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Understanding distal goals from proximal communicative actions

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Abstract

Can people interpret communicative action modulations in terms of the actor's distal goal? We investigated situations in which the proximal goal of an action (i.e., the movement endpoint) does not overlap with its distal goal (i.e., a final location beyond the movement endpoint). Participants were presented with animations of an object being moved at different velocities towards a designated endpoint. The distal goal, however, was for the object to be moved past this endpoint, to one of two occluded final locations. Participants were asked to select the location which they considered the likely distal goal of the action. As predicted, participants detected differences in movement velocity and, based on these differences, systematically mapped the movements to the two distal goal locations. These findings extend previous research on sensorimotor communication by demonstrating that communicative action modulations are not restricted to proximal goals but can also contain information about distal goals.

Keywords: sensorimotor communication; distal goals; joint action; kinematics; social cognition.

Introduction

As humans, we often engage in a wide variety of complex social interactions that require precise coordination in time and space (Sebanz et al., 2006; Sebanz & Knoblich, 2021). In order to achieve such a feat, interaction partners often predict each other's actions by relying on various types of behavioral cues. One such cue involves the modulation of kinematic parameters of an action. Actors can actively produce these kinematic modulations to communicatively provide anticipatory information to others. To illustrate, consider three friends playing Frisbee together. One of them wishes to inform the others that he is ready to catch the approaching

disk and that he will then pass it to the person standing to his right. A quick and effective way to do this would be to move his body and hands in a manner that makes it obvious to his friends not only that he is about to catch the flying disk, but also that he will throw it towards his right. Thus, these movement modulations fulfill two goals simultaneously: an instrumental goal (catching the disk to pass it on) and a communicative goal (providing additional information which allows observers to predict the instrumental goal). The general capacity to provide anticipatory information about instrumental goals by means of movement modulations has been termed *sensorimotor communication* (SMC; Pezzulo et al., 2013).

A growing body of research has investigated SMC in experimental tasks in which two participants coordinate their actions to achieve a joint goal while the information relevant to attain this goal is allocated asymmetrically between them (for a review, see Pezzulo et al., 2018). So-called "leaders" with full task information have been shown to spontaneously modulate certain kinematic features of their movements, such as grip aperture (Candidi et al., 2015), movement direction (Pezzulo & Dindo, 2011), movement amplitude (Vesper & Richardson, 2014), and velocity (Sacheli et al., 2013), to make their actions more informative, and hence more predictable for "followers" with incomplete task information (Vesper et al., 2017). As such, these movement modulations are a form of nonverbal, action-based communication that participants readily engage in whenever they need to predict each other's movements in real-time in order to achieve a joint goal (Vesper & Sevdalis, 2020).

From proximal to distal goals

For successful action-based communication to occur in these contexts, followers need to, first, perceive the kinematic modulations in leaders' goal-directed movements and, second, interpret these modulations as conveying specific information about a leader's proximal (i.e., immediate) goals, such as reaching for a particular object (Pezzulo & Dindo, 2011) or aiming towards one of several target locations (Vesper & Richardson 2014). Growing evidence indicates that followers can indeed retrieve information about others' action intentions (e.g., Becchio et al., 2008; Manera et al., 2011; Becchio et al., 2012; Cavallo et al., 2016) and use it to adapt their own behavior accordingly (Vesper et al., 2017; Sacheli et al., 2013; Candidi et al., 2015).

What is less clear from this literature is whether followers can interpret movement modulations that encode information about more *distal goals* underlying their partner's actions, i.e., goals that go beyond and temporally follow the observed proximal action. To illustrate this point, consider again our Frisbee example. While the two observing friends can benefit from the catcher's exaggerated movements by focusing on his current, unfolding action, and derive information about his proximal, most immediate goal (i.e., to catch the disk), their interpretation of the movement does not need to stop there. In fact, it is highly likely that the two friends will try to enrich their understanding of the same action by deriving not only the proximal goal underlying the observed movement, but also the more *distal goal* of the agent (i.e., to pass the disk to the right). Importantly, by focusing on the distal, higher-order goal, rather than on the proximal one, the two friends can adapt their behavior in an anticipatory manner, e.g., one of them will prepare to receive the disk, whereas the other will relax and wait for her turn. As such, communicating about distal goals allows interacting partners to be one step ahead of the current situation and thereby facilitate the coordination of their joint action.

