Movement as a message: inferring communicative intent from actions

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Abstract

Humans often communicate through seemingly arbitrary actions, like winks, waves, and nods. While these non-iconic gestures derive their meanings from cultural consensus, people, and especially children, must be able to identify these movements as gestures. Here we propose that people expect that communicative actions will be shaped to reveal that they have no external goal. In Experiment 1, we show that people judge inefficient actions as more likely to be communicative. In Experiment 2, we show that these judgments are truly driven by efficiency, rather than a movement's visual complexity. Finally, in Experiment 3, we show that repetition – which unambiguously reveals that the goal of the action is the movement itself – has a strong influence on inferences about communicativeness, independent of the motion's efficiency. Our findings show how expectations about non-iconic communicative actions can be folded into a general goal inference framework structured around an expectation for efficiency.

Keywords: Action understanding; gesture; social cognition

Introduction

Beginning in infancy, people interpret others' actions in terms of goals (Woodward, 1998), and they infer these goals by assuming that agents act efficiently (see Jara-Ettinger et al., 2016 for review; Csibra et al., 2003; Gergely et al., 1995; Jara-Ettinger et al., 2015; Jara-Ettinger et al., 2017; Király et al., 2003; Scott & Baillargeon, 2013; Skerry, Carey & Spelke, 2013; Southgate, Johnson & Csibra, 2008). For example, if Billy takes a straight path towards a box of oranges, we can infer that his goal is to get an orange. If instead, Billy moves erratically until he reaches the box of oranges, we may infer that he was originally undecided about his goal, or that he did not know how to complete it.

Goal inference is most commonly conceptualized in terms of "external" goals, such as manipulating objects, reaching locations, or searching for items. Yet many intentional actions serve a different purpose: to communicate. When people wave, wink, or nod, their goal is not to act on an external object, but to share a message: acknowledging someone's presence; indicating that they are in on a joke; or agreeing with someone's argument. For a communicative action to fulfill its goal, however, people must be able to recognize it.

The most obvious way to identify a gesture and recognize its meaning is through iconicity. For example, if Sally wants to remind Anne to cut the tag off of her dress, Sally may hold out her index and middle fingers and move them together and apart to represent a pair of scissors. The movement's inefficiency with respect to plausible external goals and its physical representation of the subject matter may enable Anne to infer that Sally is trying to tell her something. Indeed, people readily label hand motions as gestures when the movements mime the act of grabbing nearby objects (Novak et al., 2016). Even four-year-olds map iconic motions to referents faster than they map arbitrary motions to referents (Magid & Pyers, 2017), suggesting an early emerging sensitivity to the relationship between a movement's form and its meaning.

In some cases, however, it is impossible to produce iconic gestures because the meaning does not map onto an action or material referent. For example, it is difficult to conceive of an iconic gesture that represents gratitude or uncertainty. Moreover, many common communicative gestures, such as shaking one's head, or giving the thumbs up, are not iconic, showing that iconicity is not the only means of conveying communicative intent.

Because non-iconic gestures get their meaning through cultural consensus, they are only useful when the recipient is already familiar with the gesture. Yet we can also recognize new gestures even if we do not know what they mean. Imagine, for instance, watching someone raise her arm with an open hand and her palm facing inwards. Even if you do not know that this means "thank you" in some cultures, chances are that you will still suspect that this movement is a gesture. More importantly, all gestures are, at some point, novel to children, who nonetheless manage to learn their meaning and use them effectively even before their second birthday (Guidetti, 2005; Harris, et al., 2017).

Here we propose that people expect non-iconic communicative actions to be shaped so as to reveal that they have no external goals. Most directly, this predicts that people should see less efficient movements as more likely to be communicative. However, under this account, not all inefficiency is created equal: motions that quickly reveal the absence of an external goal should be seen as more likely to be communicative.

One way to indicate the absence of an external goal is through repetition. By repeating a movement without changing any physical aspect of the world, observers can quickly infer that the goal is nothing more than to produce the action itself, therefore revealing the action's communicative intent. Thus, we predict that people should perceive a repetitive movement as more likely to be communicative than a non-repetitive movement, even if both movements are equally inefficient.

Here we present three experiments that support our hypothesis. Using a simple paradigm of dots moving in two-dimensional planes (which have been shown to convey

enough information to elicit rich mental state reasoning in adults; Heider & Simmel, 1944), we explore people's intuitions about the structure of non-iconic communicative actions, independent of ostensive cues that may accompany communicative actions in natural contexts.

