Nonverbal Robot-Group Interaction Using an Imitated Gaze Cue

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ABSTRACT

Ensuring that a particular and unsuspecting member of a group is the recipient of a salient-item hand-over is a complicated interaction. The robot must effectively, expediently and reliably communicate its intentions to advert any tendency within the group towards antinormative behaviour. In this paper, we study how a robot can establish the participant roles of such an interaction using imitated social and contextual cues. We designed two gaze cues, the first was designed to discourage antinormative behaviour through individualising a particular member of the group and the other to the contrary. We designed and conducted a field experiment (*456* participants in *64* trials) in which small groups of people (between *3* and *20* people) assembled in front of the robot, which then attempted to pass a salient object to a particular group member by presenting a physical cue, followed by one of two variations of a gaze cue. Our results showed that presenting the individualising cue had a significant ($z=3.733$, $p=0.0002$) effect on the robot's ability to ensure that an arbitrary group member did not take the salient object and that the selected participant did.

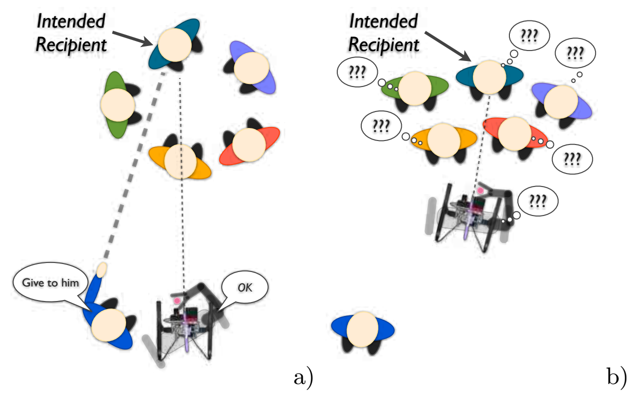

Figure 1: The exemplar scenario: a) The robot is tasked with giving an object to a particular member of a group. The group is not privy to the intended recipient. b) Upon arrival, the robot's intentions must be communicated to the group

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces-Interaction styles

General Terms

Design, Experimentation, Human Factors.

Keywords

Intended recipient, Participant roles, Social and contextual cues, Gaze

1. INTRODUCTION

Although robotics is relatively young, the quantity and quality of the research in this field is rapidly extending the horizon of possibilities. As such, the desire to see robots commonplace in society now seems fulfillable. However, recent research, such as [38, 25, 9], has made evident that a number of significant challenges remain to be overcome before a machine can effectively communicate, coexist and cooperate with a human; in contrast to building an autonomous machine that operates individually or in collaboration with other machines. For robots to be accepted into society, the robots must be capable of effective and natural interactions with humans. This move towards pervasive robotics has exacerbated the need for sophisticated Human-Robot Interaction (HRI).

For instance, consider the scenario illustrated in Fig.1a where a human tasks the robot with giving the salient object it is holding to a particular recipient, who remains unaware that the robot has been issued this instruction. Assuming that the robot is capable of the non-trivial tasks of identifying the correct intended recipient, navigating to the group of people and correctly recognising the intended recipient upon arrival, a significant problem remains. Upon the robot's arrival it is likely that the group will reconfigure [13, 17, 16] (shown in Fig.1b) and, depending on the saliency of the object the robot is carrying, the group may actively compete for it [10]. In order to ensure the item is delivered to the correct person the robot must quickly, actively and in a socially acceptable manner, inform the intended recipient that the object is intended for him/her and inform the remain-

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der of the group that the object is not intended for them. Thus, the question becomes: how can the robot effectively, expediently and reliably communicate this to the group at the hand-over stage (shown in Fig.1b)?

