means that, in order to achieve the highest compliance possible, the robot will have to depend on its persuasive power, as the social influence it could possibly cause in the group should not be very significant. Furthermore, [19] and [20] have shown that in human-human persuasion, people are usually more easily persuaded by messages from their in-group than from the out-group. If the robot is seen as an outsider by the human group, it could further hinder the persuasion efforts.

III. Hypotheses

Taking into account the related work previously discussed, we anticipate that the cues used as well as the setting chosen (group vs individual) will have a significant impact on the success of persuasion as well as on the participants' perception of the robot.

(1) Human groups present higher resistance to robot persuasion when compared to a human individual, resulting in lower compliance and higher psychological reactance. This hypothesis is an extrapolation of the human phenomenon described in [11] to robot interaction. The robot's expected lack of social influence [17] [15] and of group belonging [19] [20] also contribute to this hypothesis.

(2) Non-verbal cues reduce psychological reactance and possibly increase compliance in robot-group persuasion. This hypothesis extends the results of individual persuasion [8] [9] [10] into group persuasion.

IV. Methods

An experiment was performed where Vizzy, a humanoid robot (shown in Fig.3), tried to persuade participants into changing their answers throughout the Desert Survival Problem. The problem presents an hypothetical scenario where there has been a plane crash in a desert. Only a small group of people survived and they recovered some objects from the plane. The participants must rank the objects according to their importance for survival.

There were three study variables: Robot Gaze (use vs non-use), Robot Hand Gestures (use vs non-use), and Group size (individual vs group). In the individual condition only one participant interacts with the robot. In the group condition, a group of three participants interacts with the robot. For each group setting there are, thus, four possible conditions: No Cue, Gaze, Gestures, and Gaze+Gestures.

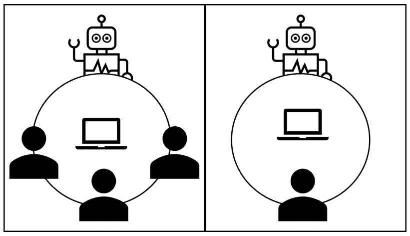

Fig. 1. Illustration of the spacial configuration of the participants and the robot for the group setting (left) and the individual setting (right).

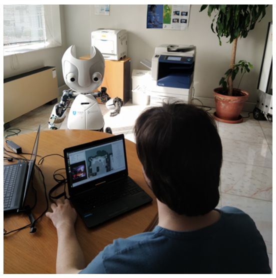

Fig. 2. Demonstration of the experimental setup for the Individual setting.

A. Experimental Setup

Participants sat in a room alone with the robot to avoid any human interference in the experiment. They were asked to order the objects for the Desert Survival Task on a laptop, whose screen was then shared with the person controlling the robot, allowing for the choice of the appropriate suggestions from a different room.

To guarantee that the robot's cues were visible to all participants in the group setting, the three participants plus the robot were all distributed around a table with a laptop facing the participants for answer submission (see Fig.1, left side).

For the individual setting, the participant sat on one side of the table with the laptop and the robot was placed on the other side, directly in front of the participant (see Fig.1, right side, and Fig.2).

B. Gesture and Gaze Design

A Wizard-of-Oz approach was used for the speech and gaze of the robot. The gestures were associated to each speech command.

The gaze behaviour had three stages: when no-one was talking, the robot looked at the laptop; when a participant spoke, the robot looked at them, looking back at the laptop once they finished; when the robot wanted to make a suggestion, it would look at the participant to elicit their attention (in the group setting, it would look around at the group), look back at the laptop, start speaking, and then redirect its look to the participant, as if awaiting for an answer.

The gestures used consisted of waving when greeting the group and pointing at the laptop with the answer sheet when requesting changes (see Fig.3). Both of these are ideational gestures, meaning they are linked to the semantic content of the speech. According to [21], the presence of any type of gesturing can lead to a higher perception of competence of the speaker, higher effectiveness of the communicative style, and higher message persuasiveness, but only ideational gestures lead to higher perceived composure of the speaker. Hence why they were selected for this experiment.

