The Odd Keepon Out: Using Toy Keepons to Examine Group Dynamics

Caroline Jaffe, Marty Keil, Geoffrey Litt

Abstract

The purpose of this project was twofold: first, to reverse engineer the toy Keepon so that we could control its motions at will, and second, to investigate how group size affects perceptions of dancing ability and social awareness in outgroup members. Drawing on foundations that we found online, we were able to gain rudimentary control of the Keepon's motors by gaining master control of the I2C bus and sending them commands from an Arduino board. Upon gaining control of multiple Keepons, we presented three conditions to participants via an online survey with videos. Each displayed an outgroup member who danced more individualistically than the one, three, or seven ingroup members. Our results indicated that the perceived dancing ability of the outgroup robot increased as group size increased, even though that robot was displaying exactly the same behavior. Additionally, the likeability of the outgroup robot increased with group size. Although these were satisfying results, the project left us with much experimental space left to explore. In the future, we would be interested in studying how group-size affects ingroup and outgroup dynamics in the context of robot embodiment, participants identifying with one of the groups, or tasks that require coordination instead of individuality.

1. Introduction

Human beings often have a clear but sometimes inexplicable sense of belonging to a group or being an outsider. These social groupings–called ingroups and outgroups–can be formed on the basis of seemingly trivial or barely perceptible similarities and differences between people. Our project sought to address how the size of the ingroup affects perceptions of an outgroup member. Specifically, the aims of our project were two-fold. First, we wanted to reverse engineer the toy Keepon robot so that we could control its motions at will–a challenge that would teach us about digital communications and reverse engineering. More importantly, though, the ability to hack a toy Keepon opens up many new research opportunities for experiments with group size. Research robots are often expensive, which makes it unrealistic to conduct experiments involving large groups of robots. If we were to gain control over the motions of many of these cheap robots, we could create a group where each member is doing the same action, artificially creating an ingroup. This new flexibility presents many possibilities for new experiments involving multiple robots and the creation of ingroups and outgroups.

Given that infrastructure, the second part of our project sought to investigate how group size affects perceptions of dancing ability and social awareness in outgroup members. We choose dancing as an activity partially because the Keepon's limited motor controls are particularly well-suited to dancing, but also because dancing is a flexible activity where being an outgroup member could potentially be an asset or a hindrance, depending on the situation and type of dancing. In the context of dancing to a contemporary popular song, we tried to see what neutral participants–those not associated with the ingroup or outgroup–thought of individualistic outgroup members in groups of increasing size. This sort of work could have applications and implications in any situation involving the formation of ingroups and outgroups; classrooms, committees, athletic teams, and musical bands are just some examples of social situations where understanding how group size affects group dynamics could be important for decision making and cooperation.

While the idea of ingroup and outgroup formation is well established within social psychology, there have been relatively few quantitative experiments investigating group size as an independent variable. One study, for example, developed what is known as the "black sheep effect": ingroup members tend to punish a poorly behaving ingroup member more harshly than they punish a poorly behaving outgroup member who performs the same bad behavior. While an interesting idea, this result says nothing about how group size influences the effect. On the other hand, there have been some experiments dealing with group size, like the public goods problem and commons dilemma. Both problems deal with how much an individual is willing to contribute to or take from a public resource. Researchers found that the size of the group had some effect on how much individuals were willing to contribute to a public resource. Furthermore, in the Asch conformity experiments, researchers studied how large a group was necessary to get participants to agree to an objective statement that was clearly incorrect, essentially quantifying aspects of peer pressure. While both interesting results that deal with group size, neither of these experiments clearly deals with ingroups and outgroups. Given the unique infrastructure available with the Keepon robots, we thought this would be a productive and exciting space to study.

With this ultimate goal in mind, we designed an experiment that examined how participants perceive dancing ability and social awareness in outgroup members as group size increases. Our first task was to reverse engineer the Keepon robot. We were able to build upon the online documentation of someone who had already taken the toy Keepon apart and posted rudimentary information on how to gain control over the motors. This documentation provided a nice foundation for our work, and helped us get the Keepons up and running in the limited time we had. We then made videos that displayed an outgroup member who danced more individualistically than a group of ingroup members of varying size. We asked participants to rate the dancing ability and social awareness of the outgroup member in comparison to a single ingroup member. We expected to see variation in these ratings as group size increased. The logic was that even though ingroup and outgroup members were doing exactly the same movements in each condition, the larger size of the ingroup would make the actions of the outgroup member stand out, and would exaggerate participants' reaction to them, whether positive or negative. This experimental setup yielded some useful and interesting results, and left us with plenty of research space yet to consider.

