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ORIGINAL ARTICLE

Expecting to lift a box together makes the load look lighter

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Abstract The action abilities of an individual observer modulate his or her perception of spatial properties of the environment and of objects. The present study investigated how joint action abilities shape perception. Four experiments examined how the intention to lift an object with another individual affects perceived weight. In Experiments 1, 2a, and 2b, participants judged the perceived weight of boxes while expecting to lift them either alone or with a co-actor. In Experiment 3, the co-actor was healthy or injured. Participants intending to lift a box with a co-actor perceived the box as lighter than participants intending to lift the same box alone, provided that the co-actor appeared healthy and therefore capable of helping. These findings suggest that anticipated effort modulates the perception of object properties in the context of joint action. We discuss implications for the role of action prediction and action simulation processes in social interaction.

Introduction

How we see the world is not just a matter of physics. Rather, cultural (Nisbett & Miyamoto, 2005; Segall, Campbell, & Herskovitz, 1966) and social (Schnall, Harber, Stefanucci, & Proffitt, 2008; Sherif, 1935) factors, as well as individual action abilities (Gibson, 1979; Proffitt, 2006) shape how we perceive properties of the environment and properties of objects.

According to ecological psychology, the relation between actors and their environment fundamentally shapes perception (Gibson 1979; Marsh, Richardson, Baron, & Schmidt, 2006). Affordances, defined as objective relations between the properties of an action system and the properties of the environment, crucially depend on the interaction between individuals and the environment. Thus, a chair affords sitting for adult humans, but climbing or hiding for a small child. Although the claim that perception is "direct" and not mediated by internal mental representations remains contested (Clark, 1997), recent research supports the claim that perception is shaped by the perceiver's potential for interaction with the environment.

In particular, work by Proffitt, Witt, and colleagues' has shown that perceivers' action abilities affect the perception of spatial properties including distance, slant, and size (Proffitt, 2006; Witt, 2011). For instance, participants judged a hill as steeper when wearing a heavy backpack, compared to judging it without this load (Bhalla & Proffitt, 1999). In addition to anticipated effort (Proffitt, Stefanucci, Banton, & Epstein, 2003; Witt, Proffitt, & Epstein, 2004), factors shaping individuals' perceptual judgments about spatial layouts include the availability of tools (Witt, Proffitt, & Epstein, 2005), and expertise in a particular action domain (e.g., Witt & Dorsch, 2009; Witt & Proffitt, 2005). These findings have been explained by the assumption that when people intend to perform an action, they engage in a motor simulation of that action. Through anticipatory motor simulation, the ability to perform the action is determined, which influences the perception of spatial properties (Witt & Proffitt, 2008).

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Perceiving the environment solely in terms of one's own action capabilities is likely insufficient for successfully engaging in social interaction. Rather, predicting others' actions and coordinating with them may require perceiving affordances for others (Ramenzoni, Riley, Davis, Shockley, & Armstrong, 2008) as well as perceiving affordances for the group (Davis, Riley, Shockley, & Cummins-Sebree, 2010; Richardson et al., 2007). This may also provide the basis for deciding whether to perform an individual action or a joint action. For instance, Richardson et al. (2007) found that people's decision to lift a wooden plank together with another person or alone systematically depended on the ratio between plank length and the dyad's or group's joint arm span. Participants with a rather long arm span took into account the shorter arm span of their partner by performing joint actions more frequently than predicted by their individual arm span. These results suggest that joint affordances play an important role in joint action performance.

It is unknown, however, whether joint action abilities affect the perception of object properties. Our action abilities change drastically as we have the opportunity to act together (Clark, 1996; Sebanz, Bekkering, & Knoblich, 2006). We can achieve things that we could not achieve alone, and many activities are less effortful when performed with others, such as lifting heavy boxes together. Do joint action abilities affect individual perception? The present study investigated whether the intention to engage in joint action affects the perception of object weight. Given the previously demonstrated effects of individuals' anticipated effort on perception (Proffitt, 2006), we predicted that individuals intending to lift a box of potatoes (Experiment 1) or a box of golf balls (Experiments 2a, 2b, and 3) with another person would judge the box as lighter compared to individuals intending to lift the same box alone. We focused on weight judgments rather than judgments about spatial layouts because joint action clearly has an impact on this dimension, making objects less effortful to lift. Furthermore, previous work has shown weight judgments to be sensitive to the social context in which individual actions are performed (Hamilton, Wolpert, & Frith, 2004; Hamilton, Joyce, Flanagan, Frith, & Wolpert, 2005).