In Experiment 1, we test whether people believe that less efficient motions are more likely to be communicative. Inefficient paths, however, are also more likely to be visually complex. Therefore, in Experiment 2, we test whether people's inferences about communicativeness are better explained by a path's inefficiency or by its superficial complexity. In Experiment 3, we show that people infer that a movement is communicative based on its repetitiveness, independent of its inefficiency. All stimuli, data, and analyses are available at https://osf.io/ehb48/.

Experiment 1

In Experiment 1, we test whether people judge less efficient paths as more likely to be communicative. If people assume that communicative actions are shaped to reveal that they do not have external goals, then participants should rate inefficient movements as more communicative than efficient movements.

Methods

Participants 30 participants (M = 32.87 years, range = 22-63) from the US (as indicated by their IP addresses) were recruited through Amazon's Mechanical Turk platform.

Stimuli The stimuli consisted of 23 seven-second videos of a white dot moving around a green screen. A short red tail trailed behind the dot, in order to make the movements easier to track.

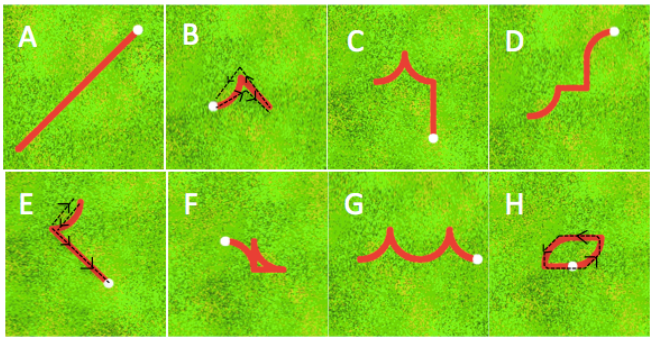

Figure 1: Examples of paths from the eight categories: a) maximally efficient paths, b) paths that retrace themselves back to their origin, c) paths that move towards more than one quadrant, d) paths that move towards only one quadrant, e) paths that retrace a part of themselves, but do not start and end in the same position, f) paths that intersect themselves, but do not start and end in the same position, g) paths that have repeated components that form a pattern, and h) paths that do not retrace themselves, but start and end in the same position. The full red trails depicted above are included here for reference. In the experiment, the red trail was one and a half times as long as the diameter of the dot, and then faded.

Paths were constructed by combining 4 of 16 possible primitive path segments, which were a set of horizontal, vertical, diagonal, and 90 degree arc segments. This resulted in a set of 4,520 unique paths, which we sorted into eight categories based on a priori features of interest that impact the path's efficiency (see Figure 1 for descriptions and examples of path categories). We then randomly selected two random paths from the first category (Fig 1A) and three random paths from all other categories (FigB-H) for a total of 23 paths. Four additional paths were also selected for use as warm-up videos.

Procedure Participants first read a brief cover story:

There is an anthropologist doing research on a remote island. Once a week, a helicopter flies over the island and the anthropologist has to signal the helicopter if he needs additional supplies. Because the tree cover on the island is so thick, the helicopter operator can only track the anthropologist's movements using an infrared camera. The camera is very good at capturing motion. Because of this, the anthropologist signals different requests using previously agreed-upon walking movements.

Some days, the anthropologist needs supplies and will move to communicate a message to the helicopter. Other days, the anthropologist will not need to communicate anything and will continue doing his research and maintaining his base camp.

You will be shown videos of the anthropologist's movements on different days and asked to rate how likely you think it is that the anthropologist was communicating something to the helicopter that day on a scale of one (definitely not communicating) to seven (definitely communicating).

After reading the cover story, participants completed a three-question quiz to ensure that they read and understood the scenario. Participants had to reread the scenario and repeat the survey until they answered all questions correctly. Next, participants were next shown four warm-up videos in order to familiarize them with the types of movements the anthropologist could make. Before proceeding onto the test phase, participants were reminded of the rating scheme. And finally, participants were told that the anthropologist was trying to communicate in roughly half of the videos.

In the test phase, each video looped continuously and was presented on a separate screen. Under each video was a 7-point scale, where participants rated how likely it was that the anthropologist was trying to communicate, from 1 (*definitely not communicating*) to seven (*definitely communicating*). The order of the videos in the warm-up phase and the order of the videos in the test phase were randomized.