In the individual motor control literature, there is evidence showing that distal goals affect the kinematics of early action components. For example, when individuals perform reach-to-grasp movements towards an object, different distal goals (e.g., throwing the object into a large box or placing it in a well) can modulate the velocity of the early transport phase of the movement (Marteniuk et al., 1987). Relatedly, studies in which participants are asked to perform two-step action sequences have shown that the specific constraints imposed on the latter component of an action (e.g., pouring from a bottle or throwing it) can influence the kinematics of earlier components (e.g., grasping the bottle) (Cavallo et al., 2016; Lewkowicz & Delevoye-Torrel, 2020). These findings can be interpreted in terms of a more general binding procedure that links both the motor and the perceptual features of a distal goal within a "common event file" (Hommel et al., 2001). As a consequence of this binding, the activation of relevant perceptual features of a distal goal can lead to the concurrent

activation of the appropriate motor program that is normally used to achieve that goal (Hommel, 2009).

In the present study, we built on the fact that distal goals can affect early action components (e.g., Lewkowicz & Delevoye-Torrel, 2020) and asked whether observers might interpret modulations of these early components in terms of distal goals (see Donnaruma et al., 2017, for a similar investigation of action sequences). Specifically, our focus here was on whether observers can identify distal goals from proximal communicative actions. By adopting this focus, we aimed at extending the application of SMC to a setting where communicative modulations provide anticipatory information not only about immediate, proximal goals, but also about distal goals.

The present study

We designed a computer-based online experiment where participants observed animations of an object being moved at different velocities from a start location towards a designated movement endpoint. The distal goal, however, was for the object to be moved past this endpoint, towards one of two occluded final locations (near vs. far), see Figure 1. After observing the animated movement, participants were asked to select the location which they considered the likely distal goal of the action. As participants were not able to observe how the box was moved to the final target, they could only rely on the observable proximal part of the movement to determine the likely final location of the box.

Since we were primarily interested in whether observers extract information about distal goals from early kinematic modulations, we manipulated the extent to which the proximal goal of an observed action overlapped with its distal goal. Specifically, we presented groups of participants with either (a) movement animations in which the proximal goal (i.e., sliding the box) and the distal goal (i.e., moving it to one of the two final locations) fully overlapped (Figure 1a: "Full overlap" condition), or (b) movement animations in which the proximal goal was separated from the distal goal but retained the relevant kinematic features associated to the achievement of the distal goal (Figure 1b: "No overlap" condition)¹.

Drawing on previous research on SMC and individual motor control, we formulated the following two hypotheses:

H₁: Participants will be able to detect differences in the velocity of the observed movements. This will allow them to consistently decide which movements to map to which of the two distal goals (i.e., final locations). Moreover, we hypothesized that the more the observed velocities differ from each other, the easier participants' decision should be and, consequently, the more consistent their mappings.

H₂: Participants will be more likely to map faster movements onto the far location and slower movements onto the near location due to implicit knowledge about the relationship between velocity and distance. Specifically, this

¹ We also collected data for one further condition with "partial" overlap, which we, however, leave out here for reasons of brevity.

hypothesis is based on the finding that the velocity of aiming movements varies as a function of movement distance (i.e., farther locations are reached with higher peak velocities; Jeannerod, 1984). Again, we expected that the larger the differences in movement velocities, the better participants would be able to consistently map them to the respective location.

In Experiment 1, we tested these two hypotheses. Experiment 2 served as a control experiment, where we assessed the extent to which our findings in Experiment 1 could be explained by potential difficulties in perceptually discriminating different movement velocities.