Somewhat counter-intuitive, but well accepted by psychologists, is that a significantly larger portion of the information conveyed whilst communicating is carried by means other than the words spoken. Mehrabian was among the first to attempt to quantify this phenomenon and proposed the now well-known, '7%-38%-55% rule' [23]. This 'rule' states that 7% of the information is conveyed by the words, 38% by the tone and 55% by body language. There is much debate over the exact distributions and the extent to which they are affected by the message content (whether it is a mood, instruction or an idea being communicated). Regardless, it seems to be commonly accepted that body language is a robust, efficient (a relatively large amount of information can be communicated over a small temporal space) and significant contributor to communication [18, 9].

With body language identified as a potential mechanism for conveying the robot's intention, a number of questions arise: What human behaviour is reasonable to expect from the group in this scenario? Is it feasible for a robot to present cues that will mitigate this behaviour, in order to allow it to achieve its task? Will the humans react in a predictable fashion to the robot presenting these cues? In this paper we attempt to examine these questions by deepening our understanding of how the lack of social and contextual cues during an interaction can result in a tendency to antinormative behaviour and greater equality of participation; from drawing on deindividuation in the context of anonymity leading to salient items being stolen in situations with few perceived social consequences [6, 10] and through observations of robot-human interactions. Furthermore, by exploring how social and contextual cues capable of mitigating this behaviour might be designed for robots and by investigating the effectiveness of a robot's presentation of these cues in the exemplar scenario presented in Fig.1b.

2. RELATED WORK

2.1 Expected Behaviour

The behaviours displayed by a group are likely to be different when visited by a robot as opposed to another human. This is due to a number of factors. Primarily: robots are relatively novel to society and we lack social norms for such encounters, we tend not to perceive robots as a human [26, 32] and, depending on how the individual perceives the robot's appearance, the robot might fall in to the 'Uncanny Valley'. In which case the robot's appearance would be highly disturbing, or even repulsive [8, 29].

Whilst the 'Uncanny Valley' is typically avoided by designing robots' appearances to be clearly non-human, the two other issues remain. The lack of established social norms and constraints in this context facilitates deindividuation within the group [5, 10]. The anonymity that the robot allows, further exacerbates this deindividuation [28]. Also, while the robot is perceived as mearly a machine, it will not cause the group to feel subject to social influence or identification [19]. This culmination of the lack of social influence and norms, and deindividuation leads to antinormative behaviour [6, 10, 28]. In which case, the group-decision (in the context of the exemplar scenario) is likely to be polarised to either: the group expediently dispossessing the robot of the salient object that it holds, or not acting in the scenario [6, 10, 28]. Introducing additional social and contextual cues is likely to reduce the presentation of this behaviour by individualising a member of the group [6, 10, 28].

2.2 Physical Presentation

The manner in which an object is presented is an important determinant in the potential recipient's acceptance of the item [11]. For instance, the speed, jerkiness of movement, the predictability of the path taken by the manipulator arm holding the object, proximity, final pose height and whether the arm movements are made within the field of view of the human, all contribute to acceptance [22, 33, 11, 12, 14, 15]. It has also been demonstrated that social and physical cues play an important role in guiding the act of transferring of an object between a robot and human. Some recent examples are presented in [20, 7, 4].

Using human-like manipulator motions (gestures) is purported to be a key factor in avoiding confusions in human-robot communication and interaction [20]. In support of this, it is shown in [7] that subjects can successfully take objects without explicit instruction, but in response to a simple reaching gesture. Furthermore, physical proximity of the robot's end-effector to a human seems also to be interpreted as an indication that the gesture, and its subsequent meaning, was directed to that particular individual [7].

Basili et al., [4], make the claim that, by having the robot mimic crucial aspects of human behaviour the human partners are able to infer the robot's intentions and to predict its actions. They go on to show, through a study of human-human handover, that a reaching-lifting gesture is a consistent prelude to a handover and can implicitly communicate intention. It seems that these reaching gestures, potentially as simple as an end-effector movement on the vector towards the human, are interpreted by the human using the task context [35] and understood as the social cue of offering.