2. Methodology

2.1 Internal Mechanisms of the Keepon

From a technical standpoint, our main goal was to gain the ability to override the default movements of a toy Keepon robot, and control its movements using an Arduino Mega microcontroller. This would enable us to control the movement of multiple Keepons simultaneously, synchronizing their movements to create a clearly perceivable "ingroup" in contrast to a single Keepon doing the default dance movements.

First, we needed to first establish a hardware interface with the robot's internal control systems. Upon opening the Keepon's plastic enclosure, we were able to easily gain access to the motors and main circuit board. The Keepon has four degrees of freedom: rotation around the Y-axis, Y-axis compression for squatting, Z-axis bending for forward bending, and X-axis bending for left-to-right movement. Each of these degrees of freedom is controlled by a servo motor. The circuit board contains two microcontrollers, a Padauk P234CS20 as a primary controller handling power management and high-level processing, and a Padauk P232CS14 as a secondary controller handling motor and sound outputs. The two microchips are connected on an I2C serial bus, with the primary controller sending messages as the master node and the secondary controller receiving those messages as a slave node.

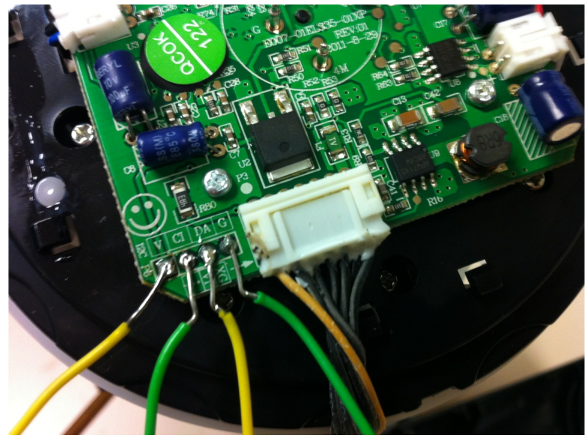

Figure 1. Wires soldered to I2C pads

2.2. I2C Protocol

Conveniently, the circuit board also contains a set of four pads that allow access to the I2C bus. By soldering wires onto the four pads and threading them through a hole in the Keeon's casing, we were able to read signals that the Keepon's master microcontroller was sending to the slave microcontroller by taking oscilloscope readings while the Keepon was in normal operation mode.

The I2C protocol is an industry standard digital communications protocol that connects a master device to multiple slave devices via a clock line and data line. I2C requires the use of open drain pins on devices; this allows for any slave node to ground the clock line and stretch the clock while preparing to receive data. The I2C protocol also requires pull-up resistors on both the clock and data lines so that the logic level of bus is never uncertain. As seen in the photo above, the pads on the Keepon's circuit board are clearly labeled V (3.3V output), CL (I2C clock line), DA (I2C data line), and G (ground), providing easy access to the I2C communications between the master and slave chips. We used the wires to connect the Arduino Mega microcontroller to the I2C bus.

2.3 Overall Setup

The Arduino Mega microcontroller was connected to a PC, which we used to program the Arduino and display feedback from the motor commands. The Arduino acted as the master device on the I2C bus, and was used to send motor control commands to the Keepon's motors. In return, the Arduino processed ACK or NACK packets from the Keepon, depending on whether the command had been successfully received or not.

