Perception of Chasing in Real Life

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***Abstract*—Perception of animacy, and of chasing in particular, has been studied and quantified by numerous studies. One such study is that of Gao et. al, which measured how well humans could perceive a chase amongst a collection of moving, animated white discs. They found that above a chasing subtlety of 30°, where chasing subtlety is a measure of degree to which one disc chases another, chasing cannot be detected. We extend the work Gao et. al. did by replicating their "search for chasing" experiment with 5 Sphero BOLT robots. Participants watched videos of the Sphero BOLTs moving around, and their ability to accurately identify the presence of chasing at various degrees of subtlety was measured. We ran two versions of the study: one with the videos at normal speed, and one sped up 2x. Our results for videos shown at their normal speed support the conclusions of the original study, with participants being unable to identify chasing at chasing subtleties greater than 30°. At 2x speed, however, the results were less conclusive, with participants struggling to detect and identify chasing across all subtlety values. Overall, our work shows that the original study's results can be extended to real life, bringing further insight into perceptions of animacy and chasing.**

I. Introduction

Perception of animacy has been a well-researched topic in the field of psychology. In such works, animacy is often defined in terms of how alive or sentient an entity is perceived to be [10]. Humans are known to show a strong tendency to perceive temporally or spatially coordinated motion between two objects in anthropomorphic terms [7][8]. Several past studies have shown that even two-dimensional moving shapes are perceived as alive, animate and as having goals, and this is referred to as perceptual animacy [8]. For example, based on different motion patterns, a large triangle and a small triangle can be perceived to be having a fight [7].

For instance, in Fig. 1, the smaller triangle, or the "child" is perceived to be "exploring outside". Perceptions of animacy and goal-directed movement of simple shapes are of great interest because they seem to hint at automatic visual processing [6] and this perception seems to be reflexive as opposed to deliberate [5].

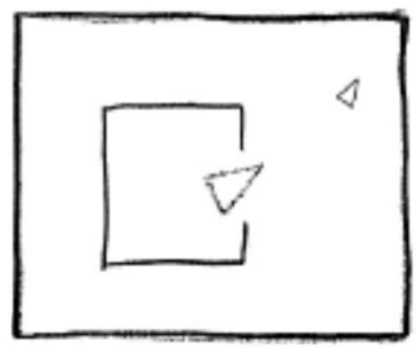

Fig. 1. In this static image, the smaller triange is perceived to be "exploring outside". [7]

However, these perceptions are dependent on different subtle aspects of the displays. Visual cues such as sudden speed changes [9] and interactions with other objects [4] influence visual perception.

A. *Chasing and Animacy*

One question that arises is how do we quantify such perceptions in animacy. A lot of past work has used animacy rating scales and linguistic analysis of open responses to study perceptual animacy. A new set of studies have challenged this view and suggested a more quantifiable, psychophysical approach to perception of animacy [6]. Notably, chasing is considered a robust and simple cue to animacy [3] and has been investigated in several studies involving perceptual animacy.

In such study by Gao et al. (2009), circular shapes moved around a 2D plane, with a "wolf" circle chasing a "sheep" circle. In the study, participants engaged in visual performance to detect whether chasing was present and identified the wolf and sheep shapes. One of the main findings of the study was that the maximum chasing subtlety angle for which participants were able to detect chasing accurately was 30 degrees. The study defined chasing subtlety as "the degree to which the wolf deviates from perfectly 'heat-seeking' pursuit" [6].

B. Robots and Animacy

A distinction that Gao et al. (2009) make is that chasing involves intentionality. More specifically, they point out that while the construct of chasing is objectively defined as one moving object (the wolf) being systematically displaced relative to another (the sheep) such that their relative proximity decreases over time, most dictionary definitions of chasing also include intentionality [6]. This distinction is particularly of interest in the context of robots, which people often perceive as more intelligent than they actually are.

