An Exploration of Social Grouping in Robots: Effects of Behavioral Mimicry, Appearance, and Eye Gaze

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Abstract

People naturally and easily establish social groupings based on appearance, behavior, and other nonverbal signals. However, psychologists have yet to understand how these varied signals interact. For example, which factor has the strongest effect on establishing social groups? What happens when two of the factors conflict? Part of the difficulty of answering these questions is that people are unique and stochastic stimuli. To address this problem, we use robots as a visually simple and precisely controllable platform for examining the relative influence of social grouping features. We examine how behavioral mimicry, similarity of appearance, and direction of gaze influence peoples' perception of which group a robot belongs to. Experimental data shows that behavioral mimicry has the most dominant influence on social grouping, though this influence is modulated by appearance. Non-mutual gaze was found to be a weak modulator of the perception of grouping. These results provide insight into the phenomenon of social grouping, and suggest areas for future exploration.

Keywords: Attention; Mimicry; Appearance; Grouping; Perception.

Introduction

People naturally categorize others into social groups. These categorizations are made quickly and often depend on superficial factors such as behavioral mimicry, physical similarity, and directed eye gaze. Despite their superficial nature, social grouping decisions can have lasting impacts on judgments about those groups (Tajfel, 2010).

Behavioral mimicry involves adopting the nonverbal behavior of an interaction partner (Baaren, Janssen, Chartland, & Dijksterhuis, 2009). Previous research identifies the importance of behavioral mimicry in the perception of human grouping. According to earlier findings, behavioral mimicry can be used to include oneself in a social group (Lakin, Chartrand, & Arkin, 2008). Moreover, some argue it facilitates social communication by increasing affiliation, which results in strengthened relationships (Lakin, Jefferis, Cheng, & Chartrand, 2003; Stel & Vonk, 2010; Baaren, Holland, Kawakami, & Knippenberg, 2004). The effects of behavioral mimicry are not limited to the partners in the exchange. Non-participating observers are known to view interactions with greater degree of nonverbal mimicry as more positive (Bernieri, Gillis, Davis, & Grahe, 1996; Parrill & Kimbara, 2006).

Likewise, physical appearance is an important factor, as research shows that the presence of similarities between the physical features of interacting parties increases their classification as a cohesive group (Dasgupta, Banaji, & Abelson, 1999). It is suggested that this increase occurs because physical appearance is a salient perceptual feature which evokes the belief that similar group members also share some psychological characteristics (Campbell, 1958; Duncan, 1976; Sagar & Schofield, 1980).

Direction of gaze is also identified as a factor in some social groupings. Groups of interaction partners in a conversational setting are found to be influenced by gaze direction (Sacks, Schegloff, & Jefferson, 1974; Goodwin, 1981). While there is some evidence that eye gaze may be an influential factor in the perception of human groups, the lack of support for an effect in a wider range of groupings suggests that this influence may not be generalized to other types of groups. However, gaze direction may enhance the influence of other factors by increasing awareness of them: it is known to cue the attention of an observer (Hietanen, 1999, 2003) even at ages as early as 5 months (Scaife & Bruner, 1975; Farroni, Johnson, Brockbank, & Simion, 2000).

The perception of social interactions and grouping in exchanges between humans and machines can also be influenced by behavior mimicry, appearance, and gaze. The effect of behavioral mimicry is investigated in a study showing that humans rate exchanges in which their facial gestures are mimicked by a robot as more favorable than those without any mimicry (Riek & Robinson, 2008). There is further evidence that a seemingly trivial physical similarity, such as wearing an armband of the same color as a marked computer, induces humans to assess computers of the same color as more similar to themselves as compared to computers of different colors (Nass & Moon, 2000). Another recent study suggests that variations in the proportion of interaction time during which a robot's gaze is directed towards a person can influence whether that person feels like a member of a group (Mutlu, Shiwa, Kanda, Ishiguro, & Hagita, 2009).

While previous studies have examined the influence of behavioral mimicry, physical appearance, and gaze in perceiving both human and human-robot groupings, none have explored more than one of these important factors at a time. The current experiment systematically varied these factors in order to determine their relative importance.