Experiment 1

This experiment investigated whether people judge boxes filled with potatoes as heavier when they intend to lift them alone, compared to intending to lift them with another person. To investigate whether the perception of object weight during actual lifting affects judgments, we asked participants to judge the weight of the boxes not only before, but also after lifting them alone or together. We predicted that participants would judge the boxes as lighter not only after joint lifting compared to individual lifting, but also while intending to lift them jointly rather than alone. It was ensured that participants understood they were to judge the actual weight of the boxes, regardless of the actions to be performed.

Methods

Participants

Forty-eight Rutgers students (mean age = 22.5 years) participated for partial fulfillment of course requirements. Participants were naïve with regard to the purpose of the experiment and they were randomly assigned to one of two conditions (solo or joint). One participant was excluded because he was not familiar with the weight system (pounds). All participants provided written informed consent before beginning the study.

Materials and procedure

In the solo condition, participants sat on a chair in one corner of a room. In the joint condition, a second participant sat in the opposite corner. Each participant was given a paper and pencil to write down their weight judgments. The instructions on the sheet read "How much does the box weigh? Please make a judgment (between 1 and 20 lb) before and after you have lifted it". On each trial, a projection screen was lifted, revealing a transparent box of about 13 × 15 × 23 inches filled with potatoes. The box could easily be grasped at the two shorter sides. Weights varied between 1 and 20 lbs. There were 20 trials with 20 different weights. The order of weights was randomized. Participants were instructed to judge the weight of the box, then to get up and lift the box and then make another judgment. Participants in the solo condition lifted the boxes alone, whereas participants in the joint condition lifted the boxes together. No feedback was provided.

Results and discussion

Four participants were excluded from the data analysis because their overall accuracy was more than two standard deviations below average. Thus, the analyses are based on 43 participants. We discarded the first five trials as practice trials because a first inspection of the data revealed that participants needed repeated exposure to different weights in order to calibrate. As participants knew that the actual weight varied between 1 and 20 lbs, there was no room for systematic biases to occur at either end of the scale; therefore, the statistical analyses are based on trials in which the box weighed 3–18 lbs.

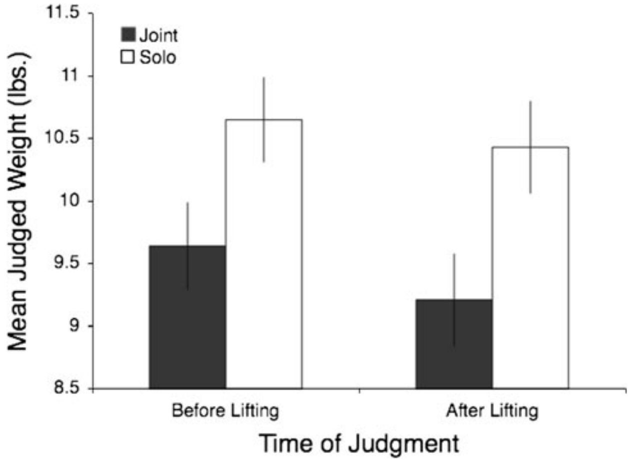

Fig. 1 Results of Experiment 1. Mean judged weight before and after lifting while expecting to lift alone (solo condition) or with a co-actor (joint condition). *Error bars* represent ±1 standard error of the mean (SEM)

Figure 1 shows the results. A 2 × 2 analysis of variance (ANOVA) with Condition (solo vs. joint) as a between-subjects factor and time of judgment (before vs. after lifting) as a within-subjects factor revealed a main effect of Condition, $F(1, 41) = 5.56$, $p < .05$, $p_{rep} > .88$, $\eta_p^2 = .12$ (Fig. 1), with joint judgments ($M = 9.42$, SD = 1.59) being lighter than solo judgments ($M = 10.54$, SD = 1.71). This analysis also revealed a tendency towards a main effect of time of judgment, $F(1, 41) = 2.98$, $p = .09$, $p_{rep} = .82$, $\eta_p^2 = .07$, with lower estimates after lifting ($M = 9.83$, SD = 1.80) than before lifting ($M = 10.15$, SD = 1.67). The interaction was not significant, $F(1, 41) = 0.32$, $p = .58$, $p_{rep} = .45$. Separate one-way ANOVAs for Judgments before lifting and after lifting revealed that in both cases, participants in the joint condition judged the weights as lighter than in the solo condition, $F(1, 41) = 4.17$, $p < .05$, $p_{rep} > .88$, $\eta_p^2 = .09$ for before lifting, and $F(1, 41) = 5.42$, $p < .05$, $p_{rep} > .88$, $\eta_p^2 = .12$ for after lifting.

