Proceedings of the Annual Meeting of the Cognitive Science Society

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Proceedings of the Annual Meeting of the Cognitive Science Society, 37(0)

Winson, David W
Jordan, J Scott
Hund, Alycia M

2015

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David W. Vinson (dvinson@ucmerced.edu)
Cognitive & Information Sciences, University of California Merced
5200 N. Lake Rd., Merced, CA 95343

J. Scott Jordan (jsjorda@ilstu.edu)
Department of Psychology, Illinois State University
Campus Box 4620, Normal, IL 61790-4620

Alycia M. Hund (amhund@ilstu.edu)
Department of Psychology, Illinois State University
Campus Box 4620, Normal, IL 61790-4620

Abstract

Perceptual variables such as perceived distance contain information about future actions. Often our goals involve the integration of another's goals, such as lifting heavy objects together. The purpose of this study was to investigate how another's actions might influence one's own goal-oriented perceptions, specifically, verbal distance estimates. Using a within-subject paradigm, we replicated a well-known finding that carrying a weighted backpack results in larger distance estimates relative to not carrying a backpack. In a crucial second condition, this effect was reversed: distance estimates were significantly greater when not carrying a weighted backpack than when carrying a backpack. In this condition, participants provided distance estimates while wearing a weighted backpack during the first phase and then gave estimates while not wearing a backpack, but following an experimenter wearing a weighted backpack in the second phase. Three additional conditions systematically documented how the observations of another's actions influenced distance estimates.

Keywords: perception; memory; affordances; distance estimation; social interaction.

Introduction

Perceived distances are greater if one wears a weighted backpack while estimating distance (Proffitt, Stefanucci, Banton, & Epstein, 2003). In their now classic work, Proffitt and colleagues found that while standing, participants' estimates to a target at a variety of distances are systematically greater when wearing a weighted backpack (see also Proffitt & Bhalla, 1999). This difference increases as actual distance increases. This effect also varies with a host of factors such as knowledge about the contents of one's backpack (Durgin et al., 2009), blood glucose levels (Schnall, Zedra & Proffitt, 2010), and current action capabilities (see Witt, 2011 for review). Often, findings such as these are accounted for via appeals to non-visual factors such as implied effort (Proffitt, 2006), action capabilities (Witt, 2011), and affordances (Gibson, 1979).

Common to each of the above-listed frameworks is the notion that perception contains information about future action: how much energy one will have to expend to complete a future action (Proffitt, 2006), what types of actions one's current skill set will allow one to complete in the immediate future (Witt, 2011), and what action options the current optic array affords one in the immediate future (Gibson, 1979). In each case, perceived future action is guided by information present within one's environment (e.g., a steep hill or heavy backpack).

Goal-driven Perception

One explanation of why it is that our perceptions tend to be contextualized by future actions is the theory of event coding (TEC— Hommel, Müsseler, Aschersleben, & Prinz, 2001). TEC asserts that (1) actions are planned in terms of the distal events they are intended to produce, and (2) areas of the brain involved in action planning also are involved in perception. Neural support for TEC derives from a host of data which indicate that pre-motor centers involved in motor planning are also activated when one perceives objects that afford motor activity (Rizolatti, Fogassi, & Gallses, 2001). Such findings imply the following: (1) what is planned during an action is the distal goal (e.g., reach the top of a hill), not the movements one needs to achieve the goal (e.g., the leg movements required reach the top of the hill), and (2) due to the overlap of the neural dynamics involved in goal planning and perception, one's perception of the event (e.g., the hill) will be contextualized by the factors one needs to incorporate into one's plans (e.g., knowledge about the content of one's backpack, blood glucose levels and current action capabilities). In light of these findings, it seems clear that our perceptions are inherently biased by our goals (Jordan, 2013).

The Social Nature of Goal Driven Perception

The overlap between action planning and perception not only gives rise to goal-driven perception, it also entails a social component. For example, expert dancers who observe the dancing of other expert dancers exhibit greater activation than novices in pre-motor areas known to be involved in action planning (Calvo-Merino, Glaser, Greźes, Passingham, & Haggard, 2005). Importantly, less motor-cortical activation occurs when experts of different dance types observe dances that are not within their own expertise (e.g., when an expert Capoeira dancer observes a Ballet dancer; Calvo-Merino et al., 2005). This can be taken as evidence that the observation of another's actions engenders motor-cortical activation similar to that of acting oneself.