Robots provide an excellent platform for testing such effects. Because their appearance and behavior can be precisely manipulated, robots allow researchers to perform studies that involve carefully varying multiple factors. Additionally, anatomically realistic motions enhance the impression of agency (MacDorman, 2006), thereby increasing the possibility of generalization to human social interaction.

Our hypotheses were as follows:

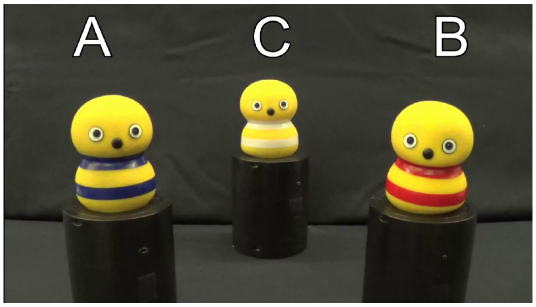


Figure 1: A sample screenshot from the videos shown to the participants.

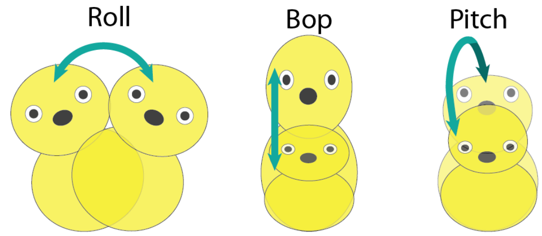


Figure 2: The move combinations used for creating dances for the robots.

H1 Behavioral mimicry will positively influence the perception of robot groupings.

H2 Similarity of physical appearance will positively influence the perception of robot groupings.

H3 Gaze will increase attention to a factor, and will therefore increase the effect of any present mimicry or physical similarity.

To test these hypotheses, we generated short video clips showing three robots that looked and behaved in systematically manipulated ways (Figure 1). Two of the robots were "leading" robots, and always performed distinct dances, wore different colors, and were oriented towards the observing human participant. The third robot, the "follower," either assumed some of the leaders' characteristics or exhibited unique ones. Participants were asked to group the follower with exactly one of the leaders. By evaluating participants' choices with respect to the presence of behavioral mimicry, physical similarities, and directed gaze, we investigated the individual and interaction effects of these three factors.

Methods

The experiment was designed to evaluate the relative influences of the three factors identified earlier on the phenomenon of social grouping. Each of these factors was a variable in this experiment, with carefully selected settings to identify their individual influences on the perception of grouping as well as their interactions.

We presented participants with a series of short video clips featuring three robots. At the conclusion of each video, participants were asked to decide whether one of the robots, a "follower" (identified as robot C) belonged in a group with one robot leader (identified as A) or a different leader (identified as B). This data allowed us to identify the relative effect of each factor in peoples' evaluations of social groupings.

Stimuli

The robots used for this experiment were modified My-Keepon robots (made by BeatBots LLC), physically similar, consumer-grade versions of the research-grade Keepon Pro robot. Keepon robots are designed for human-robot interaction studies (Kozima, Michalowski, & Nakagawa, 2009). Their minimalist exterior design and simple kinematics make them excellent stimuli for expressing attention and for differentiating their appearance with added "clothes."

We modified the 7-inch tall, snowman-shaped, interactive toy to give individual control over its three DC motors. The three motors are capable of performing four unique motions: pan (around the base), roll (left/right lean), bob (up and down), and pitch (front/back lean). Using three of these primitives (Figure 2) in different combinations, we generated three unique robot "dances". Dances are short, fixed sequences of moves that repeat over the duration of the video clip, for instance, lean left then lean right. These simple sequences are easy to identify as distinct dances.