We wrote C code in the Arduino's IDE that we used to program the Arduino board. When programmed, the Arduino outputs electrical signals through pins to the Keepon, effectively acting as a software to hardware interface. In order to gain master control of the I2C bus, we needed to ground out the clock and data lines while we powered on the Keepon. We achieved this by grounding both lines for five seconds in our code upon startup, and manually powering on the Keepon during that time interval. We then opened an I2C transmission on device 0x55 (the address of the Keepon's motor controller) using the built-in I2C Arduino library command, Wire.beginTransmission(), and sent a three-byte message that consisted of a hexadecimal motor index, motor position, and speed, using the Wire.write() command. For example, the packet we ultimately used consisted of the motor index 0x00, the motor position 0x00, and the speed 0xFF. These values corresponded to the X-axis bend motor, the left-right motion, and the fastest speed possible. Our code also had rudimentary error checking capabilities, capturing and printing the success or error code at the end of each transmission.

2.4 Issues and Ultimate Success

As is the case with any reverse engineering project, we encountered a number of roadblocks throughout the course of our project. Some were minor issues with easy solutions, while others required more careful investigation and clever solutions. Minor issues included broken or jammed motors, mixing up the I2C wires, shorted connections and melting or damaging the circuit board. Each of these issues were easily solved by replacing the Keepon or resoldering our wires.

The more substantive issues we dealt with were getting the correct voltage and frequency to run the Keepon. The Arduino runs on 5V, whereas the Keepon runs on 3.3V; after a number of different proposed solutions, we ended up using a a sequence of five diodes between each I2C wire and ground to establish the proper 3.3V voltage level for the Keepon. The forward voltage drop across each diode is approximately 0.7V, so five diodes would result in a 3.5V level on the line even with the Arduino outputting 5V. Additionally, after a couple lab sessions where we were getting inconsistent results, we found that the default operating frequency of the Arduino was 100kHz, while the internal signals sent in the Keepon were running at 25kHz. We solved this problem by setting a prescaler bit on the Arduino's I2C hardware, reducing the frequency by a factor of 4 to 25kHz.

Ultimately, we were successful in getting the Keepon to receive, process and follow the commands we sent to its motors. An oscilloscope printout of a successful transmission with the clock line (top) and data line (bottom) can be seen in Figure 2. There were some limitations to our success; for example, we were not able to combine certain motions because they required sending conflicting commands to the motors. We also could not synchronize the Keepons perfectly because the commands we sent to the motors corresponded to an action instead of a specific position. Nonetheless, we were able to control the motors of multiple Keepons to the extent that we were able to successfully create an ingroup through the similar motions of the Keepons.

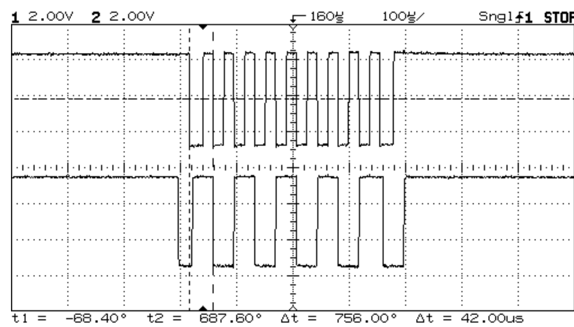

Figure 2. Oscilloscope trace of Arduino I2C commands

3 Experiment

3.1 Design

We designed our experiment to answer the question: How does the group size of a synchronized ingroup affect the perceived dancing ability of an outgroup member? To test this question, we created three conditions where a synchronized ingroup of various sizes was compared with a single outgroup member doing a different dance, the "odd Keepon out." We videotaped each condition, and used an online survey to ask participants to compare the dancing ability of the outgroup robot to a single ingroup robot, among other questions.

We chose three test conditions: 1 outgroup robot with 1 ingroup robot (1 vs. 1), 1 outgroup robot with 3 ingroup robots (1 vs. 3), and 1 outgroup robot with 7 ingroup robots (1 vs. 7). The 1 vs. 1 condition would reveal any inherent biases that study participants had towards the dancing style of either the ingroup or outgroup robot. The next two conditions, 1 vs. 3 and 1 vs. 7, could then be compared to the first condition (and to each other) to determine the effect, if any, of group size on perceptions of dancing ability.