The social aspect of goal-driven perception extends to observation of distal events controlled by another. When participants observe a computer stimulus whose movements are controlled by another actor, and the stimulus unexpectedly vanishes, the perceived vanishing point is displaced beyond the actual vanishing point, in the direction of motion (Jordan & Hunsinger 2008). Crucially, the size of this displacement is larger if the observer had previous experience controlling the stimulus. From the perspective of TEC, observing stimulus movements controlled by another activates the planning dynamics one would generate to control the stimulus oneself. And if memories of controlling the stimulus exist, these, too, are activated and alter perception even more.

Furthermore, the notion of goal-driven perception finds support from more recent studies on how one's own abilities and the abilities of others influence current perceptions. When playing a classic Pong game on a computer, participants perceive the speed of the virtual ball to be faster both when they miss the ball with their paddle and when they observe another miss the ball (Witt, Sugovic & Taylor, 2012). Additionally, participants who first played the game and then observed another play the game experienced the speed of the virtual ball in terms of the relationship between their abilities and those of the person they observed. Specifically, participants who were better than the person they observed perceived the ball to be slower while the other played (Witt, South, & Sugovic, 2014).

Collectively, the studies of Calvo-Merino et al. (2005), Jordan and Hunsinger (2008), and Witt et al. (2012, 2014) indicate that observing the goals and actions of another puts one in the planning states for the very same goals and actions, depending, of course on one's abilities (i.e., memories of having completed the task a particular way). In short, we perceive the goals and actions of others in terms of our own abilities (i.e., in terms of our action memories), as if we were doing the task ourselves.

Current Study

Given the inherently social, goal-directed, memory-rich nature of perception, the purpose of the present experiment was to systematically manipulate memories and goals to uncover under what conditions the observation of another's actions influences current perceptions. Specifically, we hypothesized that the observation of another's backpack-carrying actions would influence the perception of distance in ways that would be constrained by (1) whether or not one has recent backpack carrying experience while observing the other, and (2) one's action capabilities (i.e., wearing or not wearing a backpack) while observing the other.

Method

Sixty undergraduate students—12 participants in each of five conditions, replicating the sample size per condition from Proffitt et al. (2003)—were recruited through the participant sign-up system in the Department of Psychology at a large, Midwestern university. All participants were at least 18 years of age with normal or corrected to normal vision. Participants weighed between 100 and 200 pounds and did not have current or chronic back problems. Participants received credit for psychology courses.

Each session lasted approximately one half hour. After providing informed consent, participants were asked to give their weight by standing on a scale. Then, weights equal to 20% of the participant's body weight but no more than the maximum weight limit of 30 pounds were placed inside a backpack to be carried by the participant, replicating the experimental design from previous studies (Proffitt, et al., 2003). The participant then put on the weighted backpack. If participants were not in a condition in which carrying a weighted backpack was necessary, this step was omitted. They were then given a ruler (.3 m) as a guide to making estimates of distance. Both the experimenter and participant exited the lab and walked side by side through the basement halls of the Psychology building along a predetermined route, stopping at specific locations in order for the participant to estimate their distance to a target..

We utilized a 5 (Condition) X 4 (Distance) X 2 (Phase) mixed design with Distance and Phase as within-subject variables, and Condition as a between-subjects variable. Each participant underwent two phases. During each phase, participants stopped and made distance estimates eight times. There were four unique target locations (i.e., pieces of paper taped to the wall with the word "Target" printed in large, bold letters), and participants made two distance estimates to each target during each phase, but from a different distance each time. Target distances were 8, 10, 12 and 14 meters, replicating Proffitt et al., (2003). Thus, across both phases, participants made four distance estimates for each unique target location, with one of the four being made from each of the four distances for a total of 16 estimates. Target locations were randomized with target distances within and across phases.

As can be seen in Figure 1, in Phase One participants estimated their distance while carrying a backpack (Conditions 1, 2, 3 & 5) or not (Condition 4). In Phase Two, participants either carried a weighted backpack (Condition 5) or not (Conditions 1, 2, 3 & 4) while the experimenter walked in front of the participant while carrying a weighted backpack (Conditions 2, 4 & 5) or not (Condition 3) or simply walked next to the experimenter (Condition 1). Each condition was designed to address a specific question regarding the circumstances under which (1) memories of previous action, and (2) one's current action abilities, influence perceived distances while observing another. For this reason, the current design did not test the relationship between all possible combinations of participant backpack/no backpack, 'other' backpack/no backpack, and