Results and Discussion

We quantified each path's efficiency as

$$eff(p) = \frac{d^{\star}(p)}{d(p)} \quad (1)$$

where $d(p)$ is the actual distance travelled and $d^{\star}(p)$ is shortest distance between the start and the end points. Therefore, paths that start and end in the same location have efficiency=0, while straight (maximally efficient) paths have efficiency=1. As predicted, we found a strong negative

correlation between path efficiency and average participant judgments (r = –0.80 p < 0.001; Figure 2), with the two straight (and therefore maximally efficient) paths receiving the lowest average communicativeness ratings.

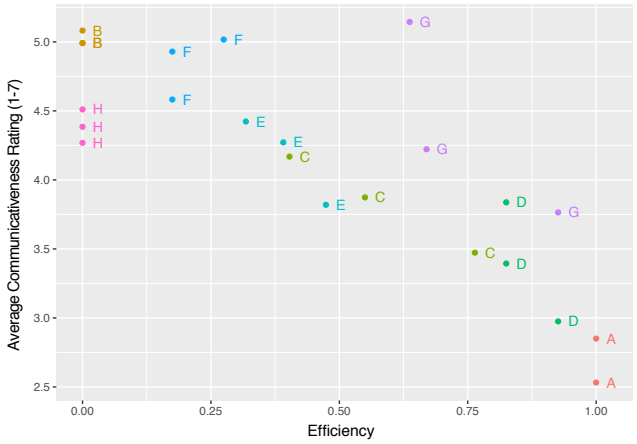

Figure 2: The relationship between path efficiency (x axis; 0, least efficient to 1, most efficient) and average communicativeness rating (y axis; 0, least likely to be communicative to 7, most likely to be communicative).

However, efficiency was not the only feature that guided participants' judgments. Among the least efficient paths (those that began and ended in the same location; categories B and H in Figure 1, with efficiency 0 in Figure 2), the paths with repetition (category B) were rated as more likely to be communicative relative to paths with no repetition (category H; p < 0.005 in a linear model constrained to H and B predicting communicativeness rating from category), suggesting that specific types of inefficiency, such as repetition, are salient cues to communicativeness. Similarly, one path from category G that formed a wave-like pattern (the example in Figure 1G) was judged as highly communicative even though it was relatively efficient, further suggesting that structural aspects of the motion, and not efficiency alone, drive judgments of communicativeness.

Experiment 2

Experiment 1 suggests that people judge less efficient motions as more likely to be communicative. However, it is possible that people's judgments were not driven by a path's efficiency, but by its shape or complexity. We evaluate this possibility in Experiment 2 by contrasting paths similar to those from Experiment 1 with paths that are visually identical, but now efficient due to lakes on the island (Figure 3). If judgments of communicative intent track the movement's efficiency, then participants should judge the version of each path bordered by lakes to be less communicative than the version that is not bordered by lakes. However, if judgments of communicative intent are tracking complexity, then the presence of the lakes should not affect participants' ratings, and both versions of the same path should be rated as equally communicative.

Method

Participants 30 participants (M = 40.83 years, range = 25 - 73) were recruited in the same manner as Experiment 1. Individuals who participated in Experiment 1 were excluded from participation.

Stimuli The stimuli consisted of twelve pairs of identical paths (total videos = 24) presented in two ways: one in which the dot's path was closely bordered on both sides by lakes (constrained trials), and one in which the path was not closely bordered by lakes (unconstrained trials; see Figure 3 for static images). Eight of the twelve paths were obtained by selecting one random path from each of the a priori categories used in Experiment 1 (see Figure 1). Additionally, because we were especially interested in paths that were perceived as highly communicative in Experiment 1, we selected four additional random paths from the set with highest communicative appearance (average communicativeness rating > 4.25 in Experiment 1) for a total of 12 basic paths.

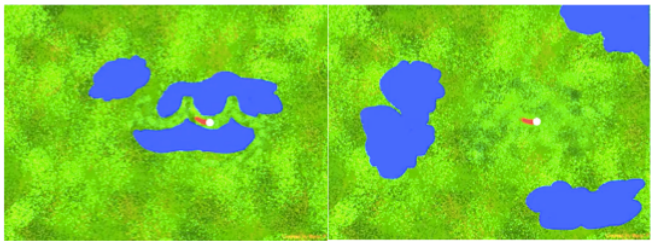

Figure 3: Static images of a constrained trial (left) and an unconstrained trial (right) from Experiment 2.