Experiment 1: Interpreting modulations

Methods

Participants We recruited 50 participants (12 women; Age: $M = 29.6$ years; $SD = 10.0$ years) through the online testing platform Testable (<https://www.testable.org/>). Sample size was determined by using the Superpower statistical package (Lakens & Caldwell, 2019) on R Studio (R Studio Team, 2019). We aimed at obtaining a medium effect size (.4) and high statistical power ($>.8$) based on a series of well-established findings showing that participants can detect subtle kinematic cues to predict other agents' goals (Becchio et al., 2008; Cavallo et al., 2016).

Participants were all proficient English speakers, and were paid 1.5£ for an estimated study completion time of 10 minutes. The experiment was performed in accordance with the United Ethical Review Committee for Research in Psychology (EPKEB). This study was pre-registered via Open Science Framework (<https://osf.io/2qkn3>).

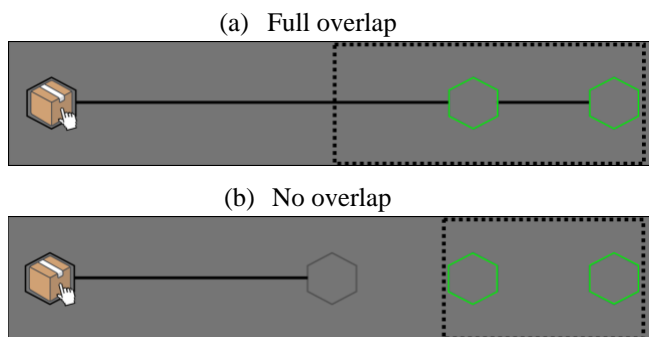


Figure 1: Layout of the experiment in (a) Full overlap and (b) No overlap condition. The black dotted line represents the outline of the occluded area during trials, where the (near and far) final locations are displayed in light green.

Stimuli The basic layout for each experimental condition of Experiment 1 is shown in Figure 1. In both conditions participants saw a stationary box within a black hexagonal location on the left side of the screen. During familiarization, participants also saw two green hexagonal locations on the right side of the screen. During trials, these two final locations were covered with a rectangular black occluder.

The box moved along a black horizontal line that connected the initial location to the final green locations on the right side of the screen (Full overlap) or to the middle of the screen (No overlap), see Figure 1.

Movement animations. Spontaneous goal-directed movements were collected by the first author using an in-house PsychoPy script that recorded mouse movements continuously within a setup that looked identical to the layout of the Full overlap condition in Experiment 1 (Figure 1a). The animated box was attached to the mouse cursor. Cursor movements were constrained by locking them to the horizontal axis, resulting in one-dimensional sliding movements. Additionally, the animated box could only move in one direction, from the left side of the screen towards the green targets on the right. To avoid any biases in the collection of these movements, our in-house script was set to randomly select trials to near and far targets, until a nearly equal number of at least 50 near and 50 far movements were recorded. This procedure led to a total of 105 movements. We then smoothed each individual movement and averaged all near and all far movements, respectively, thus obtaining two non-exaggerated movements, one for each target location (henceforth “Normal far” and “Normal near” movements). This averaging procedure was key, as it allowed us to identify systematic differences between near and far movements (e.g., peak velocity), while also controlling for more subtle differences between individual movements (e.g., in jitter). Importantly, the averaging procedure preserved distinguishable human-like features (e.g., bell-shaped velocity profile, with a fast initial phase and slower final phase) which have been frequently reported in studies looking at rapid aiming movements (e.g., Jeannerod, 1984).

Next, exaggerated movements were generated in three steps. First, we computed the standard deviation of near and far movements separately. Then, we identified the highest value (peak velocity) for each averaged, Normal movement. Finally, we rescaled both Normal movements by subtracting one and two standard deviations from the peak velocity of the near Normal movement, and by adding one and two standard deviations to the peak velocity of the far Normal movement. This procedure led to overall six different movements; two Normal ones, and four exaggerated ones (i.e., $-2SD$, $-1SD$, $+1SD$, $+2SD$) (Figure 2a).