Accuracy

Participants' pre- and post-lifting judgments in the solo condition were highly accurate regarding the actual mean of the weights presented (10.5 lbs). Single sample *t* tests showed that mean solo judgments did not significantly differ from the actual mean of 10.5 lbs. (p's > .70). Interestingly, participants in the joint condition significantly underestimated the weight with regard to actual mean weight, in both pre-lift, $t(20) = -2.80$, $p = .01$, and post-lift, $t(20) = -3.36$, $p = .003$ judgments.

These results support our prediction that boxes appear less heavy when one is intending to lift them with a partner rather than alone. Judgments in the joint condition were lower than judgments in the solo condition not only after participants had lifted a box together, but also before they did so. However, we cannot rule out the possibility that the experience of repeatedly lifting boxes together shaped weight judgments in the joint condition. Thus, participants may have judged the boxes as lighter simply because they felt lighter on previous trials. Experiment 2a was designed to rule out this explanation.

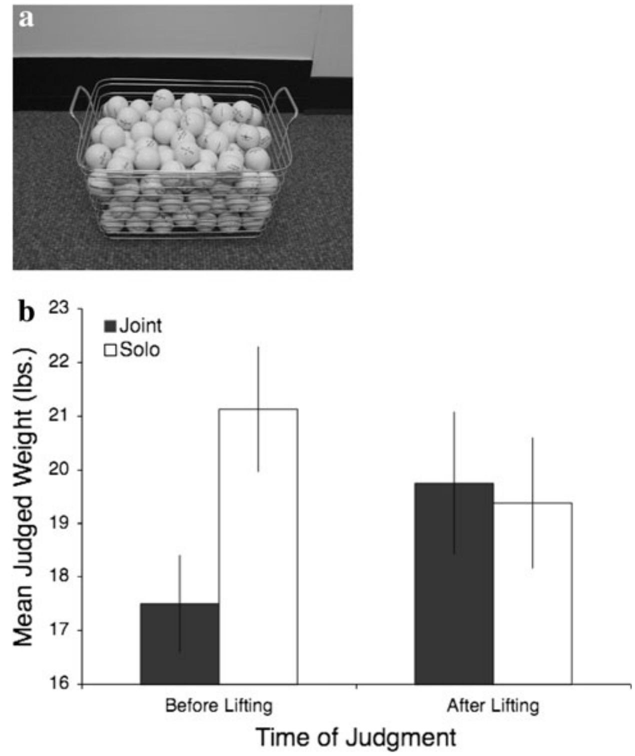

Fig. 2 Photograph of the basket of golf balls (**a**), and results of Experiment 2a (**b**). Mean judged weight before and after lifting while expecting to lift alone (solo condition) or with a co-actor (joint condition). *Error bars* represent ±1 SEM

Experiment 2a

In this experiment, participants only made a single judgment while intending to lift a box together or alone. Thus, they did not experience the effort of lifting (jointly or individually) prior to making their judgment. Furthermore, we sought to replicate the results of Experiment 1 with a different set of stimuli (golf balls; see Fig. 2a). Again, we predicted that participants intending to lift the box together would judge it as lighter than participants intending to lift it alone.

Methods

Participants

Sixteen Rutgers students (mean age = 20.75, SD = 6.65) took part in Experiment 2a, all of whom were naïve to the purpose of the experiment. They were randomly assigned to one of two conditions. Eight students (5 female) participated in the joint condition, and eight different students (5 female) participated in the solo condition. Students participated for partial fulfillment of a course requirement and provided informed consent.