Robots can exhibit traits and behaviors similar to those exhibited by humans and animals, and robots can exhibit intentionality [2]. Indeed, much research has been done on the perceptions of animacy in robots. Bartneck et al., for example, looked at how different robot embodiments affected perceptions of animacy and intelligence [1]. However, a lot of the work evaluates these perceptions of robots based on robot embodiment or direct interaction of the robot with the participant. We are interested in looking at a more quantifiable and robust perceptual animacy factor of chasing through robots. We are interested in examining how human perception of chasing and animacy changes when the chasing happens in real life using spherical robots as opposed to when the chasing occurs in animations using two dimensional circles.

II. Methods

Our study aims to mimic as best as possible the procedures in Gao et al.'s Experiment 1. In that experiment, participants viewed animations of 5 moving discs. In half of the trials, all 5 discs moved randomly, and in the other half one disc (described as the "wolf") chased another disc (the "sheep"). The chase-present trials varied in *chasing subtlety*, which Gao describes as a measure of the maximal angular deviation of the wolf's heading compared to perfect heat-seeking, which is when the chasing subtlety is 0° and the wolf is always headed directly toward the sheep. [6]. We will use this same term to describe this variation in angular deviation while chasing. Chasing subtlety is illustrated in Fig. 2.

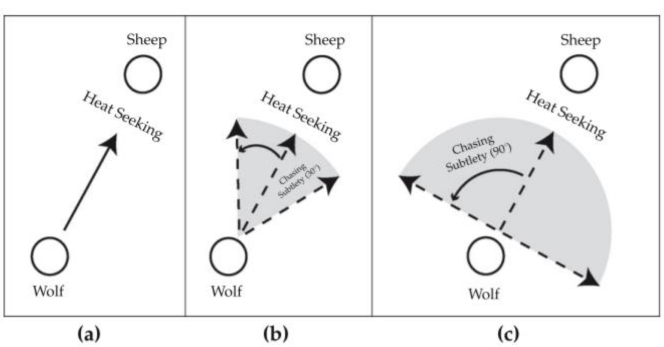

Fig. 2. *Chasing subtlety* as described in Gao et. al's study. (a) Chasing subtlety of 0°, or "heat-seeking" chasing (b) Chasing subtlety of 30° (c) Chasing subtlety of 90°. [6]

A. Participants

The study was run using Amazon Mechanical Turk (MTurk), an online crowdsourcing marketplace. A total of 60participants were recruited from their pool of workers. However, two participants in the normal speed experiment did not submit their response, so we only used data from 28 participants for the normal speed experiment and 30 participants for the 2x speed experiment. Workers on MTurk who have consistently demonstrated high performance are identified as MTurk Masters. To ensure a higher quality pool of potential participants, only those workers could see, preview and participate in the study.

B. Programming the Sphero BOLTs

5 Sphero BOLT robots were selected as analogues to the animated discs. Sphero BOLTs are small, spherical robots, with no clear markings to indicate a front or a back. We chose these nondirectional robots to prevent bias in the experiment. Each Sphero BOLT was individually controlled via the Sphero EDU app on a device (either laptop or tablet). The robots' infrared communication sensors were used to ensure that all robots started and stopped at the same time. Trajectories for each robot were randomly generated using a Python script and were designed to mimic the paths seen in the original study. When a robot was the wolf, its trajectory was derived by taking the sheep's points and randomly generating a trajectory such that its heading was within the specified chasing subtlety.

C. Filming the Trials

Once the paths for each trial were generated, we then filmed videos for the trial. A given trial consisted of the following. All robots started off in their marked initial location within a x by x grid with their LED lights turned off. During the approximately 20 second trial, the robots moved randomly throughout the marked space, or, in the case of the wolf, pursued the sheep with the specified chasing subtlety. At the end of the trial, each Sphero BOLT lit up with a unique color, which was used by participants to identify the wolf and the sheep.

Because in chase present trials how precisely the wolf and sheep follow their respective paths is critical, for all the chase present trials, the precision was checked by comparing plotted sensor data to the generated path. Fig. 3 is an example of this plotted data. If there was significant deviation between the generated and actual path, the video was eliminated from the study and a replacement trial was filmed and used instead. Finally, once filmed, the videos were edited to more clearly indicate the color of each robot. Fig. 4 is an example of what participants saw at the end of each trial.