For the No overlap condition, these six movements were reshaped so that their endpoints would all converge towards the middle of the screen (Figure 2b). To do so, we used the “rescale” function in R Studio to manually specify the maximum values of the location vectors of each movement. Critically, this procedure retained most kinematic features of the original movements (e.g., bell-shaped velocity profiles) but eliminated the differences in movement distance such that all movements now had the same endpoint. That is, the movements in the No overlap condition contained kinematic information about different distal goals (i.e., the near or far target location) while displaying the same proximal goal (i.e., the middle of the screen).

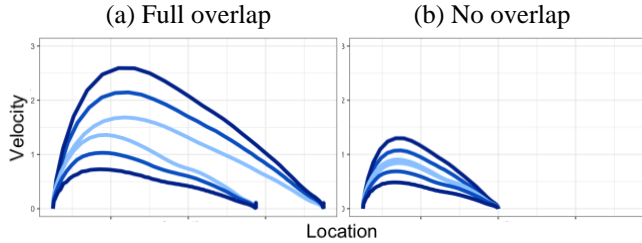


Figure 2. Velocity profiles in (a) Full overlap and (b) No overlap condition. Normal movements are colored in light blue, $\pm 1SD$ movements in blue, and $\pm 2SD$ in dark blue.

Design The experiment consisted of a mixed factorial design, with one between-subject variable (degree of overlap) and one within-subject variable (degree of exaggeration). The between-subject variable manipulated to what extent the proximal goal overlapped with the distal goal (i.e., Full or No overlap). The within-subject variable manipulated whether and to which degree the animated movements were exaggerated in terms of velocity (i.e., not at all (Normal), $\pm 1SD$, $\pm 2SD$).

In the Full overlap condition participants were presented with animations of a box moving from a start location on the left towards one of the two occluded green locations on the right side of the screen (Figure 1a and 2a). As a consequence, in this condition the proximal goal (sliding the box towards the targets) fully overlapped with the distal goal (placing the box within either the near or far target). In the No overlap condition participants were presented with the box moving to an endpoint in the middle of the screen, where it remained stationary for a few seconds and then disappeared (Figure 1b and 2b). Here, the proximal and distal goal did not overlap.

Procedure *Familiarization and instructions.* Once participants were randomly allocated to one of the two between-subject conditions, they were first presented with the complete layout of the experiment (as illustrated in Figure 1), but without the occluder covering the green target locations. Participants then saw two successive Normal movements of the box, one to the near target, the other to the far target (order randomized). In the No overlap condition, after participants saw the box moving towards the middle of the screen, they saw the box disappearing and then rapidly reappearing in one of the two green locations. After seeing the respective movement, participants in both conditions were asked to select the location where the box had moved by pressing the “n” key (for near) or “f” key (for far). Next, a black occluder covered the target locations and participants were told that during trials they would be presented with another participant’s previously recorded movements. Importantly, they were told that this previous participant had produced the movements “in ways that would help others guess to which green location he/she was moving the box”. This information was provided in order to make it explicit to participants that the movements they were about to see were communicative, that is, that they contained useful information about the previous participant’s goals.

Experiment. Participants performed 36 experimental trials, divided into six blocks. Each block contained all six degrees of exaggeration, presented in random order. A trial was completed when participants pressed one of the two assigned keys (“n” or “f”). Participants did not receive feedback at any point. Before the end of the study, participants were asked to fill out a short questionnaire about their experience with the task.

Results

From participants’ responses, we calculated the number of *Predicted* and *Inversed* mappings, aggregated across all six blocks. Predicted mapping refers to trials where participants pressed the “n” key in response to near movements (Normal, $-1SD$ or $-2SD$) and the “f” key in response to far movements (Normal, $+1SD$ or $+2SD$). Inversed mapping refers to those trials where participants reversed this association.