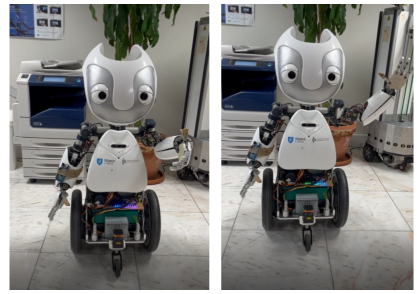

Fig. 3. Gestures used during interaction.

C. Experimental Design

Participants were asked to solve the Desert Survival Problem in collaboration with Vizzy the robot. They were told that there is a correct answer and that their results would be scored in accordance. However, this is a very subjective game, which allows for the robot to justify any suggestion it may need to make, existing reasons to lower or raise any given object on the ranking. The goal is to test how persuasive the robot can be in affecting the ranking of the objects.

Before the study starts, each participant was asked to submit an individual answer to the desert survival problem. This allows us to guarantee that the robot always gives suggestions which go against the beliefs of all participants, meaning all the participants must be persuaded. Then, all participants will gather in a room with the robot and submit one group answer. The participants will receive the objects in a randomized order and can switch them as many times as they want within a time limit.

The robot made nine suggestions throughout the interaction, using direct language, as this strategy has shown the best results in persuasion [1][3]. The robot also offered a reasoning for every suggestion. The suggestions would always be the same (see table I), for example, switching the eighth and ninth objects, however the justification would vary to match the object in that position. These nine suggestions were divided into three categories: object placement suggestions which consisted on clearly stating in which position an object should be placed; switch suggestions where the robot would ask for two specific objects to be switched; and raise/lower suggestions which consisted on the statement that a certain object should be placed either higher or lower, but with no mention of which position it should be changed. Compliance was measured as the number of suggestions accepted by the group.

TABLE I

SUGGESTIONS GIVEN BY THE ROBOT THROUGHOUT THE GAME

Sugestion Type	Suggestions
Object Placement	Most important object Second most important object Least important object
Switch Objects	Switch fifth and third objects Switch ninth and eight objects Switch tenth and sixth
Raise/Lower an object	Raise the fourth object Raise the tenth object Lower the seventh object

TABLE II

SENTENCES SHOWN TO PARTICIPANTS TO RATE IN THE POST-EXPERIMENT QUESTIONNAIRE

Sentence	Perception being evaluated
I felt the robot was looking at me.	Gaze Perception
The robot's behaviour was human-like.	Human Similarity
The robot was interactive.	Interactivity
The robot's gaze was natural.	Gaze Naturality
The robot's movement was human-like.	Movement Naturality

D. Post-Experiment Questionnaire

Once the Desert Survival task was completed, participants were asked to fill out a questionnaire individually which was used to estimate the psychological reactance as well as gather their perceptions of the robot and the interaction. According to [22], psychological reactance can be evaluated by two main components: Feelings of Anger and Negative Cognitions. Feelings of Anger can be measured through a 5-point Likert scale rating the frequency of the following feelings: Irritation, Anger, Annoyance, and Aggravation; where 1 corresponds to "did not experience this feeling at all" and 5 to "Frequently experienced this feeling". Negative cognitions may be measured by asking participants to write all their opinions about the robot, rating them as positive, neutral, or negative, and counting how many negative opinions each participant had.

Participants were also asked to evaluate their agreement with five sentences regarding the robot's behaviour (see Table II) using a 5-point Likert scale, where 1 is Totally Disagree and 5 is Completely Agree.

E. Participants

There were a total of 72 participants, half in the individual setting and half in the group setting, and evenly divided by the four conditions (Control, Gestures, Gaze, and Gaze+Gestures). Participants were assigned randomly to each condition.

There were three requirements to participate in the experiment: participants must be 18 years or older, speak fluent Portuguese as this was the language used by the robot, and never have played the Desert Survival Problem.

In order to understand the profile of the participants, let us analyse the collected demographic data shown in Table III. It is clear that there is a predominance of young people with a background in engineering. This was expected as the study

TABLE III

DEMOGRAPHIC DATA OF THE PARTICIPANTS FROM THE IN-PERSON EXPERIMENT.