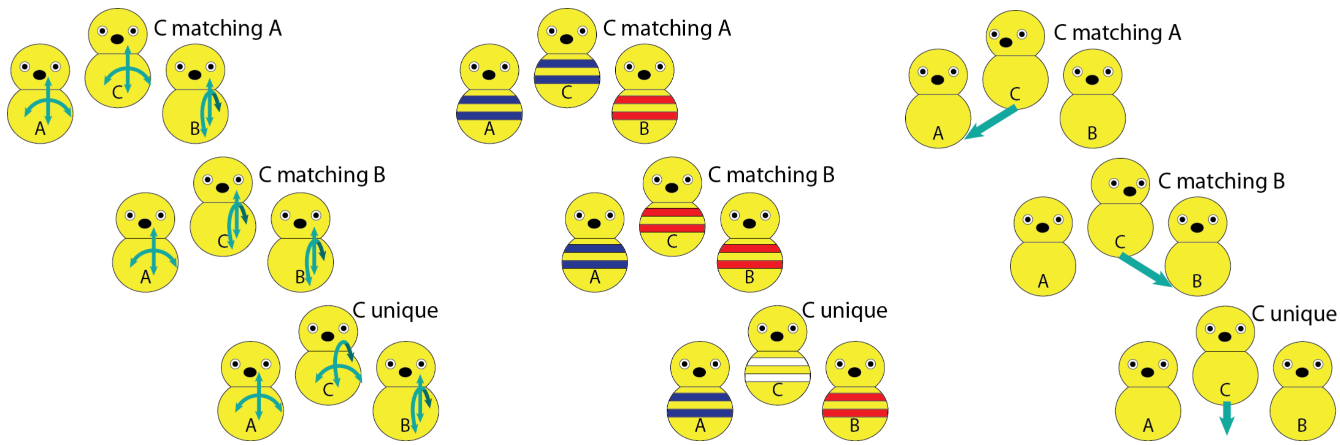
The robots in the videos varied along three dimensions, corresponding to the three experimental variables. Each variable had three possible settings: C matched A, C matched B, or C was neutral compared to A and B. Robots A and B always had different appearances and dances . The possible settings for the three variables are shown in Figure 3.

Behavioral mimicry. The first variable was the "behavior" of robot C, which was the dance that robot C performed. When C followed another robot's motions, it made identical movements to that robot with a small (two second) delay, to elicit the appearance of mimicry (Figure 3a).

Appearance. The second variable was appearance, which was varied using differently-colored "scarves" and "belts" around the necks and midsections of the robots (Figure 3b).

Eye gaze. The third variable was the direction of robot C's gaze during the video. To evoke the appearance of "looking at" one of the other robots, C oriented its eyes and body toward that robot (Figure 3c). In the neutral setting (looking straight ahead), robot C's gaze direction is the same as both leaders', providing no bias towards either.

Each combination of variable settings constituted an experimental "condition". We recorded one 30-second video clip for every condition for a total of 27 videos. For each video, we carefully manipulated the display to avoid any potential bias toward a particular robot or condition. Table 1 shows a list of all the 27 experimental conditions.



(a) Behavior: Robot A and Robot B always performed the indicated dances, while Robot C's dances matched A, B, or neither.

(b) Appearance: Robot A always wore blue bands; robot B always wore red bands; robot C wore blue, red, or white bands.

(c) Gaze: Robot C either looks towards A, looks towards B, or looks towards the observer.

Figure 3: Three factors affecting social interaction (behavioral mimicry, physical appearance, and gaze) were the dependent variables in this experiment. Each variable had three possible values, shown here.

Procedure

We recruited 103 participants (49 females) online from Amazon's Mechanical Turk. They were compensated $2.50 for their time during the experiment. Each participant was randomly assigned three sets of three videos. In each set, among the three video conditions, one of the experimental variables was constant while the other two variables had randomly-assigned values. Thus, each participant viewed nine of the 27 available videos.

After each video clip (Figure 1), the participant was asked to answer the question: "Whose group does Keepon C belong to?" This was a forced-choice response with only two options: "Robot A" and "Robot B." The next clip was shown only after the participant answered the question.

As a stimulus check, participants viewed six additional videos following the nine experimental videos. These videos were similar to the experimental videos, albeit shorter, and were followed by explicit questions about the video content: "Who is C looking at?", "Who is C dancing like?", and "Who does C dress like?". This stimulus-check enabled us to remove data from participants who were unable to interpret the factors appropriately for instance, not interpreting the robot's gaze as the orientation of its body and eyes.

Results

The raw experimental data of the responses for each experimental condition is shown in Table 1. Of the 103 initial participants, we excluded six (5.8%) for failing stimulus checks. We analyzed the responses of the remaining 97 participants.