Movement differentiation (H_1) To test whether participants interpreted the observed velocity modulations in a consistent manner, we calculated the *absolute* difference between the total number of Predicted mappings and the total number of Inversed mappings. This gave us a *Consistency score* for each participant ranging from 0 to 12. A score of 0 meant that participants mapped velocities randomly to targets and a score of 12 meant that participants mapped with absolute consistency. We then compared the Consistency scores of each condition to 0 using separate Bonferroni-corrected one-sample *t*-tests. The scores differed significantly from 0 across all degrees of exaggeration and degrees of overlap (all $t(24) > 3.0$, $p < .001$, $d > 1.3$, one-tailed), see Figure 3A. This result shows that participants were able to distinguish the different animated movements and thereby consistently map them to either the near or the far target location, regardless of how exaggerated the velocity profile was and regardless of whether the proximal goal of the action overlapped with the distal goal (Full overlap) or not (No overlap). This confirmed the first part of our hypothesis H_1 .

To address the second part of H_1 , specifically the role of exaggeration and overlap, we conducted a 2×3 ANOVA with Consistency scores as dependent variable, degrees of overlap (Full overlap, No overlap) as between-subject variable and degrees of exaggeration (Normal, $\pm 1SD$, $\pm 2SD$) as within-subject variable. We found a significant main effect of degrees of overlap ($F(1,47) = 23.6$, $p < .001$, $\eta_p^2 = .21$) and a significant main effect of degrees of exaggeration ($F(2,94) = 71.1$, $p < .001$, $\eta_p^2 = .41$). There was also a significant interaction between these factors ($F(2,94) = 8.9$, $p < .001$, $\eta_p^2 = .08$). Pairwise comparisons using Bonferroni-corrected *t*-tests within the Full overlap condition showed significant differences between Normal and both exaggerated movements ($\pm 1SD$: $t(94) = -3.72$, $p = .001$, $d = .76$; $\pm 2SD$: $t(94) = -5.64$, $p < .001$, $d = 1.3$), but not between $\pm 1SD$ and $\pm 2SD$ ($t(94) = -1.9$, $p = .2$, $d = .46$). In the No overlap condition, all pairwise comparisons between degrees of exaggeration yielded significant differences (all $t(94) < -4.8$, $p < .001$, $d > 1.1$). These results show that the larger the differences in

movement velocities, the more consistently participants mapped them to the respective location, thus confirming the second part of our hypothesis H₁. While participants map consistently in both No overlap and Full overlap, they do so even more consistently in the Full overlap condition.

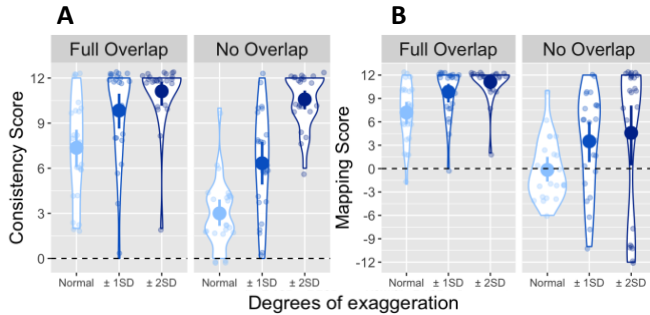


Figure 3. Distribution of Consistency (A) and Mapping (B) scores in Experiment 1 in the Full overlap (left panel) and No overlap (right panel) conditions, for the three degrees of exaggeration. The dashed line indicates random mapping in (A), and random mapping direction in (B)

Mapping direction (H₂) To investigate whether participants were more likely to map movements to targets according to the Predicted mapping, we calculated the *signed* difference between Predicted and Inversed mappings. This *Mapping score* could range from +12 (fully predicted) to -12 (fully inversed). We computed separate Bonferroni-corrected one-sample *t*-tests comparing the Mapping scores of each condition to 0 (i.e., no consistent mapping direction). We found that only in the Full overlap condition participant's responses were significantly different from chance (all $t(24) > 7.2$, $p < .001$, $d > 1.95$, two-tailed), see Figure 3B. In the No overlap condition, however, participants were not more likely to produce a consistent mapping in any of the two directions (all $t(23) > -.17$, $p > .08$, $d > .04$, two-tailed). Thus, in the No overlap condition, individual participants overall used a consistent mapping (resulting in a Consistency score that significantly differed from chance, as reported above), yet, across participants, there was no complete conformity as to the direction of that mapping (i.e., whether to map faster movements to the far location and slower movements to the near location or vice versa).