Creating a synchronized ingroup required choosing a dance move that could clearly signify the existence of a group, without making it seem like the ingroup robots were actually physically connected, or clones of each other. We chose a simple left-right bending motion for the ingroup, because it was noticeably different from the more sophisticated dance moves that the outgroup member was using. Practical considerations also played a role–we found that this movement was the easiest one to consistently generate using the control methods we had developed. Connecting all the ingroup Keepons on the same I2C bus turned out to produce an appropriate amount of variation between the movements of the individual robots. Because we were controlling the speed of oscillation and not the actual positions of the robots at any given time, small mechanical variations between the robots produced accumulating variations in position between them.

The outgroup member in each test condition was run in unmodified factory condition in ”music mode”, which caused it to do a variety of movements using a significantly greater range of motion than the ingroup members.

Each test condition was videotaped with the Keepons arranged in a straight line and the outgroup robot placed in an arbitrary position in the line. For the two larger group conditions, we avoided placing the robot on either end of the line to avoid any perception of that robot being an ”outcast” based on its position. The videos were set to the song ”We No Speak Americano” by Yolanda Be Cool, which has a strong beat at approximately the same tempo as the ingroup's dancing. The videos were also post-processed to contain letter labels on each robot for identification purposes, and cut to 30 seconds in length.

We created an online survey using the Qualtrics system, which displayed the three video clips to respondents in random order and asked them questions after each one, pertaining to a randomly selected robot in the ingroup and the outgroup robot. Respondents were asked to:

- Rate the dancing skills of each robot on a 1-7 scale
- Explain their reasoning for rating one robot higher
- Rate the social awareness of each robot on a 1-7 scale
- Choose which robot they liked better
- Choose which robot was having a better time

In addition, respondents were asked to provide information about their gender, age, race, strength of musical background, strength of dancing background, their opinion on what makes a good dancer, a self-evaluation of being introverted or extroverted, and choosing a preference for being one of a group or standing out as an individual.

3.2 Hypothesis

Our hypothesis was that the outgroup Keepon would be seen as better at dancing than the ingroup Keepon in the 1 vs. 1 condition, because of its more varied movements. However, we predicted that creating an ingroup-outgroup condition by adding more ingroup Keepons would cause the ratings of the outgroup Keepon's dancing ability to decrease, because it would be perceived as being out of sync with the group, a negative trait. We also predicted that this effect would become stronger with larger group size; that is, the outgroup Keepon's dancing ability would be perceived as even lower with larger groups.

4 Results

4.1 Quantitative Results

We examined the first responses in each of the three test conditions. In each case, the first responses judging the unique dancer's ability are significantly different from the first responses judging the group dancer's ability. In all three test cases the unique dancer is rated as a better dancer than the group dancer (p=1.658E-15, df=102). As the group size increases, from 1v1 to 1v3 to 1v7, the dancing ability of the unique dancer is rated higher (Figure 3), thereby revealing a strong effect due to group size. In the 1v1 condition, the dancing ability of the unique dancer was rated at a mean score of 4.5 and in the 1v7 condition, the unique dancer was rated at a mean score of 5.5. This difference is highly significant difference (p=0.0027, df=62). The difference between 1v3 and 1v7 was also significant (p=.0114, df=62).

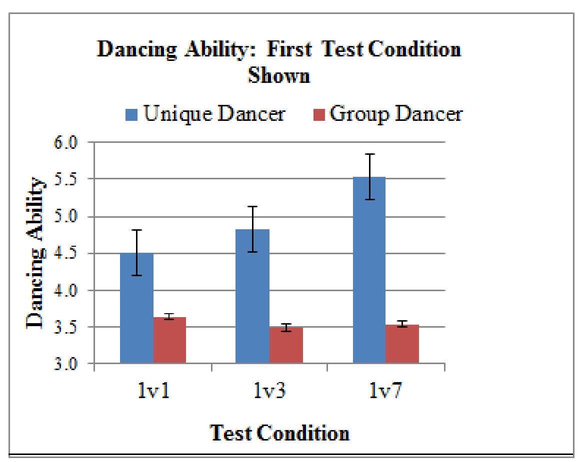

Figure 3. Graph of perceived dancing ability by each test condition seen first.

When comparing dancing ability across all three test conditions for all responses there is no significant difference (p=.230759, df=102) between group size (Figure 4).