Manipulation checks. First, we evaluated whether participants showed any overall preference for choice A or B by comparing the number of responses for each group across all videos. We found no significant difference between grouping decisions (A or B) for all possible conditions considered together, $\chi^2(1, N = 873) = 2.979, p = ns$, indicating that any difference in grouping responses was not due to innate user preferences for one group.

A second check evaluated if the neutral condition for behavior, appearance, and gaze was biased towards either A or B. For each variable, we compared responses for conditions in which robot C displays a unique setting. In other words, we analyzed grouping responses on conditions represented by lines in Table 1 that have a "C" only in the column representing our variable of interest, and in no other columns. We found no statistical grouping preference for unique appearance ($\chi^2(1, N = 291) = 0.99, p = ns$) or for gaze ($\chi^2(1, N = 291) = 0.77, p = ns$). For unique behavior, this analysis showed a statistically significant bias towards response B ($\chi^2(1, N = 291) = 16.36, p < 0.01$). This bias is readily visible from condition 27 in Table 1. Notice that the unique behavior for robot C was generated by merging the motion primitives from the distinct dances of robots A and B. The manipulation check suggests that the motions of robot B's dance were more prominent in the "unique" dance generated for robot C. This could be due to a difference in the visual salience of the motion primitives from robot B's dance. Since the unique dance behavior for robot C showed a statistically significant bias toward B, we did not perform any analysis that relied on the uniqueness of robot C's "neutral" dance behavior.

Independent features. The influence of each experimental variable on the grouping responses is shown in Figure 4. We calculated the proportion of responses influenced by a given factor x by computing the fraction of all responses that assigned Robot C to the same group as the robot that also exhibits x. For example, if robot C's behavior matched A's, the proportion of responses influenced by C and A's behavior is the number of responses that grouped C and A, divided by the

#	C matches Behavior	Appearance	Gaze	Response A	B
1	A	A	A	38	0
2	A	A	B	30	1
3	A	A	C	36	0
4	A	B	A	18	9
5	A	B	B	20	9
6	A	B	C	19	9
7	A	C	A	30	0
8	A	C	B	33	2
9	A	C	C	35	2
10	B	A	A	13	23
11	B	A	B	13	18
12	B	A	C	11	24
13	B	B	A	1	31
14	B	B	B	0	36
15	B	B	C	0	34
16	B	C	A	2	22
17	B	C	B	0	31
18	B	C	C	1	31
19	C	A	A	24	10
20	C	A	B	17	8
21	C	A	C	20	5
22	C	B	A	1	36
23	C	B	B	6	31
24	C	B	C	7	24
25	C	C	A	12	21
26	C	C	B	15	21
27	C	C	C	9	24

Table 1: Raw results from the experiment. Each row is a condition, and columns 2, 3, and 4 show the variable settings. Responses for each condition are in the right two columns.

total number of responses.

The results in Figure 4 show that behavior significantly influenced grouping, $\chi^2(1, N = 582) = 9.83, p < 0.01$. The influence of appearance on grouping was marginally significant, $\chi^2(1, N = 582) = 3.16, p = 0.075$. The influence of gaze, however, was not significant, $\chi^2(1, N = 582) = 0.00035, p = ns$.

Paired features. It is possible that the experimental variables acted in concert to influence each choice of perceived grouping. To obtain information into these cross-relations, we considered the factors pairwise (Figure 5). There was a significant decrease in positive grouping responses based on similar behavior when behavior and appearance were in conflict (Figure 5b), indicating that appearance mediated the effect of behavioral similarity, $\chi^2(1, N = 327) = 21.0, p < 0.01$. However, when appearance and behavior conflicted, responses supporting behavior were statistically more likely than responses supporting appearance, $\chi^2(1, N = 186) = 18.09, p < 0.01$ (Figure 5a), indicating that behavior overwhelmed appearance in determinations of grouping.

There was no significant difference in grouping when behavior and gaze were in conflict, $\chi^2(1, N = 330) = 0.436, p = ns$, as well as when appearance and gaze were in conflict, $\chi^2(1, N = 287) = 0.784, p = ns$. Thus, gaze did not mediate the influence of either behavior or appearance on grouping.