We again conducted a 2x3 ANOVA, this time with Mapping scores as dependent variable, degrees of overlap as between-subject variable and degrees of exaggeration as within-subject variable. The ANOVA yielded a significant main effect of degrees of overlap ($F(1,47) = 39.5$, $p < .001$, $\eta_p^2 = .28$), as well as a significant main effect of degrees of exaggeration ($F(2,94) = 10.4$, $p < .001$, $\eta_p^2 = .1$). The interaction, however, was not significant ($F(2,94) = 0.15$, $p = .85$, $\eta_p^2 = .001$). Bonferroni-corrected post-hoc *t*-tests were used to analyze the main effect of exaggeration. In the Full overlap condition, only the comparison between Normal and ±2SD yielded a significant result ($t(94) = -2.8$, $p = .02$, $d = 1.3$), whereas in the No overlap condition the comparison

between Normal and both exaggerated movements yielded significant results ($\pm 1SD$: $t(94) = -2.6$, $p = .03$, $d = .7$; $\pm 2SD$: $t(94) = -3.4$, $p = .003$, $d = .63$).

Discussion

We hypothesized that participants would be able to detect differences in the velocity of the observed movements and would consistently map the movements to one of the two final locations, particularly when the velocity differences were exaggerated (H₁). Our results support this hypothesis, as indicated by the significant differences in Consistency scores compared to a non-consistent baseline and by the significant differences in Consistency scores found between Normal movements and exaggerated movements ($\pm 1SD$ and $\pm 2SD$).

In line with previous findings showing that, during the execution of natural reaching movements, velocity and target distance are associated (Jeannerod, 1984), we further hypothesized that participants would map slower movements to near locations and faster movements to far locations (i.e., Predicted mappings) (H₂). Our results in the Full overlap condition provide clear evidence in support of this hypothesis, as shown by the high Mapping scores in that condition. The extent to which participants produced these mappings was also strongly influenced by the degrees of exaggeration, as more exaggerated movements led the majority of participants to produce more Predicted mappings, thus yielding higher Mapping scores.

Taken together, our findings provide initial support for our more general hypothesis that people can understand simple one-dimensional movements that instantiate proximal goals as a means to gain anticipatory information about more distal goals. Specifically, our results in the No overlap condition suggest that movement modulations, despite the fact that they were reshaped so as to only achieve a proximal goal, can be used to extract information about the upcoming, more distal goal. Interestingly, our findings in this condition show that, even when movements are not exaggerated, participants still produce a higher than chance rate of consistent movement-to-location mappings (see Consistency score, Figure 3A). However, when looking at the direction of these mappings (see Mapping score, Figure 3B), we found that there was no clear preference towards either of the two potential mapping directions (i.e., Predicted or Inversed) in this condition. Interestingly, when movements were exaggerated in the No overlap condition, a minority of participants reversed the mapping entirely (see Figure 3B, $\pm 2SD$). To investigate whether this pattern of results reflects an uncertainty about how to map the perceived velocity differences onto the occluded target locations, or if it is simply due to a difficulty in perceptually discriminating between movements of different velocity, we conducted Experiment 2.

Experiment 2: Perceiving modulations

Methods

Participants We recruited 50 participants (14 women; Age: $M = 28.7$ years; $SD = 8.2$ years) through Testable. The conditions of recruitment were identical to Experiment 1.

Stimuli, Design, & Procedure Participants were presented with exactly the same animated movements that we used in Experiment 1, but their task was now to identify whether the movements they would see were fast (by pressing the “f” key) or slow (by pressing the “s” key). The only difference to Experiment 1 concerned the familiarization, where participants saw the occluded scene right away, and consequently never saw the two target locations on the right side of the screen. This choice was made to have participants focus on the velocity differences without making implicit associations about movement distance. As in Experiment 1, participants did not receive any kind of accuracy feedback at any point.