Materials and procedure

Participants were tested individually and sat in one corner of the experimental room. On the floor approximately four feet in front of the participant was a 2 lb. wire basket filled with 18 lbs of golf balls (177 golf balls), totaling 20 lbs. The basket remained hidden from view until all instructions were given. The experiment consisted of a single trial. Participants were instructed to judge the weight of the box, then get up and lift it (either alone in the solo condition, or with the experimenter in the joint condition), and to then make another weight judgment. Participants were instructed to "indicate how heavy the basket appears". They were told that the actual weight ranged from 15 to 25 lbs. Participants wrote down their judgments on a sheet of paper that was on the desk beside them. The experimenter served as the co-actor in the joint condition for two reasons: (1) to eliminate any differences in the strength of the co-actor between participants (e.g., height, gender, or build of co-actor) and (2) to reduce any effect of social facilitation (Zajonc, 1965) brought about by having an additional person present in the joint condition.

Results and discussion

Figure 2b shows the results. A 2 × 2 ANOVA with Condition (solo vs. joint) as a between-subjects factor and Time of Judgment (before vs. after lifting) as a within-subjects factor revealed a significant interaction, $F(1,14) = 4.74$, $p = .047$, $p_{rep} = .88$, $\eta_p^2 = .25$ (Fig. 2). There was neither a main effect of condition nor of time of judgment (all p's > .25). A separate one-way ANOVA for judgments before lifting revealed a main effect of Condition (solo vs. joint), $F(1, 14) = 5.99$, $p = .028$, $p_{rep} = .91$, $\eta_p^2 = .30$, where joint judgments were lighter than solo judgments. There was no significant difference between solo and joint judgments after lifting.

Accuracy

Judgments before joint lifting were significantly below the actual mean weight of 20 lb, $t(7) = -2.76$, $p = .03$. Judgments in all other conditions did not differ significantly from the actual mean (all other p's > .36, using single sample t tests).

These findings confirm our prediction. Even in the absence of the experience of joint lifting, participants expecting to lift a basket of golf balls with another person judged it as lighter than those expecting to lift it alone. Unlike in Experiment 1, judgments after lifting did not significantly differ between the solo and joint condition. It could be that the difference between the solo and joint condition after lifting in Experiment 1 reflects an effect of repeated lifting. In particular, repeated lifting may have led participants in the joint condition to perceive the boxes as not so heavy, whereas participants in the solo condition might have suffered from fatigue. This effect did not occur in the present experiment, where participants only lifted the box a single time. In fact, judgments after lifting were surprisingly accurate. They were slightly higher, though not significantly different from the actual weight. In contrast, judgments before lifting were slightly too high in the solo condition, and significantly too low in the joint condition. Taken together with the results of Experiment 1, it appears that solo judgments are generally more accurate, whereas judgments in the joint condition reflect a tendency to underestimate the actual weight.

A possible explanation for this underestimation is that participants intending to act together engaged in motor simulation of their part of the joint action to be performed. Predictive forward models (Wolpert & Flanagan, 2001) based on prior experience in jointly lifting boxes could have yielded predictions about the effort required to lift the box together. Anticipated effort, in turn, may have affected weight judgments. However, an alternative explanation is that participants' judgments simply reflect a cognitive bias whereby a particular social context leads to the underestimation of quantities. Experiment 2b was designed to rule out this possibility.

Experiment 2b

If the effects observed in Experiments 1 and 2a were due to cognitive bias, then judgments about other properties, such as quantity (i.e., the number of golf balls in the basket), should be similarly affected by the joint action context. If, on the other hand, the observed underestimation of box weight in the joint condition reflected effects of anticipated effort on perception, then judgments about quantity should not be affected by whether participants are intending to lift a box alone or together. Motor effort, per se, reflects weight, and not quantity. Thus, only weight judgments should be influenced as a direct effect of anticipated effort.

Methods

Participants

Twenty Rutgers students (mean age = 19.9, SD = 1.68) took part in Experiment 2b, all of whom were naïve to the purpose of the experiment and randomly assigned to one of two conditions. Ten students (4 female) participated in the joint condition, and 10 different students (4 female) participated in the individual condition. Students participated for partial fulfillment of a course requirement and provided informed consent.

Materials and procedure

The same materials and procedure were used in Experiment 2b as in Experiment 2a, except for an additional request to estimate the number of golf balls in the basket. Prior to making judgments about the box's weight, participants were asked to "indicate how many golf balls are in the basket". All other instructions remained identical to those of Experiment 2a. Consistent with the constraint on the range of possible weights (±25%), participants were told that the actual number of golf balls ranged from 135 to 225.