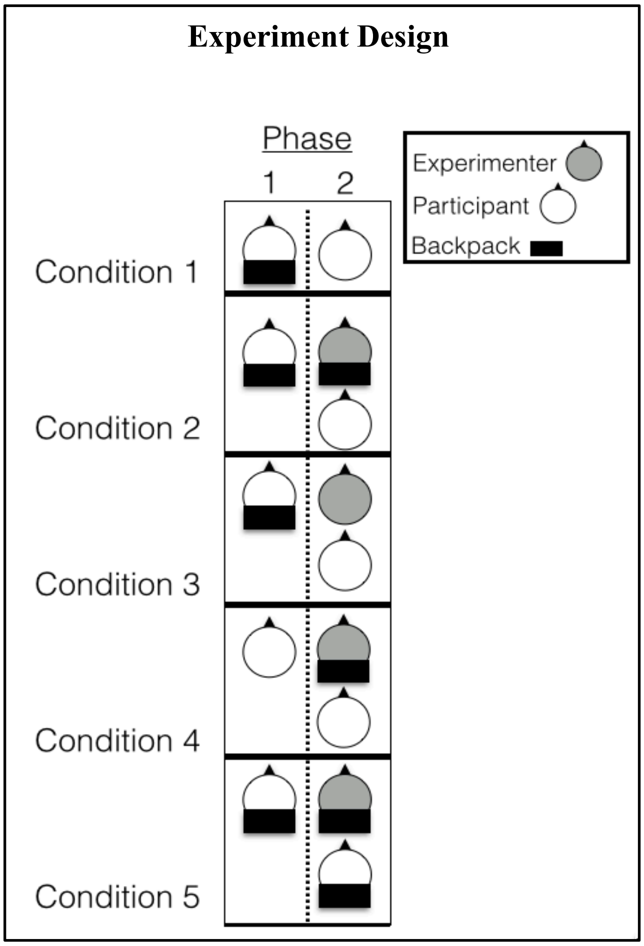

Figure 1: Experiment Design. Each condition (left) contained two phases (top) where participants (white) either carried a backpack (black) or not. In some conditions participants followed an experimenter (gray) in Phase two who carried a backpack or not.

phase. Rather, as will be seen, we only tested those conditions that were essential to determining the necessary and sufficient conditions for producing a difference between Conditions One and Two.

Condition One was designed to replicate the results of previous studies (Proffitt, et al., 2003). Thus, we predicted that distances estimates in Phase One, in which participants made distance estimates while wearing a backpack, would be greater than distance estimates made in Phase 2, during which the participant did not wear a backpack and the experimenter simply walked next to the participant.

Condition Two was exactly the same as Condition One, save for one crucial difference. Specifically, in Phase Two, when the participant made distance estimates while not wearing a backpack, s/he followed the experimenter who was, in fact, wearing a weighted backpack. We created this manipulation to see what would happen to the participants' distance estimates in Phase Two when (1) their action memories of having carried a backpack in Phase One were activated by someone else carrying a weighted backpack, and (2) the participants' current action capabilities in Phase Two were different from those of the other actor (i.e., the participant did not wear a weighted backpack in Phase Two, while the experimenter did). We liken our Phase Two participants in this condition to the Phase Two participants in Witt et al. (2014) who watched another play pong (during Phase Two) after having done so themselves (during Phase One). As was stated above, Witt et al. (2014) discovered that participants who were better at Pong than the person they observed perceived the ball to be slower while the other played. That is, participants experienced the velocity of the stimulus in terms of the relationship between their own abilities and those of the person they were observing. If one assumes the *better* participants experienced the Pong game as being "easier" than the *worse* participants experienced it to be, it might be the case that our Phase Two participants will experience the trek from target to target as being more difficult for the experimenter, particularly in relation to their own experiences carrying the backpack (i.e., backpack-carrying memories) and their current action abilities (i.e., not wearing a weighted backpack). As a result, our participants might actually give larger distance estimates in Phase Two than Phase One as their Phase Two perceptions come to be influenced by their action memories, the observed efforts of the experimenter, and the perceived discrepancy in the difficulty of the task. In short, we predict a reversal of the traditional backpack effect in Condition Two.