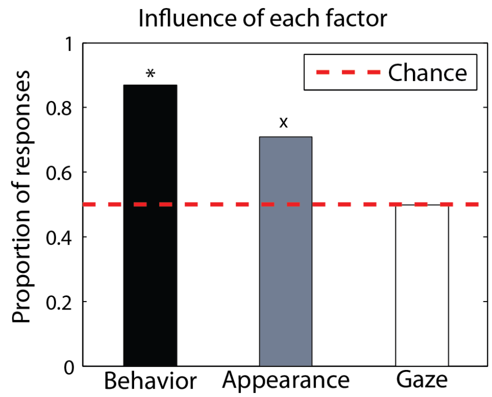


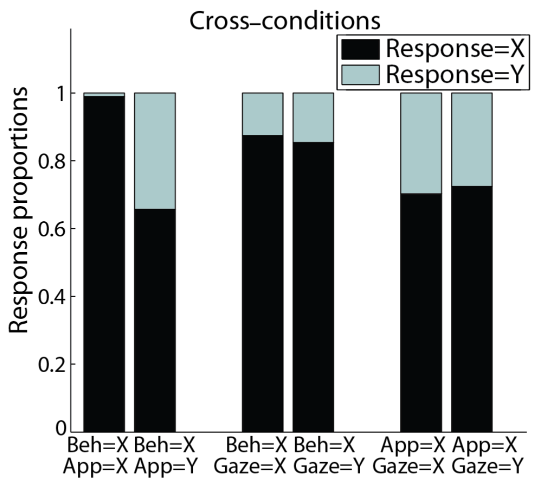
Figure 4: Comparison of the proportion of responses positively influenced by each factor individually. ($* : p < 0.01, \times : p < 0.1$)

Discussion

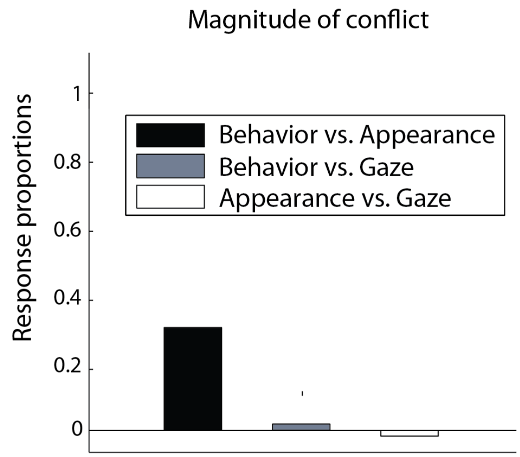
Results of the experiment suggested that behavioral mimicry has a significant influence on the perception of robotic grouping, outweighing the other physical and cognitive factors (Figure 4), thereby supporting hypothesis **H1**. We showed that appearance has a marginal but notable effect on the perception of robotic grouping, partially supporting **H2**. Gaze was seen to be a very weak factor and did not appear to influence peoples' perceptions of grouping, leading us to reject hypothesis **H3**. It is important to note that each of the three variables were able to influence decisions when they were present without conflicts from the other variables. Comparing choices based on single variables while others are neutral demonstrates the effect of each variable individually: conditions 9 and 18 (behavior), conditions 21 and 24 (appearance) and conditions 25 and 26 (gaze) show that apart from gaze, each variable is perceptually salient and able to influence a participant in the absence of other cues.

Our experiment supports the findings of previous studies that identify behavioral mimicry (Riek & Robinson, 2008) and physical similarity (Nass & Moon, 2000) as strong factors in grouping perception. Our findings add to the literature by establishing behavior mimicry as a more influential factor than appearance in robot groupings, and suggests the need to explore such influence among human interactions.

Figure 5a illustrates the interactions between pairs of features, which elucidated not only the independent effect of each feature, but also the interaction of these effects during grouping. The distribution of responses for interactions between behavior and appearance is depicted in the first pair of bars. Behavior and appearance responses tallied together show no correlation ($\chi^2(1, N = 393) = 1.22, p = ns$), establishing that behavioral mimicry and appearance-matching were able to independently influence the observers' perceptions of groups. Furthermore, these results show that when C imitated both the appearance and behavior of a leading robot, nearly 100% of all responses grouped C with the mimicked



(a) The percentage of responses for cross-conditions, either in alignment or at odds, are shown in each pair of bars. Matching appearance and behavior (at some X) achieved a high percentage of votes for X and low percentage at for any Y (bar 1). Conflict of appearance with behavior X gave fewer responses for X (bar 2). Similar comparisons are made for all three conflict conditions.