Results and discussion

Weight judgments

Figure 3 shows the results. A 2 × 2 ANOVA with Condition (solo vs. joint) as a between-subjects factor and Time of Judgment (before vs. after lifting) as a within-subjects factor revealed a main effect of Time of Judgment, $F(1, 18) = 7.22$, $p = .015$, $p_{rep} = .94$ $\eta_p^2 = .29$ (Fig. 3). There was no main effect of condition and no interaction (p's > .33). A separate one-way ANOVA for Judgments before lifting revealed a significant effect of Condition, $F(1,18) = 4.59$, $p = .046$, $p_{rep} = .88$, $\eta_p^2 = .20$ (equal variances not assumed), where Solo judgments were heavier than joint judgments. This seems to be the driving factor behind the main effect of time of judgment reported above.

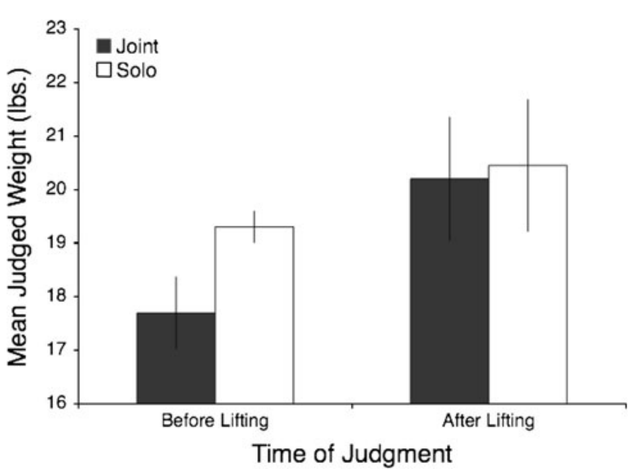

Fig. 3 Results of Experiment 2b. Mean judged weight before and after lifting while expecting to lift alone (solo condition) or with a co-actor (joint condition). *Error bars* represent ±1 SEM

Accuracy

As in Experiments 1 and 2a, single sample t tests showed that post-lift judgments (p's > .10) did not differ significantly from the mean actual weight. However, pre-lift judgments in both the individual, $t(9) = -2.33$, $p = .045$, and Joint conditions, $t(9) = -3.36$, $p = .008$, were lower than the actual weight.

Number judgments

Mean judgments of the number of golf balls before lifting were 155.3 (SD = 16.50) in the joint condition, and 161.8 (SD = 20.17) in the solo condition. Mean judgments after lifting were 168.1 (SD = 31.17) in the joint condition, and 166 (SD = 31.43) in the solo condition. A 2 × 2 ANOVA with condition (solo vs. joint) as a between-subjects factor and time of judgment (before vs. after lifting) as a within-subjects factor revealed neither a main effect of Condition, Time of Judgment, nor a significant interaction, all p's > .10. A one-way ANOVA comparing pre-lift judgments in the individual versus joint conditions revealed no significant difference, $F(1, 18) = .622$, $p = .44$. There were no significant correlations between individual participants' weight judgments and number judgments.

As predicted, weight judgments were affected by the intention to lift alone or together while number judgments were not. This indicates that anticipated effort rather than a cognitive bias underlies the underestimation of object weight when intending to lift objects together.

Lower weight judgments before joint lifting were observed consistently across Experiments 1, 2a, and 2b (as evidenced by the significant main effect of Condition for judgments given before lifting). In contrast, the pattern of post-lifting judgments varied across experiments. In Experiment 1, judgments after lifting showed the same pattern as judgments before lifting, whereas in Experiments 2a and 2b there was no difference in weight judgments after joint or individual lifting. This can be explained by the fact that Experiments 2a and 2b only involved a single trial, so that the effort associated with repeated lifting of the box did not affect post-lifting judgments. Finally, whereas in Experiment 2a estimates in the solo condition decreased after lifting the box and estimates in the joint condition increased, in Experiment 2b, they increased in both conditions. This may be due to the fact that participants' initial judgments in Experiment 2b tended to be too low in both conditions, so that lifting the box led to upward corrections.