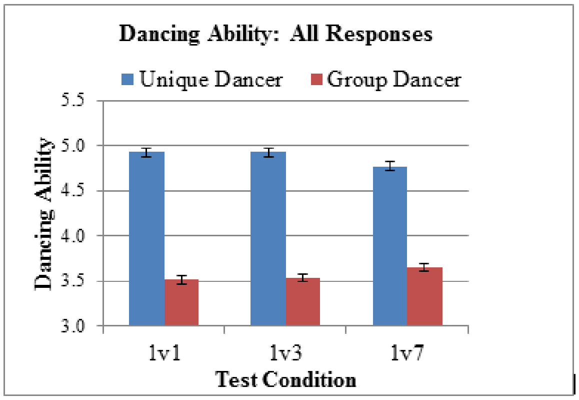

Figure 4. Graph of mean dancing abilities for all three conditions and all order of responses.

The difference between these results and those for the first response alone can be explained by a clear ordering effect. Thus, those shown the 1v7 condition first rate all three conditions higher than those that were shown the 1v3 condition first. Similarly, those shown the 1v3 condition first rate all three conditions higher than those that were shown the 1v1 first (Figure 5). Clearly, judges anchored their scores to the first judgment and then didn't adjust them.

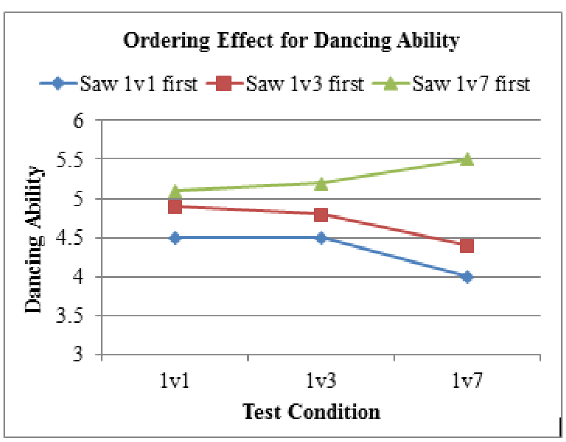

Figure 5. Ordering effect across all three conditions.

There was no significant difference (p=.236733,df=62) between the unique dancer and group dancer's perceived social awareness across the three test conditions for first responses (Figure 6).

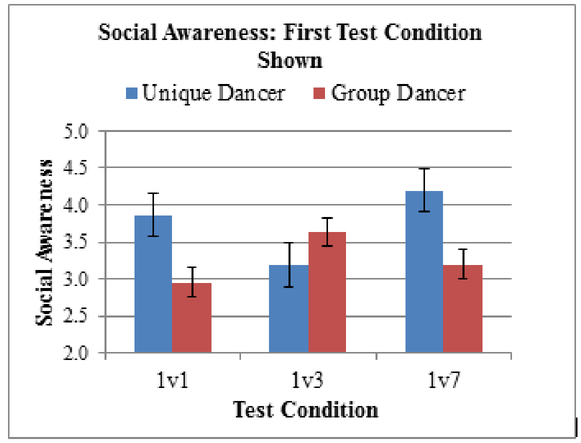

Figure 6. Graph of perceived social awareness by each test condition seen first.

When asked to compare the likeability of the unique robot and a robot chosen from the group, the study shows near 50:50, or random measures of likeability in 1v1 test condition for both robots. However, when the group size is increased to 3 and 7 the percent of participant that like the unique robot increase significantly to 75% in both cases (Figure 7).

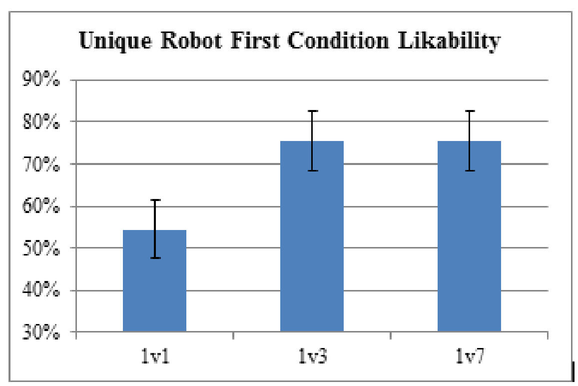

Figure 7. Graph showing the percent of respondents who liked the unique robot more than the group robot choice.