2.3 Gaze

Another cue that has been shown useful in directing an interaction to a particular individual, is gaze. For instance, the Equilibrium of Intimacy theory states that the fundamental effects on a gazed upon individual, is a heightening of arousal [1]. Argyle and Ingham [3] further explored the relations between distance, gaze and mutual gaze and provided further evidence to suggest that it can be used to establish and maintain a connection between two parties.

Interestingly, Stephenson [34] reports an observer bias towards reporting more eye gaze at a distance; a claim based on studies in which participants attempted to detect eye gazes amongst fixation points about the head. This is interesting as it shows observers' willingness to accept gazes in the vicinity of the head as being direct eye gazes. A contextual element to gaze was added by Argyle [2], in which it is suggested that gaze has a number of different functions and that its role will vary depending on situation. Recent research, such as [24, 36, 25, 5], supports the claim that gaze, even if it be that of a robot's, serves to individualise a member of a group.

Cues such as the those previously mentioned are relatively easy for a robot to generate and present. Clearly then, a robot can leverage a person's familiarity with social cues and ability to interpret them within a context in order to

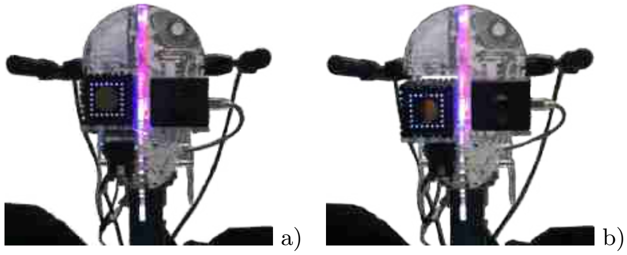

Figure 2: The 'Look' - a) The robot orientates its head (at ~*180°/s*) and eyes to towards the selected participant b) the robot then dips its gaze by *10°* for *0.5s* before returning it to that shown in a)

Figure 3: 'No Look' - The robot does not actively orientate its head towards the selected participant and it lowers its gaze to *-30° from horizontial*

individualise a member of the group and to facilitate object transfer. These cues require social-interaction space and contextual-task space in order to be interpreted and, therefore, will be referred to in the remainder of this paper as sociocontextual cues; for the sake of brevity.

3. DESIGN OF THE CUES

The following sub-sections describe the design of the sociocontextual cues used in the experiments. Three cues were used: a physical presentation cue designed to offer an object to a particular individual within the observing group, and two gaze cues. One designed to individualise a particular member of the observing group and the other was designed to the contrary.

3.1 Physical Presentation Cue

Building on the previous work in manipulation [37, 27, 30] by our research team, we developed and implemented a reaching gesture in compliance with the recommendations made in [22, 33, 11, 12, 14, 15, 20, 7, 4]. For safety reasons, the robot was isolated from the participants with the use of a physical barrier; in this case a table. The target end-effector position is the point which lies on the line between the robot and intended receiver (the goal bearing), and that is *10cm* (a nominal margin) towards the robot from the edge of the table on the participants' side.

The cartesian coordinates of the target end-effector position in 3D space and the end-effector pose objectives including collision and joint limit checks, the straightness of the pose on the vertical plane and the orientation of the presented object were used to create cost function based on sigmoids. The cost function was minimised using Levenberg-Marquardt's (LM) algorithm to obtain a valid pose for the given task constraints/objectives. [37, 30]. The manipulator's inbuilt inter-pose planner was also configured so as to conform to the speed and jerkiness recommendations made in the aforementioned literature. In practice, the temporal duration of this cue was *10-12 seconds*; depending on the goal bearing.

3.2 Gaze Cues

As previously mentioned, we designed two gaze cues for use in this study. The first, designed to individualise a particular member of the observing group, shall be referred to herein with as the Look. The other, designed to overtly avoid eye gaze with any members of the observing group and thus encourage deindividuation, shall be referred to herein with as the No Look. The robot's head was orientated at *80° counter clock-wise* from the sagittal plane, at approximately *15°/s*, as a precursor to both the Look and No Look cues (marked Scan End in Fig.6).