Procedure The pre-test phase in Experiment 2 was identical to Experiment 1. However, the scenario included an additional description explaining that there are lakes on the island and the quiz included a fourth question about the lakes. The test phase was also identical to Experiment 1, except that participants were assigned to one of five trial orders, which were all pseudo-randomized so that the two versions of the same path were never presented consecutively. Additionally, after the test phase, we asked the participants whether they used any explicit strategies when rating the videos.

Results and Discussion

Figure 4 shows the average perceived communicativeness for each path when it was constrained (x-axis) and when it was unconstrained (y-axis). Overall, participants rated the unconstrained paths (M=4.64) as significantly more communicative than the constrained paths (M=2.99; t(11)= -8.03, p < 0.001). The only path that did not follow this trend was the straight path. However, adding external constraints does not change this path's efficiency because a straight line is already the most efficient way to travel between two points, whereas in the case of the nonlinear paths, the lakes make the inefficient movements efficient given the external constraints.

To analyze the roles of efficiency and the presence of the lakes, we ran a linear regression, predicting average communicativeness rating as a function of the path's efficiency (irrespective of the presence of lakes; Eq. 1), condition (constrained vs. unconstrained), and their interaction. In line with Experiment 1, we found a general effect of efficiency (β= -1.24; $p < .01$) and, as predicted, a general effect of condition (β=2.01; $p < .001$). We also found a marginally significant interaction between the condition and path efficiency (β= -1.14; $p = .059$), suggesting that the effect of adding lakes had a greater impact on less efficient paths.

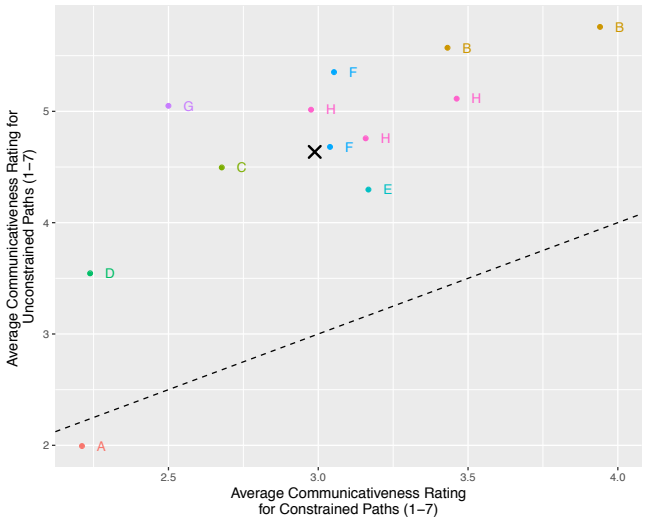

Figure 4: The average communicativeness rating (1, least likely to be communicative to 7, most likely to be communicative) for the constrained and unconstrained versions of each path. Letters correspond to the categories in Figure 1. The "X" indicates the average communicativeness for all constrained and all unconstrained paths and $x=y$ is shown as a dotted line.

This pattern of results is striking. Even though nothing about the shape of the paths changed, by using situational constraints, we were able to alter people's judgments about the communicative intent behind each movement. This provides strong evidence that people track inefficiency, and *not* complexity, when inferring whether a movement was done with communicative intent.

To ensure the robustness of the results, we also did a meta-analysis combining the results of Experiments 1 and 2, predicting the participants' individual (rather than average) answers based on the path's efficiency (Equation 1) and condition (constrained vs. unconstrained)[1] with random intercepts for participant and path category. Consistent with our past results, we found a main effect of efficiency ($p < 0.01$), a main effect of condition ($p < 0.001$), and a significant interaction between efficiency and condition ($p = 0.002$).

Finally, to determine whether participants used any explicit strategies in the task, we analyzed the free response question. Only 9 out of 30 participants mentioned explicitly paying attention to the lakes when rating the videos, suggesting that participants were not simply responding to the presence or absence of lakes. Also, it is important to note that if people's judgments were only driven by the presence or absence of lakes, then responses should have been bimodal, with no variance within each category. Instead, consistent with the results of Experiment 1, people's judgments were also sensitive to each path's efficiency

As in Experiment 1, the communicativeness ratings for the unconstrained versions of paths that started and ended in the same location were higher for the paths that returned to their origin by retracing themselves (category B; Figure 1) than for the paths that did not retrace themselves (category H; Figure 1). Although paths in both categories were equally inefficient, participants rated the paths that repeated the same movement as more communicative. This suggests that specific types of inefficiency, such as repetition, may be salient cues to communicativeness.