Nationality	Participants
Portuguese	97%
Italian	1.5%
Serbian	1.5%

Age Groups	Participants
18-24	82%
25-34	15%
55-64	3%

Gender	Participants
Female	47%
Male	53%

Field of Study/Work	Participants
Engineering	71%
Social Sciences	13%
Arts	6%
Natural Sciences	4%
Other	6%

and recruitment of participants were carried out within the University. This can be a limiting factor of the study as its participants are not a good representation of all population, but rather of a younger university-aged population who is probably more familiar and more interested in robots than the average person.

V. RESULTS

The normality of the data was tested using the Shapiro-Wilk test. Because the data was non-parametric, the analysis was done using ANOVA on ranks combined with the Mann-Whitney U Test for pair-wise comparisons. When more than one pair-wise comparison was performed, a Bonferroni correction was applied to avoid alpha inflation. We start by verifying the participants were able to recognize the robot's cues, followed by the verification of the hypothesis and a general discussion.

A. ANOVA on Ranks

To perform our ANOVA, we paired the conditions to test the effect of each cue. In order to test the effect of Gaze, the No Cue and Gestures conditions were grouped as No Gaze, and the Gaze and Gaze+Gestures were grouped as Gaze. Similarly, to test the effect of Gestures, the No Cue and Gaze conditions were grouped as No Gestures, and Gestures and Gaze+Gestures were grouped as Gestures. These groupings were only used for the ANOVA on Ranks. For the following pair-wise comparison, we used each condition separately.

Regarding the Cue Perception by the participants, the ANOVA on Ranks showed significant differences on the *Gaze Perception* ($p < 0.001$), *Interactivity* ($p = 0.028$), *Gaze Naturality* ($p < 0.001$), and *Movement Naturality* ($p < 0.001$), between the Gaze and No Gaze conditions. Given the significant effects found with the ANOVA, pair-wise comparisons were performed for every Cue Perception except for Human-Likeness as it did not show any significance on the ANOVA.

Regarding the *Compliance* and *Psychological Reactance* variables, the ANOVA on Ranks showed significant differences on the *Compliance* between the Gestures and No Gestures conditions ($p<0.001$) and the Individual and Group conditions ($p<0.001$). The p-value for the comparison of *Irritation* ($p = 0.05$) between Individual and Group conditions was at the threshold, but it was still considered for pair-wise comparison. Given the significant effects found with the ANOVA, pair-wise comparisons were carried out for the *Compliance* and *Irritation*.

B. Verification of Cue Perception by the Participants

Firstly, there was a verification of the participants' perception of the robot's Gaze and Gestures through the analysis of the 5-Point Likert scale responses regarding the Gaze Perception, the Gaze Naturality, and the Movement Naturality. This analysis was carried out firstly as the previously explained ANOVA, followed by a pair-wise comparison between each Cue condition and the No Cue condition for the significant variables. To avoid alpha inflation, a Bonferroni correction will be applied with a new alpha of 1.67%.

The pair-wise comparison yielded the following results for the Group setting. When compared to the No Cue condition (M = 1.67, SD = 1.05), there was an increased Gaze Perception in both the Gaze (M = 3.89, SD = 1.10, $p = 0.002$), and Gaze+Gestures (M = 4.22, SD = 1.23, $p = 0.002$) conditions for the Group setting. When evaluating the Gaze Naturality, the Gaze (M = 3.22, SD = 0.92, $p < 0.001$) and Gaze+Gestures (M = 2.89, SD = 0.74, $p = 0.001$) conditions achieve a significantly higher rating than the No Cue condition (M = 1.44, SD = 0.50). This clearly shows participants were able to identify the robot's use of Gaze.

In the No Cue condition (M = 1.11, SD = 0.31) there is a significantly smaller Movement Naturality than in all the Cue conditions: Gaze (M = 3.22, SD = 1.23, $p = 0.001$), Gestures (M = 2.78, SD = 0.91, $p = 0.001$), and Gaze+Gestures (M = 3.11, SD = 0.57, $p < 0.001$). Confirming that the Gestures were also detected by the participants.