Fig.2 shows the Look as seen by the intended recipient as illustrated in Fig.1. The Look commences with the robot reorienting its head towards a individual member of the observing group at approximately *180°/s*. The effect of this relatively high angular rotation is dramatic and was designed to draw the groups' visual attendance to the robot's head. The effect is further exacerbated by the robot's head itself, which has been designed so that an approximately *10mm* wide strip along the sagittal plane is brightly illuminated as seen in the figure.

At this point in the overall cue, the robot's gaze is directed to a particular member of the group, which in itself serves to somewhat individualise said group member [24, 36, 25, 5]. The robot then dips its eyes by *10°*, to align it eyes towards the salient object, pauses for *0.5 seconds* and then returns its gaze to the individual. This action is designed to strengthen the illusion that the robot is scrutinising the particular member of the group and to further individualise this particular group member in both their eyes and in the eyes of the group.

Conversly, the No Look, shown in Fig.3, was designed to avoid eye gaze with any members of the observing group and thus encourage deindividuation. In the No Look, the robot's eyes were dipped to *-30° from horizontal*. Which, as can be seen from the figure, gives the impression that the robot is not looking at the group. This cue did not involve a head reorientation.

As the intention was to explore the effects of individualising a member of the group or adding to the anonymity within the group, both of the gaze cues were designed to be overt. They were designed to convey the coarse message of either: "I am looking at you" or "I am not looking at anyone" so that we could more clearly see any effect that individualising a particular group member would have in the context of the scenario presented in this paper.

4. EXPERIMENT

To further deepen our understanding and in order to evaluate the effect of the previously described cues, we conducted a field experiment during a University-wide open day for prospective undergraduate students. When a small group of people (up to *20* people) assembled in front of the robot, it attempted to pass a salient object to a particular group member by presenting the physical sociocontextual cue, followed by one of two variations of a gaze sociocontextual cue.

In the following sub-sections we describe our: participants, experimental design and procedure, evaluation measures and hypotheses.

4.1 Method

4.1.1 Participants

There were *456* participants (*283* male and *173* female). They were predominately final year high school students. There was no remuneration for participation.

The experiment was designed with two participant roles:

Selected - Refers to the particular participant that the robot selected randomly in each trial and to whom it attempted to transfer a salient object.

Onlooker - Refers to all other participants present during the trial.

4.1.2 Setting

We used the RobotAssist platform (Fig.4), an approximately *1.5m* tall mobile robot with an approximately *0.35m* radius. As can be seen in the figure, the robot is equipped with a wheeled base and an anthropomorphic upper body. The upper body consist of a six degree-of-freedom (DoF) manipulator and a two DoF sensor laden head. The first DoF of the head is configured to pan the entire head. The second DoF tilts the eyes only; giving the impression that the eyes are moving rather then the head nodding. Not shown in the figure is the Point Grey Dragonfly2 camera (fitted with a *190*° wide angle lens) attached to the robot's chest during the experiment. The platform is detailed in [21].

The experiment was staged in a stall situated in a large exhibition arena, during a University-wide open day, see Fig.5. The robot was standing behind a table that was set approximately *2m* back from the traffic corridor. The machine used for making cotton candy was on the table, as shown in Fig.6.

4.1.3 Experiment Cases

There were two cases for the robot issued gaze cue:

Look - Immediately prior to commencing the handover the robot performed the Look cue.

No Look - Immediately prior to commencing the handover the robot performed the No Look cue.

The cues were performed as described in Section 3.2. All other acts/cues were consistent throughout the trials.

4.1.4 Procedure

Each trial commenced with the robot announcing, via its inbuilt speakers, that it was an *"advanced machine capable of complex tasks, one of which it would now demonstrate"*. The robot then commenced making cotton candy, a process that takes approximately *2 minutes*. The motivation for having the robot make cotton candy was: a) it is a novel scene likely to naturally draw spectators, and b) the expected participants would likely find cotton candy salient. Thus, the experimenters could observe more natural behaviour, as the participants would not require coercion and/or instruction to participate in the experiment.