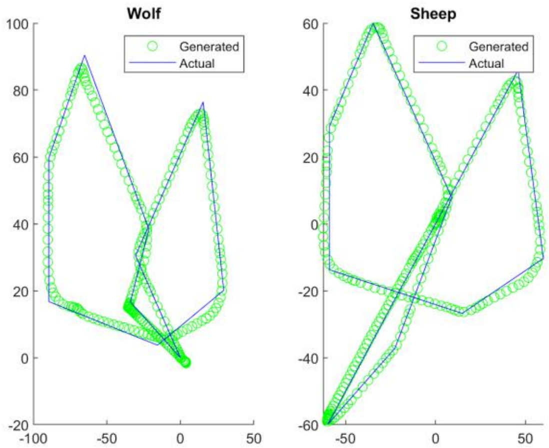

Fig. 3. Plotted sensor data and generated path for a trial with a 0° chasing subtlety.

Fig. 4. Screenshot of the end of a trial. 5 Sphero BOLTS are each lit up with a unique color to allow participants to identify the wolf and the sheep in chase-present trials.

C. *Running the Study*

We ran two versions of the study on MTurk: one with the videos at the original speed and one with the same videos sped up 2x. The 60 participants were split evenly across the two versions of the study. Each version consisted of 48 trials: 24 chase present and 24 chase absent. The 24 chase present trials were comprised of 4 trials for each of the 6 chasing subtleties we tested (0°, 30°, 60°, 90°, 120°, and 150°). The order of the trials was randomized but consistent across participants. After each video was shown, participants were asked whether they thought chasing was present and were told whether their answer was correct. When they correctly identified a chase, they were then asked to identify the wolf and the sheep. At the end of the experiment, participants were surveyed on whether they had difficulty identifying the robots, whether they used a specific strategy to identify chasing, what made this task difficult, and whether they viewed the robots as animate objects.

III. Results

A. *Explanation of Study Metrics*

We used two measurements, detection accuracy and identification accuracy, to evaluate the results of the experiment. Detection accuracy was measured as the % correct of determining whether a chase was present. Identification accuracy was measured as the % correct of identifying both the wolf and sheep correctly. We calculated these measures across the 6 different chasing subtleties (0°, 30°, 60°, 90°, 120°, 150°) to evaluate chasing subtleties impact on the participants' perception of chasing.

B. *Normal Speed Experiment*

Fig. 5a depicts detection accuracy as a function of chasing subtlety. The shape of the curve suggests that chasing subtlety has an impact on the perception of chasing. To confirm this, we conducted a linear regression of chasing subtlety on detection accuracy of participants. The analysis showed a significant relationship between chasing subtlety and the detection accuracy of participants ($p = 0.001214$). We can conclude that chasing subtlety has a statistically significant effect on detection accuracy.

From the figure we can see that detection accuracy is only higher than the chance performance of 50% (performance if participants were to randomly guess for every trial) for chasing subtleties of 0° and 30°. This suggests that participants were only able to reliably see chases for chasing subtleties of 0° and 30°.

Table 1 shows the results of paired t-tests between the detection accuracy of participants for the 6 chasing subtleties and the chance performance of 50%. The analysis did not show a significant relationship between 0° and 30° chasing subtleties and the detection accuracy of participants ($p = 0.8534$). We can conclude that the difference in detection accuracy between chasing subtleties of 0° and 30° is not statistically significant. Furthermore, the analysis did show significant relationships between both the 0° and 30° chasing subtleties and the 120° and 150° chasing subtleties. We can conclude that the differences in detection accuracy between 0° and 120°, 0° and 150°, 30° and 120°, and 30° and 150° chasing subtleties are all statistically significant. However, we cannot conclude that the differences in detection accuracy between 0° and 60°, 0° and 90°, 30° and 60°, and 30° and 90° chasing subtleties are all statistically significant.