Conditions Three through Five (see Figure 1) were designed to ensure that the predicted outcome of Condition Two, were it to occur, was clearly due to (1) the activation of action memories, and (2) the discrepancy in action capabilities between the participant and the experimenter in Phase Two of Condition Two. Thus, in Condition Three we tested the necessity of a discrepancy between the action capabilities of the participant and the experimenter in Phase Two by replicating Condition Two, but not allowing the experimenter to wear a backpack in Phase Two. If we find a reversal of the traditional backpack effect in Condition Two, and a discrepancy between the action capabilities of the participant and the experimenter during Phase Two is *necessary* to produce the reversal, then we should find no reversal in Condition Three. In short, we should once again replicate the traditional backpack effect.

In Condition Four, we tested whether or not the activation of action memories during Phase Two is necessary to produce the reversal we anticipate in Condition Two. To test this idea, we replicated Condition Two except for the fact the participant did not wear a weighted backpack during Phase One. If the social activation of action memories is necessary to produce a reversal of the traditional backpack effect, then there should be no difference between Phase One and Phase Two distance estimates in Condition Four, as the participants will have no backpack action memories to be activated by the experimenter during Phase Two. And given the participants' action capabilities will be basically the same in both phases (i.e., they wear a backpack in neither Phase One nor Phase Two), there should be no differences in distance estimates between the two phases.

Finally, in Condition Five, we once again tested whether a reversal requires a discrepancy in the action capabilities of the participant and the experimenter during Phase Two. However, this time we equated the action capabilities of the participant and the experimenter in Phase Two by having the participant wear a weighted backpack, (versus having the experimenter wear no backpack during Phase Two, as we did in Condition Three). Again, if a Phase Two discrepancy in action capabilities is necessary for a reversal, then there should be no reversal in Condition Five.

While a full model would have provided a more robust series of results, these five conditions were carefully chosen to address the subtleties of our assumptions that both (1) a memory of carrying a weighted backpack, and (2) the presence of an action-capability discrepancy between the participant and the experimenter would result in perceived distances that are greater when not carrying a weighted backpack than when carrying one.

Results

We report the difference between phases within each Condition (5) and Distance (4). That is, we first averaged the distance estimates for each distance in each phase. We then subtracted estimates in Phase One from estimates in Phase Two (Phase Two – Phase One), separately for each distance. A negative value for the resulting difference score reveals that distance estimates were larger in Phase One than in Phase Two. Underestimations are typical of verbal distance estimates (Proffitt, et al., 2006). For this reason we do not consider accuracy a significant predictor of the effects of memory or social factors on perceived distances.

Average difference scores were analyzed using a 4 (Distance) X 5 (Condition) mixed ANOVA; p-values along with estimates of effect sizes—partial eta squared (η_p^2) and Cohen's d[1], respectively—are reported. As predicted, there was a main effect of Condition, $F(4,216) = 4.56$, $p = .001$, $\eta_p^2 = .077$, and no main effect of distance or interaction between Distance and Condition (all $Fs < 1$). A pairwise simple effects test with Bonferroni correction revealed the main effect was driven by three significant differences between Conditions. Specifically, a highly significant difference occurred between Condition One and Condition Two ($p < .001$, $d = 1.38$). As can be seen in Figure 2, the traditional backpack effect was replicated in Condition One, and reversed in Condition Two. That is, difference scores were negative in Condition One ($M = -2.97$, $SD = 4.42$) and positive in Condition Two ($M = 2.59$, $SD = 3.57$). In addition, when treating each condition independently where each participant's difference scores were averaged, one sample t-tests revealed difference scores were significantly different from zero for both Condition one ($t(11) = -2.33$, $p = .04$, $d = .67$) and Two ($t(11) = 2.51$, $p = .03$, $d = .72$).