Figure 4: The RobotAssist HRI research platform with the components key to this paper labelled

Figure 5: The setting for the experiment

Once the cotton candy making procedure was complete the robot then displayed the object in front of its chest, close to its body - as shown in Fig.6. The robot then orientated its head to the *Scan Start* and began to rotate counter-clockwise at approximately *15*°*/s*, the head's rotation paused for *2 seconds* at *P1*, *P2* and *P3* and came to rest at *Scan End*.

During the head scanning stage, the robot used Intel's OpenCV implementation of the Haar face detect algorithm to detect the faces of the onlookers. From these, the robot randomly chose the selected participant. The head bearing and the target pose required for the manipulator to reach the participant were then calculated.

The robot then randomly selected the experiment condition. In the case of Look being selected (Fig.7a), the robot

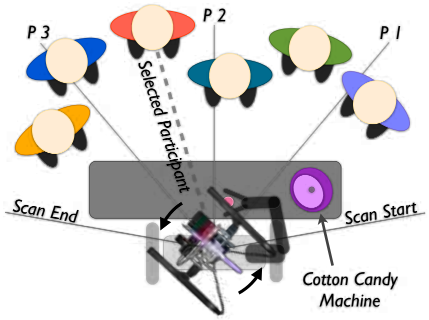

Figure 6: Illustration of the experiment set-up

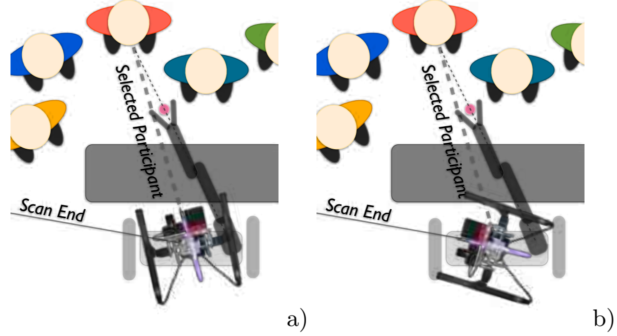

Figure 7: Illustration of the two experiment cases. The: a) Look handover and, b) No Look handover

orientated its head to the bearing of the selected participant and then completed the Look followed be the physical presentation cue (as described in Section 3.2). In the case of No Look being selected (Fig.7b), the robot's head remained at the *Scan End* orientation, the robot then completed the No Look followed by the physical presentation cue (as described in Section 3.2).

4.2 Measurement

The type of gaze cue performed by the robot was the only independent variable. The dependent variables involved two quantitive measures of participant behaviour.

Time to Take - This is a measure of the time from when the gaze cue completed, until a participant (either the selected or an onlooker) moved to take the object. If no move was made within *25 seconds* the object was considered not taken. Preliminary trials indicated that after this time, if the object had not already been taken, people tended to ask if they could take the item rather than just taking it. In order to quantify this measure, the robot was configured to log images of the scene from its chest camera. The log was taken for a duration of *30 seconds* from when the robot controller reported the gaze cue to be complete. The images were logged at approximately *2Hz*, each logged image was time-stamped on capture. The image in which the participant (selected or onlooker) moved to take the object was identified by an experimenter, post-experiment, and the time to take was determined from the time-stamps.

Success - This refers to whether the object was taken by the selected participant (considered success) or by an onlooker. As previously mentioned, during the scanning stage the robot first attempts to detect the faces of all participants and then, from those, randomly chose the selected participant. The images during this stage were collected from the robot's eye camera, the image that contained the randomly chosen selected participant was autonomously identified and cropped to the size of the face. The image of the selected participants face was then time-stamped and logged; all other images from the scan were discarded. An experimenter reviewed the chest camera log, post-experiment, and identified if it was the selected participant or an onlooker that took the object, or whether the object was not taken.