Looking at Figure 5b, we can confirm that even though some participants seemed to be able to detect chasing for chasing subtleties beyond 30°, they were not able to accurately identify the wolf and the sheep in these trials, with identification accuracies for 60°, 90°, 120°, and 150° all below the chance performance of 16.7%.This suggests that they did not detect the correct chase and thus did not accurately detect chasing in these trials.

If we compare the data from our experiment to the data from Gao's experiment shown in Figures 6a and 6b, we can see that in our experiment we saw much lower rates of both detection accuracy and identification accuracy (max of ~90 in Gao's experiment vs. max of ~60 in our experiment). We presume that this can be explained by either our use of Amazon MTurk, which could have given us a less-engaged participant pool, or by our implementation of chasing. In order to avoid collisions between the physical Sphero BOLT robots, our implementation of chasing had sharper turns and more lag between the wolf and sheep than seen in the videos of animated discs used in Gao's experiment. This could have made it more difficult for participants to accurately detect chasing in our experiment.

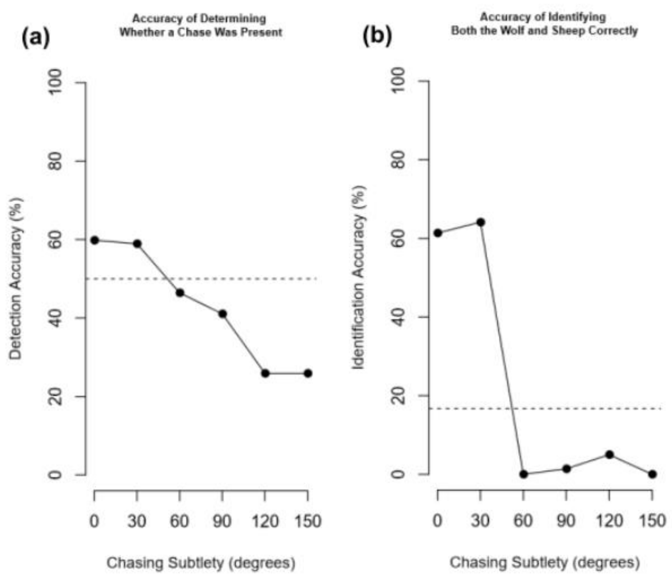

Fig. 5. (a) % correct of determining whether a chase was present as a function of chasing subtlety. Chance performance (dashed line) is 50%. (b) % correct of identifying both the wolf and sheep correctly (given that the chase was accurately detected in the trial) as a function of chasing subtlety. Chance performance (dashed line) is 16.7%.

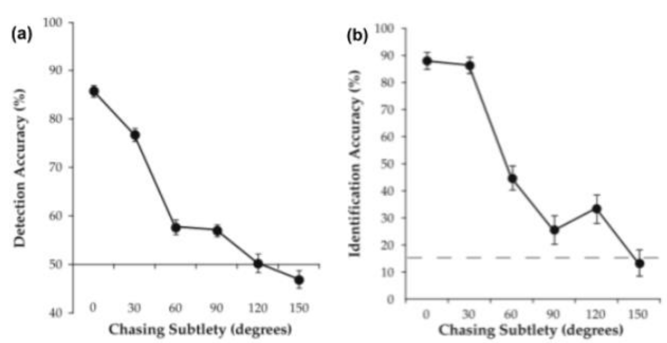

Fig. 6. (a) % correct of determining whether a chase was present as a function of chasing subtlety as found in Gao et. al.'s experiment. Chance performance (dashed line) is 50%. (b) % correct of identifying both the wolf and sheep correctly (given that the chase was accurately detected in the trial) as a function of chasing subtlety as found in Gao et. al.'s experiment. Chance performance (dashed line) is 16.7%. [6]