In the Individual setting, there was no statistical difference in the Gaze Perception ($p > 0.05$) or in the Gaze Naturality ($p > 0.05$) between any of the conditions. This probably happened because the robot was placed directly in front of the participant, meaning its gaze was already directed at them in the No Cue condition. This does not necessarily mean participants did not notice the movements of the robot's head and eyes, simply that it did not contribute to their perception of the robot's Gaze. Indeed, when analyzing the Movement Naturality, there is a significant difference between the No Cue (M = 1.78, SD = 1.03) and the Gaze (M = 3.78, SD = 1.13, $p = 0.005$) conditions, meaning the participants did notice the Gaze movement. There was no statistical difference in any of the Cue Perception variables between the No Cue and the Gestures conditions.

C. Individual vs Group settings

The first hypothesis predicted the Group setting participants would exhibit lower compliance and higher psychological reactance than the ones in the Individual setting. To verify this hypothesis, the Compliance, the Feelings of Anger, and the Negative Cognitions were compared for the No Cue condition. Indeed, the compliance of the Individual setting (M = 4.33, SD = 1.63) was significantly higher than that of the Group setting (M = 2.67, SD = 0.94, $p = 0.019$) (See Fig.4, left). In terms of the Feelings of Anger and Negative Cognitions experienced, the only statistically significant difference was on the Irritation. The Group Irritation (M = 2.55, SD = 0.83) was significantly higher than the Individual one (M = 1.78, SD = 0.72, $p = 0.043$) (See Fig.4, right).

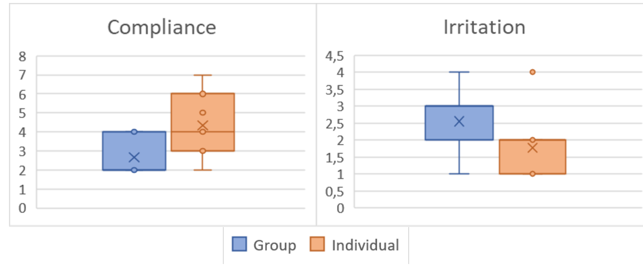

Fig. 4. Box and Whiskers plots for the group and individual compliance and irritation experienced.

D. No Cue vs Cue conditions

We performed pair-wise comparisons between the Cue condition and each No Cue condition, totalling three comparisons for each dependent variable. To avoid alpha inflation, a Bonferroni correction will be applied with a new alpha of 1.67%.

The second hypothesis predicted that the non-verbal cues would result in increased compliance and decreased psychological reactance. For the group setting, the compliance was significantly higher in both the Gestures (M = 5.00, SD = 0.00, $p < 0.001$) and Gaze+Gestures (M = 4.00, SD = 0.82, $p = 0.010$) conditions than in the No Cue condition (M = 2.67, SD = 0.94) (see Fig. 5, left). The irritation was significantly smaller in the Gaze condition (M = 1.56, SD = 0.50, $p = 0.012$) than in the No Cue condition (M = 2.56, SD = 0.83) (see Fig. 5, right).

For the Individual setting, there was no statistical difference in the compliance, negative feelings or negative cognitions towards the robot between the different conditions. It is possible that the effects of the non-verbal cues are not noticeable in the Individual setting due to two factors: firstly, the previously discussed lack of recognition for the gaze behaviour and secondly, the fact that, in the No Cue condition, the compliance (M = 4.33, SD = 1.63) was already quite high and the feelings of Irritation (M = 1.78, SD = 0.92), Anger (M = 1.11, SD = 0.31), Annoyance (M = 1.78, SD = 1.03), Aggravation (M = 2.11, SD = 1.59), and the amount of Negative Opinions (M = 1.11, SD = 0.87) were quite low, meaning there was not a very significant space for improvement.

E. Compliance by Type of Suggestion

In the Group setting, Direct (M = 0.5, SD = 0.65) suggestions were significantly less accepted than both Switch (M = 1.5, SD = 0.87, $p < 0.001$) and Raise/Lower requests

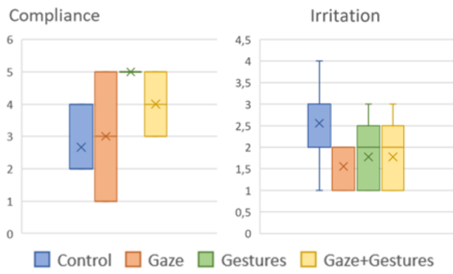

Fig. 5. Box and Whiskers plots for the group compliance and irritation experienced by condition.