4.3 Hypotheses

From the understanding of group behaviour acquired in Section 2, we developed the following hypothesis and predictions.

Hypothesis - The robot's presentation of anonymity-reducing sociocontextual cues will lead to reduced equality of participation within the crowd.

Prediction - Upon presenting such a cue, the robot will be more successful in confining the interaction to the selected participant. Specifically, we predict:

1. a decreased likelihood that the object will be taken by an onlooker as opposed to the selected participant.
2. an increased likelihood that the object is taken.

5. RESULTS

Trials involving experimenters, children and less than three participants were not considered in the results, leaving *64* trials for analysis. A total of *4,173* (*4,111* - scene and *62* - face) labelled images of the *64* trials were autonomously collected by the robot during the experiment. A MATLAB script was written that automatically collated and replayed the collected data in a readably interruptible manner. Fig.8 shows two examples of the collated data. As can be seen, the scene images capture the participants and, the robot's head and arm movements. Fig.8a shows an example of a Look trial, the robot's eyes can be seen to be directed towards a participant. Fig.8b shows an example of a No Look trial, the robot's eyes can be seen to be directed downwards. On average, *64.2* scene images were logged per trial.

Table 1 details the participant role-trial distribution that occurred during the experiment. The robot randomly selected the experimental case (Look or No Look) for each trial. The experimenters were not aware of robot's selection *a prori* to the robot acting. The experimenters did not attempt to control the number of participants or to select the participants for the trials. In total, *64* trials (*40* - Look and *24* - No Look) were conducted over a *5* hour period (*10:30-15:30*).

There was a similar number of onlookers per trial for both cases ($\bar{x}$=*5.9* - Look and $\bar{x}$=*6.5* - No Look). Likewise, the gender representation per trial was similar for both cases (Male: $\bar{x}$=*4.4* - Look, $\bar{x}$=*4.5* - No Look and Female: $\bar{x}$=*2.5* - Look, $\bar{x}$=*3.0* - No Look). There was an overall bias towards male participation per trial (Male: $\bar{x}$=*4.4* and Female: $\bar{x}$=*2.7*). This bias seemed (subjectively) to the experimenters to be consistent with the Open Day attendance.

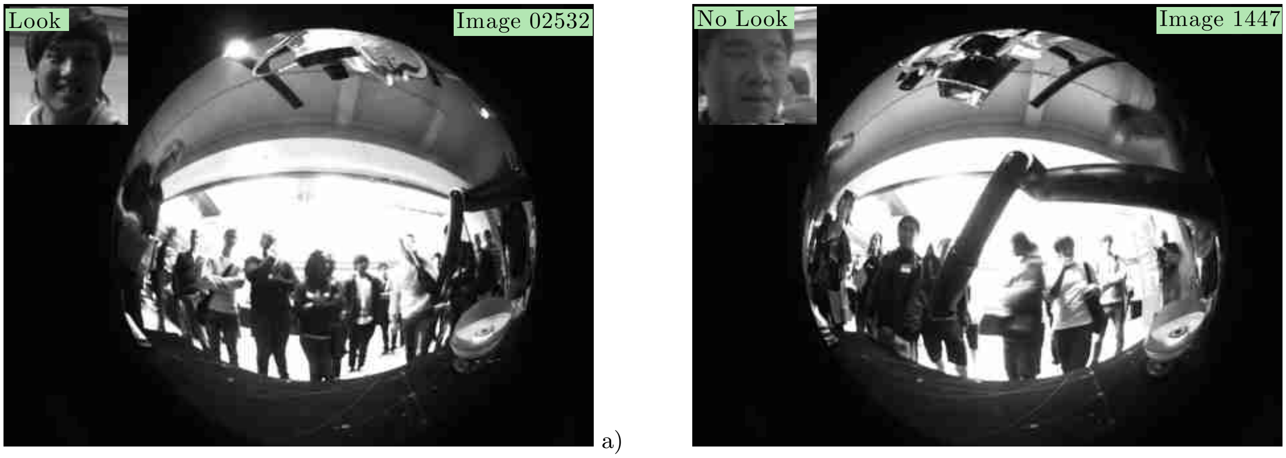

Figure 8: Two examples of the replayed experiment data: a) A Look trial, the robot's eyes can be seen to be directed towards a participant. b) A No Look trial, the robot's eyes can be seen to be directed downwards