Experiment 3

If communicative actions are structured to reveal their communicative intent, then these movements may boast features that "efficiently" demonstrate their inefficiency with regards to external goals. Here we test the prediction that repetitive movements are viewed as more likely to be communicative, independent of their efficiency. To do this, we manipulate the number of times a path is repeated, while keeping the path's basic shape and total distance constant. If the repetitiveness of a path spurs judgments of communicative intent, then participants should rate versions of a path with more repetitions as more communicative relative to versions of that path with fewer repetitions. However, if repetitiveness is not a cue to communicativeness, then the number of repetitions should not affect participants' ratings.

Methods

Participants 30 participants (M = 34.23 years, range = 23-59) were recruited in the same manner as Experiment 1. Individuals who participated in Experiments 1 and 2 were excluded from participation.

Stimuli The stimuli consisted of 21 seven-second videos similar to the ones used in Experiment 1. The stimuli were designed by first creating seven "basic" paths composed of two primitive path segments each (see Figure 5). The final stimuli set consisted of three versions of each basic path: the basic path (no repetition), the basic path that then retraced itself back to its origin (one repetition), and the basic path that retraced itself back to its origin, and then repeated that path again back to its origin (two repetitions). In order to obscure the critical manipulation, paths with one repetition were rotated 90 degrees counterclockwise and reflected over the x-axis, and paths with two repetitions were rotated 180 degrees counterclockwise. Additionally, we altered the

[1] All paths from Experiment 1 were coded as unconstrained for condition.

length of each path segment so that the total distance traveled by each version of the basic paths was matched.

Procedure The cover story, warm-ups, and test phase were identical to Experiment 1, except that after the test phase, we asked participants whether they used any strategies when rating the videos.

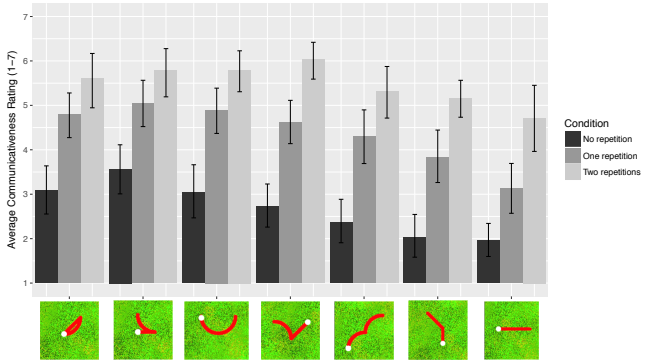

Figure 5: The average communicativeness rating (1, least likely to be communicative to 7, most likely to be communicative) for paths with no repetition, one repetition, and two repetitions. Vertical bars show 95% confidence intervals. Images along the x-axis show the shapes of the unrepeated basic paths and are ordered based on the basic path's efficiency (see Eq. 1).

Results and Discussion

As in Experiments 1 and 2, we averaged participant ratings to obtain a mean communicativeness rating for each path. To analyze the role of repetition and efficiency, we ran a linear regression predicting average communicativeness rating as a function of the path's base efficiency, and the number of repetitions. Consistent with Experiments 1 and 2, we found a general effect of efficiency (β= -1.16; p = .001) and, as predicted, a general effect of repetitions (β=1.40; p < .001). We did not find a significant interaction between repetitions and base path efficiency (β= 0.31; p = .407).

When asked whether they used any strategies, 17 of the 30 participants mentioned paying attention to the amount of repetition, back-tracking, or patterns while watching the stimuli. However, participants also rated less efficient paths as more communicative, suggesting that even if participants were explicitly basing their judgments on repetition, they were also still implicitly tracking how efficiently the movements mapped onto external goals independent of the number of repetitions. Additionally, there was nothing in the experimental set-up that indicated that communicative movements ought to be more repetitive than goal-directed movements. Indeed, one could plausibly infer the opposite: that moving from one point to another in the exact same way is instrumental in the pursuit of a specific external goal.