4.2 Qualitative Results

Questions about how the study participant decided why the unique robot was the better dancer produced the following selected responses:

- ”E(group robot) was truly ”average” since it was the same as most of the others - just back and forth, boring. F (unique robot) was different but still to the beat.”

- ”It (unique robot) was more thoughtful”

- ”Robot C (group robot) is playing it safe, using its one ”Night at the Roxbury” move for the whole song, because it’s easy and works. B (unique) isn’t afraid to get creative, mix it up, and do some advanced business.”

Several of the responses to this question emphasized the ability of the unique robot to stand out from the other group robots, the unique robot’s creativity, and the merits of the unique robot’s risky choice to depart from the behavior of the group.

5 Discussion and Conclusion

In conclusion, we were able to successfully find a trend in participant responses that varied with the size of the ingroup: we found that the perceived dancing ability of the outgroup Keepon increased with group size. This trend presumably asymptotes with very large groups, but within the group sizes used in our experiment, the effect appears to be linear. Although the specific trend actually differed from our predictions, the fact that there was a trend corresponding to group size confirmed our hypothesis. We had anticipated that the the ratings of the outgroup Keepon’s dancing ability would decrease as group size increased, because it would be perceived as being more and more out of sync with the group. In fact, the perceived dancing ability of the outgroup member increased with group size, given our test conditions; we found that participants valued the creativity of the outgroup Keepon more than we had anticipated. We might attribute this result to the fact that a modern conception of dancing ”well” to a popular contemporary song requires creativity and individuality, which the outgroup member certainly possessed. If the activity of the ingroup had required more conformity, participants may have disliked the individuality of the outgroup member and we may have seen a different trend.

We were unable to find conclusive results regarding the social awareness of the robots, which may have been related to our specific methodologies. First, directly asking people to rate the ”social awareness” of nonhuman objects may have confused them; a more specific question about the robots’ awareness of the others’ actions could have been more appropriate. Also, some survey respondents interpreted the pauses in the outgroup Keepon’s motion as being socially aware, whereas others interpreted the pauses as signs of an inability to dance smoothly. Furthermore, based on the comments in the survey, it seemed some participants interpreted social awareness as the ability to stay with the ingroup, which understandably confounded our results. Directly controlling the outgroup Keepon to avoid these pauses or asking a more clear question may have alleviated this issue.

Another important qualification of our results is that our study participants came from a limited sample population. Almost everyone who took the survey was between the ages of 18-24, and most were Yale undergraduates. Doing a similar survey with a wider range of ages, nationalities, and cultural backgrounds might produce significantly different results. For example, participants from a cultural background that places a higher value on conformity might have appreciated the individuality of the outgroup Keepon less than the sample of the Yale population that took the survey.

In addition, we found that the likeability of the outgroup Keepon increased as group size increased. Again, we guess that this preference may be especially pronounced in our sample population: students in a Western university that embraces individuality and standing out from the crowd. Future studies might explore whether the effect is smaller, diminished or perhaps even reversed in other cultures that emphasize the value of conforming to the group norms. For example, in contrast to the individualist bias in many Western cultures, many Eastern cultures emphasize a collectivist set of values that discourage standing out from the crowd.

It is also worth noting that our outgroup dancer was rated as being a slightly better dancer in the 1 vs. 1 case. It would be interesting to do a similar experiment where the outgroup dancer was perceived as being worse in the 1 vs. 1 case, to see if larger group sizes would still cause the outgroup dancer to be perceived as better, or if the effect would be reversed and cause the outgroup dancer to be perceived as even worse.

The framework that we developed for controlling a group of cheap Keepon robots could potentially be used to conduct other studies of ingroup and outgroup dynamics. For example, it might be interesting to reproduce other scenarios besides dancing using the Keepon’s range of motion, since dancing is an activity where standing out from a crowd is usually considered positive. Simulating other activities like a military march or an exercise routine, where more conformity is expected of participants, could dramatically change the results. Varying the physical appearance of some of the Keepons or letting the participant identify more explicitly with either the ingroup or outgroup might have also produced some useful results. While we generated some substantive and interesting results, we believe there is still ample experimental space to explore.