Experiment 3

What could be the mechanism underlying the observed effect of intended joint action on weight judgments? The

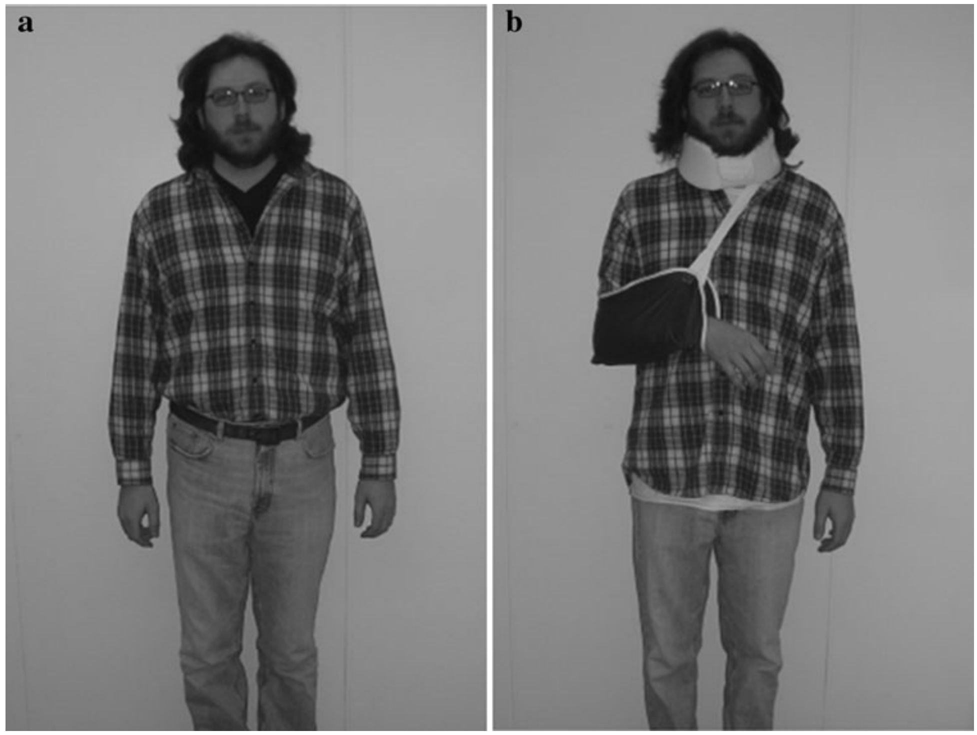

Fig. 4 Experimenter who served as co-actor in healthy state (**a**) and injured state (**b**)

results of Experiment 2b provide some evidence that anticipated effort rather than a general cognitive bias led to the observed modulation of weight judgments. If this is true, then participants' weight judgments should be modulated by the physical ability of their co-actor, such that weight judgments decrease more if the co-actor is perfectly able to lift the box compared to when the co-actor is limited in his or her ability to lift the box. However, it could also be that sharing the intention to perform a joint action is key. Rather than the anticipated physical effort, the knowledge that one is intending to act together upon an object may change one's perception of it. In particular, a study by Schnall et al. (2008) indicates that social support has similar effects as raising one's individual action abilities. When participants thought about a supportive other, a hill seemed less steep to them compared to when they thought about an unfriendly person. In our experiments, having a shared intention (Bratman, 1992; Tomasello, Carpenter, Call, Behne, & Moll, 2005) or a shared goal (Butterfill, 2011), or experiencing joint commitment (Gilbert, 1999; Gräfenhain, Behne, Carpenter, & Tomasello, 2009), may have created a feeling of social support that made the boxes in Experiments 1 and 2 appear lighter in the context of joint action.

To test these alternative explanations, we manipulated the co-actor's perceived physical ability. In the joint condition, half of the participants were paired with an apparently injured co-actor, and half with a healthy co-actor (Fig. 4; the co-actor in all conditions was also the experimenter). To rule out effects of exposure to an injured individual, the same experimenter was present in the solo condition and appeared injured or not. Thus, there were four between-subjects conditions: joint-healthy (participants expecting to lift with a physically healthy partner), solo-healthy (participants expecting to lift alone, with the healthy person present in the room), joint-injured (participants expecting to lift with an injured partner), and solo-injured (participants expecting to lift alone, with the injured person present in the room).

If anticipated effort plays a role in the observed effects on weight judgments, participants intending to lift a box with an uninjured co-actor should judge it as lighter than participants intending to lift it with an injured co-actor. Weight judgments in the solo condition should be the same regardless of whether an injured or healthy person is present. Alternatively, if having a shared intention or a shared goal is critical, judgments in the two joint conditions should be the same, because in both cases, participants are intending to act together with another person. In this case, one would expect a main effect of the joint condition compared to the solo condition.