Results

Movement discrimination From participants’ individual responses, we counted the total number of correct and incorrect responses for each movement, across all six blocks, depending on the degree of exaggeration and the degree of overlap. We then subtracted these two values to obtain a *Discriminability score* that ranged from +12 (fully discriminable) to -12 (fully indiscriminable), which we could use to directly compare the results of Experiment 2 with the Mapping score of Experiment 1. As expected, participants were able to discriminate the movements, as shown by the significant difference from chance (i.e., from 0) when movements were Normal, $\pm 1SD$ or $\pm 2SD$, in both Full overlap and No overlap conditions (all $t(24) > -2.8$, $p < .001$, $d > 1.0$, two-tailed).

Comparison across experiments To test whether the task (matching to targets or only discriminating velocity) had an impact, we conducted an ANOVA comparing the Mapping score of Experiment 1 and the Discriminability score of Experiment 2 in the No overlap conditions. The ANOVA yielded main effects for Experiment ($F(1,47) = 6.93$, $p = .01$, $\eta_p^2 = .06$) and degrees of exaggeration ($F(2,94) = 45.2$, $p < .001$, $\eta_p^2 = .36$), and an interaction between these two factors ($F(2,94) = 11.2$, $p < .001$, $\eta_p^2 = .12$). To further explore this interaction, we conducted Bonferroni-corrected post-hoc t -tests comparing participants’ responses for each degree of exaggeration across the two Experiments. The tests revealed significant differences when movements were exaggerated ($\pm 1SD$: $t(94) = -2.3$, $p < .02$, $d = .65$; $\pm 2SD$: $t(94) = -4.5$, $p < .001$, $d = .99$), but not when they were Normal, $t(94) = 1.7$, $p = .09$, $d = .79$.

We repeated the same between-experiment analysis for the Full Overlap condition. This ANOVA only yielded a main effect of degrees of exaggeration ($F(2,94) = 43.9$, $p > .001$,

$\eta_p^2 = .28$), but no significant differences between Experiments ($F(1,47) = .56$, $p = .46$, $\eta_p^2 = .007$).

Discussion

We found in Experiment 1 that participants in the No overlap condition, collectively, lacked a preference for a particular mapping direction. This finding led us to wonder whether difficulties in perceiving the differences in velocity between the two (near and far) movements could have had an impact on their performance. However, the results of Experiment 2 indicate that participants can indeed perceive the differences in velocity between these movements. This, and the significant differences in the exaggerated No overlap conditions between the Mapping scores of Experiment 1 and the Discriminability scores of Experiment 2, suggest that the pattern of results found in Experiment 1 cannot be solely due to a difficulty to perceptually discriminate the movements. Instead, it seems that modulations in velocity, even when they are correctly categorized, are not uniformly associated to a unique distal goal in this condition. Thus, not all participants saw the predicted connection between velocity and distance (cf. Jeannerod, 1984) when the proximal goal of the observed movement did not overlap with its more distal goal.

Conclusion

The aim of the present study was to investigate whether observers can interpret proximal communicative actions in terms of their distal goals. We hypothesized that participants would be able to detect communicative modulations in the velocity of movements and consistently interpret them in terms of their distal goals (i.e., final locations), even though those distal goals could never be directly observed.

Our findings support this hypothesis overall, providing first evidence that observers can derive information about distal goals from simple, one-dimensional movements. Specifically, participants in Experiment 1 were able to infer the likely distal goal of an action by relying on differences in movement velocity, and in turn benefitted from exaggerated velocity differences by producing more consistent mappings. As such, the present study provides further support to the already well-established finding in SMC that observers can predict their partner’s upcoming actions by relying on subtle kinematic modulations in their goal-directed movements, while at the same time extending these findings to a setting where observers need to infer not their partner’s immediate, proximal goals, but their distal goals.

The present study offers interesting perspectives for future research on joint action and communication. As argued at the outset, it is likely that people engaged in a joint action will try to predict their partner’s distal goals by relying on a wide variety of kinematic cues. Being able to make such long-term predictions can be particularly useful in situations where co-actors produce a complex action sequence (Schmitz et al., 2018), such as dancing or playing Frisbee. In such scenarios, providing relevant information about the upcoming distal goals early on in the action sequence would be a useful and effective manner to facilitate coordination.

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