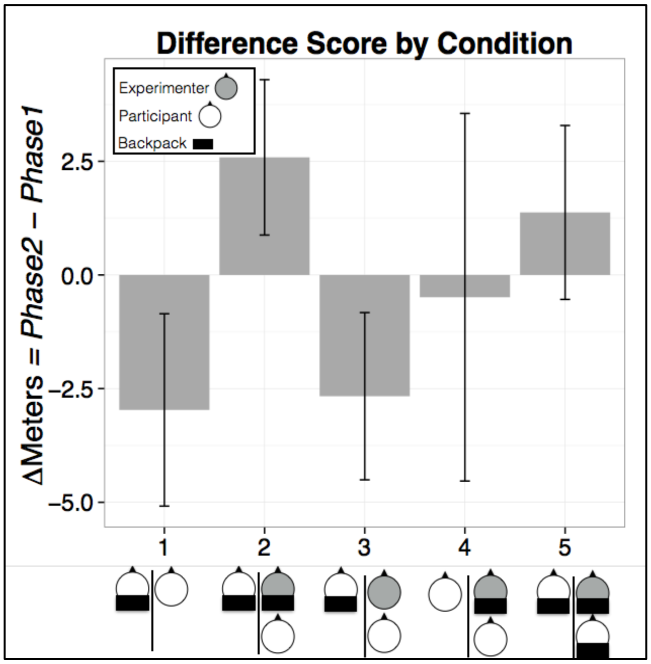

Figure 2: Difference scores for estimates of distance by condition along with standard error bars of each condition are presented. Differences in phases one (left) and two (right) are represented by the experimenter, participant and backpack figures below each condition.

As can be seen in Figure 2, carrying a weighted backpack in both phases lead to greater estimates in Phase two of Condition Five ($M = 1.38$, $SD = 4.0$). Condition Five scores were also significantly different from those in Condition One ($p = .006$, $d = 1.03$), as was the case with difference scores in Condition Two.

Difference scores in Condition Three ($M = -2.67$, $SD = 3.84$) replicated the traditional backpack effect, like Condition One. Condition Three estimates were significantly different from Condition Two ($p < .004$, $d = 1.42$) and marginally different from Condition Five ($p = .063$, $d = 1.03$). However, given the estimated effect size is large, we speculate that a true effect may exist. Furthermore a one samples t-test revealed difference scores in Condition Three were significantly different than zero ($t(11) = -2.41$, $p = .03$, $d = .70$), as were difference scores in Condition Five ($t(11) = 1.19$, $p = .26$, $d = .34$).

Condition Four was not significantly different from any other condition ($M = -.49$, $SD = 8.4$), or from zero ($t(11) = -0.20$, $p = .84$, $d = .06$).

Discussion

Condition One replicates the well-known finding that distance estimates are larger when one wears a weighted backpack (Proffitt et al., 2003). Condition Two reversed this traditional pattern; that is, distance estimates were larger

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[1] Cohen's d for simple effects was determined by using the mean difference score for each participant, collapsed across distances.

in Phase Two, while participants were *not* wearing a weighted backpack. The pattern of differences across Conditions Three through Five are consistent with the assertion that the reversal occurred in Condition Two because (1) the participants' memories of carrying a backpack in Phase One were activated by the observation of the experimenter carrying a backpack during Phase Two, (Calvo-Merino et al., 2005), and (2) participants perceived Phase Two distances in terms of the action-capability discrepancy between themselves and the experimenter (i.e., lighter burden and heavier burden, respectively, Witt et al., 2014) such that the heavier burden of the experimenter amplified the participants' perceived distances beyond what they would be if the participant had no memory of carrying a backpack, and there were no action capability discrepancy. For the sake of brevity, we refer to this collection of arguments as the Socially Relative Action Capabilities (SRAC) account.

Condition Three supports the SRAC account because it shows that the reversal will not occur if the experimenter does not wear a weighted backpack during Phase Two. This reveals that the simple observation of another during Phase Two was not sufficient to generate the reversal. Rather, for the reversal to occur, there must be a discrepancy in the action capabilities of the participant and the observed other. In short, the lack of discrepancy in action capabilities between the participant and the experimenter led the participant to experience Phase Two distances in terms of his/her own action capabilities. Given participants in this condition wore a backpack in Phase One, and did not wear one in Phase Two, their data simply replicated the traditional backpack/no backpack effect.

Condition Four supports the SRAC account because it reveals that the reversal requires the creation of backpack carrying memories in Phase One, even if there is an action-capability discrepancy in Phase Two. This indicates that the Phase Two action-capability discrepancy in Condition Two produced the reversal because the backpack carrying dynamics of the experimenter activated the backpack carrying memories the participant had created during Phase One. This finding is akin to the Calvo-Merino et al. (2005) finding that the amount of pre-motor activation generated while one observes another dancing is contingent upon the amount and type of dance experience the observer has. In short, without a memory of carrying a weighted backpack, the participant was unable to experience the experimenter's burden *as if the participant were carrying the backpack his/herself*. Given participants in this condition wore a backpack in neither Phase One nor Phase Two, there was no difference in distance estimates between the two phases. Another advantage of this lack of change across phases is that is demonstrates that all of the other phase differences in the other conditions were not due to simple repetition effects.