Methods

Participants

Forty-five Rutgers students (mean age = 19.38, SD = 1.54; 19 female) participated for partial fulfillment of a course requirement. All were naïve to the purpose of the experiment and were randomly assigned to one of four conditions. Two participants were excluded because they misunderstood the instructions.

Materials and procedure

The same materials and procedure were used as in Experiment 2a. The only difference was the additional manipulation of the co-actor's apparent physical ability (injured vs. healthy). In the injured conditions, the experimenter (acting as the lifting partner in the joint condition) wore a CVS Pharmacy brand Adult Arm Sling on his dominant (right) arm and a Futuro Brand Soft Cervical Collar around his neck (Fig. 3). To ensure participants knew the dominant arm was injured, and to reinforce the believability of the injury, the experimenter asked participants with help in filling out their own data sheet (i.e., writing down their gender and age). If asked about the cause of the injury, the experimenter replied he had been in a minor car accident the previous weekend. After the experiment, participants were debriefed and questioned regarding the believability of the injury. Two participants expressed doubts about the injury; therefore, their data were excluded. All others indicated they thought the injury was real, which was further evidenced by the look of surprise and laughter after finding out the truth. It may be noted that the injury was so believable that one participant, after having been made fully aware that the injury was fake, still said upon leaving "Hope you feel better".

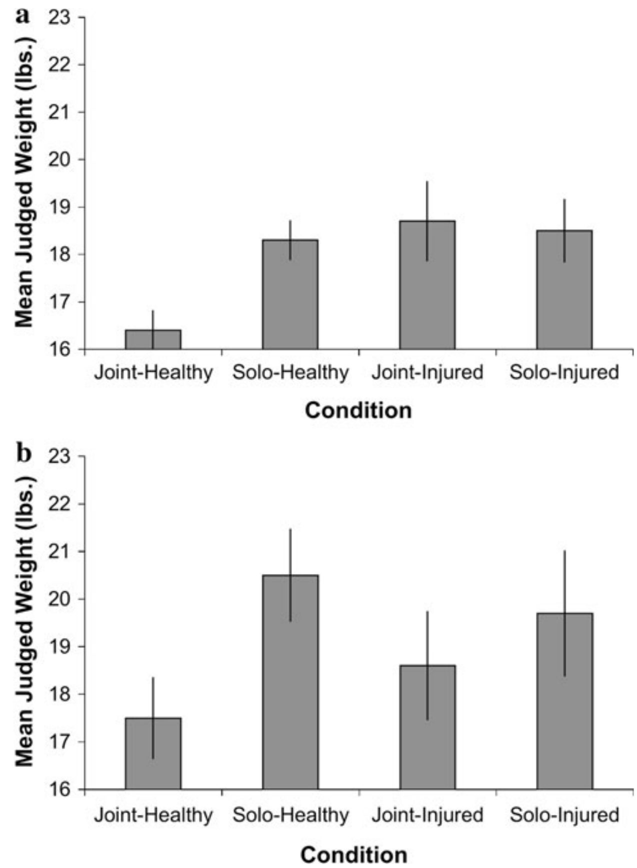

Fig. 5 Results of Experiment 3. Mean perceived weight of a 20 lb basket while expecting to lift alone (solo condition) or with a co-actor (joint condition) (**a**), or after lifting (**b**). The physical state of the other person could be healthy or injured. *Error bars* represent±1 SEM

Results and discussion

One participant was excluded from data analysis because her judgment prior to lifting was more than two standard deviations outside of the group mean. Thus, the analyses are based on data from 40 participants.

Weight judgments

Figure 5 shows the results. A one-way ANOVA revealed a significant main effect of condition, $F\,(3,36) = 2.97$, $p = .045$, $p_{\text{rep}} = .89$, $\eta_p^2 = .20$. As we had a priori expectations regarding the qualitative relationship between conditions, we next ran a planned contrasts analysis with the contrast coefficient of the joint-healthy condition set at −3 and the other 3 conditions set at 1. This analysis showed that participants in the joint-healthy condition provided significantly lower judgments, $t(3,36) = 2.95$, $p = .006$, than participants in the solo-healthy, solo-injured, and joint-injured conditions. A one-way ANOVA for post-lift judgments revealed no significant differences between conditions, $F\,(3,36) = 1.43$, $p = .25$.