Table 1: Participant role-trial distribution

	Case	Onlooker	Selected	*Total*
Look	*Male*	150	24	*174*
	Female	85	16	*101*
No Look	*Male*	91	18	*109*
	Female	66	6	*72*
	Total	*392*	*64*	**456**

Table 2: Outcomes frequency

	Case	Success	Fail	Not Taken
Look	*Male*	22	0	2
	Female	10	6	0
No Look	*Male*	7	7	4
	Female	1	3	2

Table 2 details the outcomes frequency; where the possible outcomes are Success - the selected participant took the item, Fail - an onlooker took the item, and Not Taken - the item was not taken. A *2*x*3* (gender was not considered) Chi-Square analysis was performed and a significant main effect was revealed between Look and No Look ($\chi^2=14.29$, $p<0.001$). Over the *64* trials, the Look resulted in a success rate of *32/40* and for No Look, *8/24*. The z-ratio for the significance of the difference between these two independent proportions confirmed significance ($z=3.733$, $p=0.0002$). A *2*x*2* Fisher Exact Probability Test was used to analyse the Look and No Look success frequencies by gender. A significant gender effect was revealed ($p<0.05$).

Figure 9 shows the temporal distribution of the time to take the object, for both cases and over all *64* trials. As the sample rate of the logged scene images was approximately *2Hz*, it was reasonable only to determine the time to take to the nearest second. Therefore, for each case, histograms (with bin sizes of *1 second*) of the time to take the object, with the instances where the object was not taken ignored, were constructed and then normalised with the number of trials of the respective case. For the Look trials: $\bar{x}=10.91$ $\sigma=3.23$, *mode=10 and median=10*. For the No Look trials: $\bar{x}=8.94$, $\sigma=3.01$, *mode=6 and median=9*. A two-sample pooled t-test with equal variances ($n_1+n_2>40$) reveals a significant difference in the time to take between the two conditions $t=2.417$, $p=0.019$. The proportion of the trials in

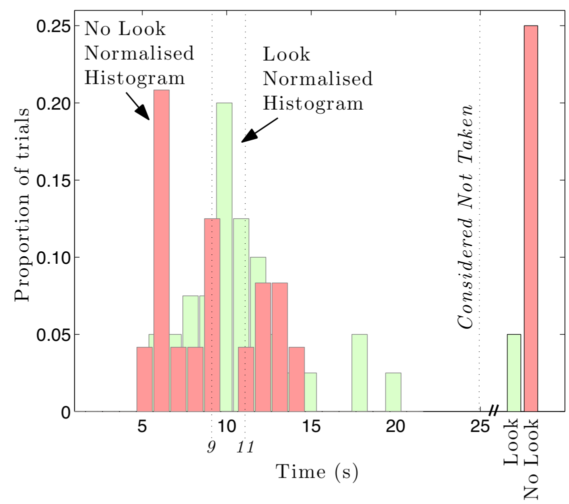

Figure 9: Time elapsed after the gaze cue before the object was taken

which the object was not taken within *25 seconds* is significantly higher in the No Look trials ($p<0.007$ - found through a *2*x*2* Fisher Exact Probability Test analysis).

6. DISCUSSION

The empirical results presented in this paper provide support for our hypotheses that the robot's presentation of individualising sociocontextual cues will lead to reduced equality of participation within the crowd. While all *64* trials used the physical presentation cue, only *40* trials used the sociocontextual cue designed to reduce anonymity (the Look) while the remaining *24* trials use a sociocontextual cue designed to further encourage anonymity (the No Look).