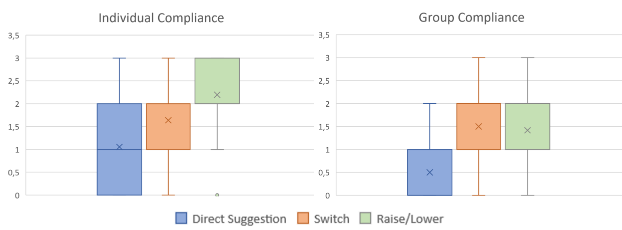

Fig. 6. Box and Whiskers plots for the group and individual compliance by request type.

(M = 1.42, SD = 0.95, $p < 0.001$) (See Fig.6, right). Switch and Raise/Lower requests were equally accepted.

In the Individual setting, there was also a significant difference between the Direct Suggestions (M = 1.06, SD = 0.91) and the Switch (M = 1.64, SD = 0.92, p = 0.007) and Raise/Lower (M = 2.19, SD = 0.88, $p < 0.001$) requests (See Fig.6, left). However, there was also a difference between the Switch requests and the Raise/Lower requests (p = 0.007).

VI. Discussion

The results of this study support the hypothesis that non-verbal cues have a similar effect on group persuasion to the one in individual persuasion shown in previous studies. Specifically, it was verified that a robot's gestures improve compliance by the group, and the gaze behaviour decreases psychological reactance. The gaze affected one of the two domains of the intertwined model for psychological reactance: Feelings of Anger, shown by the diminished irritation.

This effect is particularly important in group persuasion as it was also shown that the psychological reactance experienced by the group is higher than that of an individual and the compliance is lower, as predicted in the first hypothesis. This way, non-verbal cues can potentially be used to approximate both the compliance and the psychological reactance of a group to that of an individual.

Something that must be kept in mind is the setting in which the experiment was performed. It describes the effect of non-verbal cues on persuasion in a game setting. As such, the results are great evidence for implementation of these cues in casual settings, for example for companion and server robots. These cues need to be studied further before being used in more serious or even critical and risky situations such as healthcare or public safety as there is no guarantee people will react the same way. Even within this game, it is possible to verify a relation between the compliance and the type of suggestion made. More serious suggestions which affected the game the most, meaning the direct suggestions regarding the first, second, and last object in the list, showed a significantly smaller compliance in all of the conditions. Suggestions that seem to have less impact on the game, such as switching the eighth and ninth object or simply raising or lowering one object without a direct indication to which placement, resulted in a significantly higher compliance. This happened both in the individual and in the group settings.

For future work, it would be interesting to study the effects of varying degrees of gesturing complexity on group persuasion. Since a significant effect on compliance was achieved using simple cues, perhaps more complex gestures can lead to an even higher compliance or have an effect on psychological reactance similar to that of the gaze behaviour. Repeating the experiment with an automated group gaze behaviour could also be of interest. The automated gaze could improve the perceived gaze naturality (M = 3.22, SD = 0.92) which might potentiate its effects on persuasion.

VII. Conclusions

Persuasion refers to the act of attempting to sway the beliefs, attitudes, or behaviors of others through effective communication. This capability is particularly relevant in ensuring the seamless integration of autonomous robots into various aspects of human life, such as in educational settings as teachers or aids, in healthcare facilities, or even in professional environments as co-workers. However, group persuasion is a difficult task which often results in low compliance and high psychological reactance. The results of this study provide evidence for the role of non-verbal cues in facilitating group persuasion.

This study aims at evaluating the effects of gaze and gestures on group persuasion and it showed promising results, providing evidence for the use of gesturing to increase group compliance and gaze to decrease psychological reactance. This effect has previously been shown on individual persuasion, but our work demonstrates it also happens in a group setting. This effect could potentially show itself even more useful in group persuasion due to the increased psychological reactance and lower compliance experienced by groups when compared to individuals.

VIII. Acknowledgments

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