Finally, Condition Five's relationship to the SRAC account seems unclear. At first glance it might seem inconsistent with the SRAC account because it looks as though we have replicated the outcome of Condition Two even though there was no action-capability discrepancy between the participant and the experimenter in Phase Two (i.e., both were wearing backpacks). In other words, Condition Five might be taken to imply one can reverse the traditional backpack effect without a Phase Two action-capability discrepancy.

One way to resolve this issue might be to compare Condition Five to Condition Three. In both conditions, participants developed backpack-carrying memories during Phase One, and there was no action-capability discrepancy between the participant and the experimenter during Phase Two. Given the results of the two conditions are so large (i.e., Condition Three gave rise to a negative phase difference, while Condition Five gave rise to a positive phase difference), yet their methods were so similar, it seems the differences in their results might be due to the different degrees of burden in Phase Two. In other words, given there were no action-capability discrepancies between the participants and the experimenters during Phase Two, participants perceived distances in terms of their own, current action capabilities. In Condition Three, this assertion implies that participants perceived distances in terms of not wearing a backpack, and, as a result, we replicated the traditional Proffitt et al. (2006) finding. In Condition Five, however, participants perceived distances, during Phase Two, in terms of wearing a backpack. Given this was the second phase in a row during which they were asked to carry the backpack, it may be the case participants were somewhat fatigued during Phase 2 and, thus, perceived distances in terms of the extra effort required to carry the backpack during Phase Two. In short, they perceived distances during Phase Two, as did those in Condition Three, in terms of their own, current action capabilities (i.e., more effort required than during Phase One). This account might also explain why the difference scores in Condition Five were not significantly different from zero, while the differences scores in Condition Two (i.e., the reversal condition) were. The positive difference scores in Condition Two actually constituted a reversal of the traditional backpack effect, while the positive difference scores in Condition Five were due to fatigue brought on by carrying the backpack during two consecutive phases.

Collectively, the results of the present experiment are consistent with the findings of Calvo-Merino et al. (2005), Jordan and Hunsinger (2008), and Witt et al. (2014), supporting the assertion that when we perceive another control an event that we have previously controlled (e.g., complete a specific dance, control a stimulus on a computer screen, or make estimates of the distance to a target) our perceptions of the event are influenced by (1) our own *remembered* action capabilities, and (2) our *current* action capabilities in relation to those of the person we are observing. These factors influence the degree to which we experience the 'other' as if we were doing their task ourselves.

One might argue that our use of a within-subjects design may have introduced problems regarding confounding task demands that were less obvious in previous studies that utilized a between-subjects design. For example, researchers empirically (Durgin et al., 2009) and theoretically (Firestone, 2013; but see also Proffitt, 2013 for a response) argue that estimates of distances and hill slopes are influenced by the obvious nature of the task. Participants in backpack experiments may develop their own explanation of why they were wearing a backpack while indicating perceptual judgments, specifically, that the experimenter expects them to give larger estimates while wearing the backpack. To this point, at the end of the current experiment, participants were asked if they had any idea when the experimenter was going to ask them to stop and make their next distance estimate. They were also asked if they thought any of the target distances were repeated, or if they simply felt similar. Further, participants were asked if they knew why the experimenter conducted the experiment or what they thought the experiment was about. In all conditions, participants did not report being aware of design features regarding distances and remained unaware of the specific hypotheses of each condition, including thinking that estimates of distance ought to be larger when observing another carry a weighted backpack.

We utilized a within-subjects design because it is important to demonstrate changes in perception *within individuals* as opposed to *between groups*. By systematically controlling factors such as Phase One experience (i.e., backpack versus no backpack), and whether or not the experimenter wore a weighted backpack in Phase Two, we clearly demonstrated changes within individuals across the phases. And given the clear pattern of changes in difference scores across our different conditions, it seems difficult to sustain the assertion that it was inappropriate to utilize a within-subjects design. To be sure, we did predict that participants' distance perceptions would be influenced by memory and action-capability discrepancies between the participant and the experimenter, which one might assert participants "picked up on" via demand characteristics. Given that not a single participant mentioned being aware of such issues during our post-experiment questioning, we believe this interpretation is highly unlikely. Rather, as stated by the SRAC account, we assert participants' distance perceptions were influenced by memory and action-capability discrepancies because (1) the overlap of brain dynamics involved in action-planning and perception renders perception inherently goal-directed, and (2) the goal-directed nature of perception extends to the perceptions of others.

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