Presenting the Look cue resulted in a significant difference (*z=3.733, p=0.0002*) in the proportion of the trials in which it was the selected participant who took the object (*32/40*) compared to the trials in which the No Look was presented (*8/24*). These results suggest that, through the use of the Look cue the robot was able to manipulate the participants into conforming to the role of onlooker or selected. Furthermore, they suggest that the robot was able to non-verbally and implicitly communicate its intention to the group in a manner that induced conformity. These results confirm our prediction that presenting the Look cue will increase the likelihood that the object will be taken by the selected participant, rather than an onlooker.

Our prediction that the overall likelihood that the object is taken will be larger when the robot has presented the individualising cue was also confirmed. Results show that whilst the object was typically taken *2 seconds* sooner ($p=0.019$) in the No Look trials than in the Look trials ($\bar{x}=10.91$ - Look and $\bar{x}=8.94$ - No Look), the proportion of trials in which the object was not taken was significantly larger ($p<0.007$) in the No Look trials (*0.25* for No Look as opposed to *0.05* for Look). During the Look trials the move to take the object was centred around the time the manipulator came to rest. Interestingly though, the results show that in the No Look trials the move to take the object was on average *2 seconds* prior to the manipulator coming to rest. This is likely due to the group having not associated ownership of the object with an individual and actively competing for it. Also, subjectively, from the comments and gestures made by the participants and from reviewing the logs, it seems to the experimenters that the participants were less likely to take the object in the No Look trials as they were confused as to: a) whether the demonstration was over, b) whether the cotton candy was on offer, and/or c) whom it was on offer.

Evident in the results, but not predicted, was a significant gender bias towards males ($p<0.05$) taking the cotton candy. This could potentially be due to a gender affinity or restraint, although from [31] it seems that males tend more to think of robots as being human-like, where as females perceive them as being more machine-like. This could also account for the gender bias, as it is reasonable to ascribe the reduced effect of the individualising cues to females' tendency to not anthropomorphise robots; which would reduce the social influence of the cue. In such, this result warrants further investigation and will be explored in future work.

Limitations - That presented, has a number of limitations. The participants used in the study were undoubtedly somewhat prepared for encountering novel stimuli as they travelled to a university, potentially for the first time, for the Open Day. As such, these participants may not be representative of the general population. Also, these results may not generalise across cultures or even demographics/age-groups. In future we intend to conduct similarly structured experiments off-campus in public places so that a more representative range of participants are available for the robot to attract. Another limitation of the study was the limited interactivity of our robot. A number of participates showed signs that they had potentially understood the robot's intention, but remained hesitant. If, in these situations, the robot were able to detect the hesitation and re-issue the cue it seems possible that our results would improve.

7. CONCLUSIONS

In this study, we focused on quantifying the ability of a robot to mitigate antinormative behaviour by presenting appropriate sociocontextual cues. A field experiment was conducted in which a total of *456* participants were attracted, in small groups (up to *20* people per group) by the robot which would then attempt to pass a salient object to a particular group member.

We found that the robot's presentation of individualising sociocontextual cues during a robot-group interaction lead to a reduction in the antinormative behaviour of the group and a reduction in the equality of participation. Specifically, we found that a presented cue's tendency to individualise had a significant effect ($\chi^2=14.29$, $p<0.001$) on the behaviour of the group. Upon the robot's presentation of individualising sociocontextual cues we found that the selected participant took the object in *4/5* cases, as opposed to *1/3* when a non-individualising cue was presented (*z=3.733, p=0.0002*). These results suggest that, through the use of the individualising cue, the robot was able to manipulate the participants into conforming to the role of onlooker or selected.

While the results presented in this paper are limited, they provide evidence to support our hypotheses that the likelihood that an object will be taken by a selected participant is increased upon the presentation of cues that individualise that participant. Further work is required to generalise our results and to extend our understanding of a robot's use of sociocontextual cues during human-robot interactions.

8. ACKNOWLEDGMENTS

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