Accuracy

Regarding pre-lift judgments, single-sample *t* tests with 20 as the test value showed that judgments in three conditions were significantly lower than the actual weight of 20 lbs: joint-healthy [$t(9) = -8.43$, $p < .001$; $M = 16.40$, SD = 1.35], solo-healthy [$t(9) = -4.02$, $p = .003$; $M = 18.30$, SD = 1.34], and solo-injured [$t(9) = -2.24$, $p = .05$; $M = 18.50$, SD = 2.12]. In single sample *t* tests with 20 as the test value, the only post-lift condition that significantly differed from the actual weight (was significantly lower) was joint-healthy $t(9) = -2.91$, $p = .02$; ($M = 17.50$, SD = 2.72).

These results show that intending to lift with another person makes the load look lighter, but only when intending to lift with a healthy person who is capable of providing a significant amount of help. Intending to lift with a seemingly injured individual (i.e. someone in an arm-sling and neck-brace) did not affect participants' perception of weight in a similar fashion as intending to lift with a healthy individual. An increased feeling of social support through shared intentions in the joint condition cannot explain the observed effects. Rather, it seems likely that participants judged boxes as less heavy because they anticipated the effort during joint lifting.

General discussion

The set of experiments presented here examined how one's resources in combination with the resources of others can modulate perception. Three experiments showed that intending to lift a box together decreases judgments of its weight compared to intending to lift the same box alone, provided that the co-actor appears capable of helping. This indicates that perception is shaped not only by what we can do by ourselves but by what we can do with others.

Our findings extend earlier studies that have investigated how individual action abilities affect the perception of the environment and of object properties. These studies have consistently found that individual ability, be it determined by expertise, the availability of tools, or current fitness levels, affects how individuals judge distances to be covered, slants to be mastered, and the size and movement speed of objects to be manipulated (for review, see Proffitt, 2006; Witt, 2011). The present findings indicate that the perception of object properties also reflects changes in individual ability brought about by interpersonal coordination. It remains to be investigated whether joint action abilities modulate the perception of other properties apart from object weight, such as distance.

How does intending to act together shape weight judgments? This could take several forms. On the one hand, one could assume that the joint affordance of boxes to be lifted together directly affects weight perception. The notion of joint affordance suggests that co-actors perceive the environment in terms of what they can do together. For instance, an object might afford joint lifting given its length and the combined arm span of the dyad (Richardson et al., 2007), or a doorframe might afford walking through side by side given two people's combined shoulder width (Davis, Riley, Shockley, & Cummins-Sebree, 2010). One could argue that in our experiments, boxes afforded joint lifting given the presence of a healthy co-actor, and that this directly changed the perception of their weight. It is also possible that participants perceived something like 'lift-ability' rather than weight so that the information they used to make the weight judgments was not information about weight per se.

On the other hand, it seems possible that participants simulated the action they intended to perform, relying on their own motor system (Cross et al., 2009). It has been proposed that internal simulation involves predictive mechanisms that generate predictions about the sensory consequences of actions (Wolpert & Flanagan, 2001). Such internal models can be used not only to generate predictions about one's own actions (e.g., Blakemore, Frith, & Wolpert, 1999) or about perceived actions (Parkinson, Springer, & Prinz, 2011; Wolpert, Doya, & Kawato, 2003; Wilson & Knoblich, 2005) but can also be used to predict the outcomes of jointly performed actions (Sebanz & Knoblich, 2009). It has been demonstrated that the motor system is sensitive to the effort required to lift an object (Alaerts, de Beukelaar, Swinnen, & Wenderoth, 2011). Accordingly, the anticipated effort derived from anticipatory motor simulation (Kilner et al., 2004) could have biased weight judgments. An interesting prediction that follows from this account is that seeing objects being lifted by two people should also make them look lighter compared to objects that are being lifted by a single person.

Finally, although the accuracy of the weight judgments varied somewhat across the three experiments, it is noteworthy that people tended to be less accurate in the joint action context, consistently underestimating the weight of the boxes to be lifted together. This is consistent with a view where our perceptual system is optimized for guiding our interactions with the environment rather than deriving action-independent object properties. In a context where engaging in joint action is a possibility, it may be highly useful to be able to anticipate common effects in order to decide when and with whom to collaborate. In fact, one could speculate that effects of anticipated joint action on perception might act as a driving force for collaboration. While this remains to be explored, the findings reported in this study lead us to conclude that the joint action abilities of a group shape the individual perception of its members.

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