Participants' attention to repetition provides evidence that people expect communicative actions to be structured in a way that reveals that they are not directed at external goals. With each repetition, participants found the same basic movement to be more communicative, even though the distance and duration of travel were held constant.

General Discussion

Our findings provide the first evidence that people assume that movements made with communicative intent are shaped to reveal that they are not instrumental to external goals. In Experiment 1, we found that people judged less efficient motions as more likely to be communicative. In Experiment 2, we found that these judgments were driven by the path's inefficiency rather than by its complexity. Finally, in Experiment 3, we found that participants judged repetitive motions as more likely to be communicative.

Although people assume that communicative actions will be inefficient in regards to alternative external goals, not all inefficient movements are communicative. For example, someone may perform unnecessary inefficient steps out of ignorance or ritual. People appear to believe that movements that quickly reveal the absence of external goals (such as repetitions) are more likely to be communicative, independent of the movements' efficiency. Thus, taken together, our results suggest that people's expectations about communicative actions are not guided by inefficiency alone, but rather by inefficiency that quickly reveals that the goal is in the action itself.

The experiments presented here are consistent with work showing that when a movement is intentional, but does not efficiently accomplish an external goal, people infer that the goal of the action is the movement itself (Schachner & Carey, 2013). One critical difference, however, is that Schachner and Carey (2013) did not find an effect of repetitiveness on the inference of movement-based goals. Importantly, in their study, the agent was alone and there was no prior mention of possible communicative intent. This difference further suggests that repetition is associated with communicative actions, rather than with the broader class of actions where the goal is the movement itself (such as dancing).

Here we focused on people's expectations about the structure of communicative actions, rather than on the structure of communicative actions themselves. Intuitively, however, the assumption that communicative actions are shaped to reveal that they have no external goal is reasonable and related work has shown that when people need to create communicative systems through motion, they tend to use repetitive and inefficient trajectories to disambiguate their communicative intent (Scott-Phillips, et al., 2009). Additionally, many gestures in the US–such as winking or extending one's index finger and pinky to inform someone to "rock on"–consist of movements that are rarely produced when pursuing external goals. Moreover, gestures that may be confounded with external goals are often repeated. For example, Lisa could shake her head to look quickly in another direction or to move a piece of hair from her face, but if she repeats the movement, an observer can infer that her goal is not to accomplish those external goals, but to signal disagreement.

In these cases, conventional communicative gestures may take their repetitive form due to cultural evolution; gestures that gain meaning through cultural consensus and survive

over time may be those that effectively reveal that they are communicative. Alternatively, communicative gestures may be shaped from their onset to reveal that they are not directed towards external goals. If someone is trying to communicate something with her body, then engaging in on-line reasoning about whether an observer will recognize that she is trying to communicate may cause her to favor movements that do not seem to pursue external goals. Work investigating the production of novel gestures or gesture production across development could help to disambiguate the origins of the inefficiency and repetition that seem to exist in conventional communicative gestures.

In each experiment, we told participants that roughly half of the movements were done with communicative intent. This explicit communicativeness prior enabled us to uncover what types of inefficiency seem *most* communicative. All of the paths used in our experiments (except for the two straight paths) were inefficient. Therefore, according to our theory, it would have been reasonable for participants to rate all inefficient paths as communicative. However, because we were interested in relative ratings of communicativeness, rather than absolute judgments of communicativeness, setting the explicit prior of 50 percent allowed us to get graded responses. Future work will investigate whether inefficiency and repetitiveness also affect the tendency to spontaneously infer that a movement is communicative.

In our studies, we used large-scale two-dimensional movements, rather than footage of hand or arm movements in order to control for subtle cues that may be encoded in biological motion (e.g., Vaziri-Pashkam, Cormiea & Nakayama, 2017). In real life, ostensive cues often accompany communicative gestures (e.g., Behne et al., 2005; Lempers, 1979) and may simplify the task of inferring the communicative intent of a movement. However, we predict that that our findings should hold even with more naturalistic stimuli (e.g., hands, arms) and future work will investigate this question. Additionally, our studies show that even in the absence of these cues, people assume that communicative movements are structured in a way that would not be an efficient means to accomplishing an external goal. Thus, together with ostensive cues, these assumptions may allow people to rapidly infer communicative intent from the myriad possible alternative goals.

Acknowledgments

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