TABLE I. RESULTS OF PAIRED-T-TESTS OF DETECTION ACCURACY BETWEEN CHASING SUBTLETIES

	0	30	60	90	120	150	Random
0	-	t = 0.19487 p = 0.8534	t = 1.2022 p = 0.298	t = 1.2158 p = 0.3012	t = 5.6858 p = 0.00134	t = 5.6858 p = 0.00134	t = 2.4804 p = 0.08924
30		-	t = 1.1721 p = 0.3189	t = 1.184 p = 0.3182	t = 6.5751 p = 0.001823	t = 6.5751 p = 0.001823	t = 3.873 p = 0.03047
60			-	t = 0.29465 p = 0.7793	t = 1.8127 p = 0.1429	t = 1.8127 p = 0.1429	t = -0.343 p = 0.7542
90				-	t = 0.97555 p = 0.3912	t = 0.97555 p = 0.3912	t = -0.59904 p = 0.5914
120					-	t = 0 p = 1	t = -5.4 p = 0.01245
150						-	t = -5.4 p = 0.01245

C. 2x Speed Experiment

Figure 7a depicts detection accuracy as a function of chasing subtlety, and Figure 7b depicts identification accuracy as a function of chasing subtlety. It is clear from these figures that the trends of the 2x speed experiment do not match the trends of the original study done by Gao et al. and the normal speed experiment discussed in Section IIIB. This suggests that the speed of the trials affected participants' ability to accurately detect chasing.

One participant noted at the end of the experiment that one video did not play. This could suggest that more participants had this issue with possibly more than one video, yielding this unexpected data. Also, we hypothesize that the faster speed of the videos made it more difficult to follow the sharp turns that the Sphero BOLT robots make.

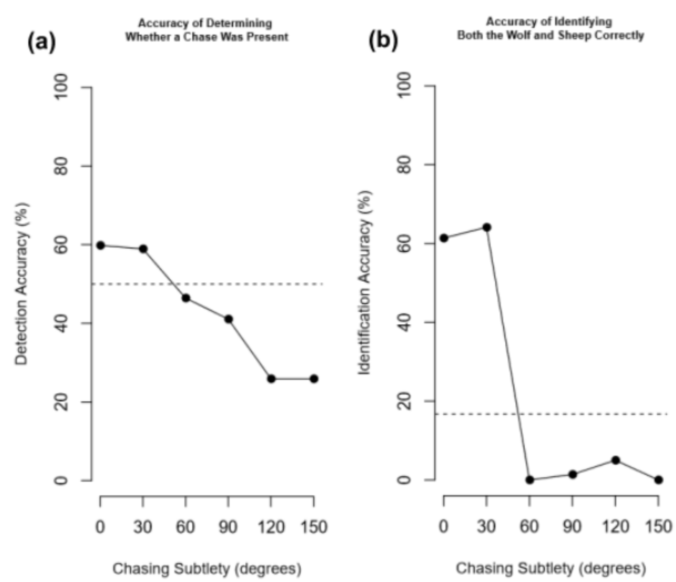

Fig. 7. (a) % correct of determining whether a chase was present as a function of chasing subtlety. Chance performance (dashed line) is 50%. (b) % correct of identifying both the wolf and sheep correctly (given that the chase was accurately detected in the trial) as a function of chasing subtlety. Chance performance (dashed line) is 16.7%.

IV. CONCLUSION

This experiment supports the conclusions of the original study done by Gao et. al. Gao's study found that participants are unable to reliably detect and identify chasing of animated discs when chasing subtlety is beyond 30°, and the results of this experiment suggest that Gao's result can be extended to real life objects. In chase-present trials, there is always a statistical correlation between the wolf's path and the sheep's path. The results of this study further confirm Gao et. al's conclusion that a human's ability to perceive chasing as animacy requires minimal reduction to this correlation.

In order to further investigate our results, we would like to run this study again, but with in-person participants and real-time Sphero robots. In addition, there are ways we could expand on our current study. For example, studies that say that visual memory capacity is limited by the number of objects, and not by the number of features. In fact, it has been argued that four is a good estimate for the number of objects; you can remember sixteen visual features, just as you can four features. Exploring whether or how performance improves when the number of robots is decreased might be of interest. Furthermore, the original study consists of 5 experiments that all explore the psychophysics of chasing. We would like to further explore how the results of Gao's study extend to real life by replicating all or some of the other 4 experiments (for a review, see Luck & Vogel, 2013) Luck & Vogel, 1997; Vogel, Woodman, & Luck, 2001.

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