(b) The difference made by the second factor conflicting with the first for each conflict comparison in (a). Appearance lowers a high proportion of responses from behavior when in conflict. Gaze lowers a statistically insignificant proportion of responses from both behavior and appearance.

Figure 5: A comparison of the proportion of responses influenced by pairs of factors.

robot (Figure 5a, bar 1). Alignment of behavioral mimicry and physical appearance was overwhelmingly influential.

In contrast, conflicting appearance and behavior caused a significantly less decisive split in the percentage of responses grouping C with either leaders. Responses grouping C with the leader of the same appearance as C increased to nearly 35%, while responses grouping C with the robot behaving like C decreased to 65% (Figure 5a, bar 2). The relative change in responses matching behavior when cues conflicted suggests the effect of appearance was weaker than that of behavior. Future work should investigate the minimum amount of behavioral mimicry that continues to have such an effect.

Examining behavior and gaze in a similar way (second pair of bars in Figure 5a) reinforces the earlier observation that gaze had a weak influence on grouping. Though the results show that a large proportion of participants grouped C with the leader towards whom C's gaze was directed and whose behavior C imitated (Figure 5a, bar 3), these results were independently incapable of determining the strength of gaze's effect because behavior had a powerful influence on perception. We next considered trials in which behavior and gaze opposed each other (Figure 5a, bar 4). If gaze had a significant influence, the conflict between these two factors would decrease the proportion of grouping responses in favor of either factor. However, responses in line with behavior remained high, and those in favor of gaze remained low (Figure 5b). We conclude that C's direction of gaze is nearly irrelevant to grouping patterns and it does not independently influence the perception of grouping.

The pairings of appearance and gaze, both in agreement and in conflict (bar 6 and 7 in Figure 5a), show similar trends as behavior and gaze. While there was a decreased proportion of responses for appearance, likely due to the dominance of behavior, the results still show an insensitivity to gaze.

Initial statistical analysis confirmed that there was no significant bias towards any individual setting of behavior, appearance, or gaze direction. Additionally, to enable the perception of directed gaze and mimicry, the leader robots were positioned equidistantly in front of the follower; the follower began its dance approximately 2 seconds after the leaders. While the delayed start of the follower may have induced participants to be especially attentive to behavior, it provided for a more ecologically-valid mimicry of behavior where some time is necessary for the leader to be observed and imitated.

While both one-directional (Naiman & Breed, 1974; Hietanen, 1999, 2003; Scaife & Bruner, 1975; Farroni et al., 2000; Langton, Watt, & Bruce, 2000) and mutual gaze (Naiman & Breed, 1974) are shown to be strong factors in perceiving human interactions, the current experiment investigated one-directional gaze, rather than mutual gaze, in an attempt to simplify this perception factor and to evaluate whether one-directional gaze is able to bias human perception of robots at all. Although, it is possible that the non-reciprocated gaze could also be perceived as alienating, we hypothesized that gaze would increase grouping perception in the direction of the gaze. This was disproved by the lack of significant difference between grouping patterns in conditions 25 and 26 in Table 1, (appearance and behavior were neutral). Evidence exists to show that robot gaze does not reflexively cue attention as human gaze does, which may explain why the gaze direction didn't have an effect on grouping (Admoni, Bank, Tan, Toneva, & Scassellati, 2011). Further work would establish whether the considerably more influential mutual gaze is necessary to elicit an effect on the perception of grouping.

Conclusion

In this study, we investigated the effects of behavioral mimicry, physical similarity, and eye gaze on perceptions of social groupings using precisely controllable robots. Statistically significant results showed that behavioral cues dominate the perception of grouping, both in isolation and even with conflicting cues of appearance and gaze. Appearance was also found to significantly influence grouping patterns despite conflicting behavioral cues. Non-mutual gaze was found to be a weak factor in modulating grouping patterns.

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