5-7-2011

Distance Judgments for Joint Action: The Perceptual Consequences of Anticipated Coordination

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Recommended Citation

Meagher, Benjamin R., "Distance Judgments for Joint Action: The Perceptual Consequences of Anticipated Coordination" (2011). *Master's Theses*. 73.
http://digitalcommons.uconn.edu/gs_theses/73

Distance Judgments for Joint Action: The Perceptual Consequences of Anticipated Coordination

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B.A., Gordon College, 2007

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Arts

at the

University of Connecticut

2011

APRROVAL PAGE

Master of Arts Thesis

Distance Judgments for Joint Action: The Perceptual Consequences of Anticipated Coordination

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Abstract

Recent perception research has revealed that judgments of distance are influenced by the energetic cost required to perform particular actions, such as walking, across these distances (Proffitt, 2006b). However, this prior research has focused almost exclusively on the perceptual consequences of solo action, despite the fact that individuals regularly become embedded within social units for the purpose of joint action (Richardson, Marsh, & Schmidt, 2005). In two experiments, the current work sought to test the hypothesis that forming a social unit creates a new perception-action system with distinct perceptual attunement of the environment scaled to the *unit's* action-potential. Participants, accompanied by a confederate, were asked to judge the distance between themselves and a target location after being told they would be carrying a heavy box to it either individually or jointly. Surprisingly, even though carrying with another person requires less physical effort, participants judged distances to be farther when they expected help, thus challenging the comprehensiveness of Proffitt's (2006) energetic economy account. Instead, these findings are explained in terms of the constraints on unit coordination that result from both the task itself and from perceptions of one's partner.

Distance Judgments for Joint Action: The Perceptual Consequences of Anticipated Coordination

All mental processes invariably take place within a biological body that moves and acts in an environment. The acknowledgment of this fact lies at the heart of recent approaches to understanding cognition that emphasize its situated and embodied nature (e.g., Barsalou, 1999; Clark, 1997; Lakoff & Johnson, 1980; Semin & Smith, 2008). Though these labels have been used for a widely diverse range of ideas and theories, a common unifying principle among them is the rejection of the traditional model of the mind as an abstract information processor of amodal, symbolic representations (e.g., Fodor, 1975; Newell, 1980). Despite the predominance of this conceptualization for the last half-century, research has begun to suggest that this classical theoretical approach has largely missed the mind's primary adaptive function: to facilitate action. As Clark (1997, p. 1) notes, "We imagined minds as a kind of logical reasoning device coupled with a store of explicit data – a kind of logic machine and filing cabinet. In so doing, we ignored the fact that minds evolved to make things happen."

The research to be described here takes as its starting point the basic premise that mental activity developed first and foremost so as to allow humans to better act within their immediate environment. This paper will begin by briefly describing the mounting evidence suggesting that cognition is tied directly to one's physical, bodily state (i.e., it is embodied) as well as to the immediate context and environment (i.e., it is situated). It will then consider a particular mental activity, visual perception, through the lens of Gibson's (1979) ecological approach, a perspective that similarly argues that modern day vision is the result of evolutionary adaptations reflecting the interplay between an organism's anatomy, its environment, and its way of life in that environment. Two visual adaptations are of particular relevance to the studies described below. First, perception of spatial layout is influenced by the anticipated energetic costs necessary to perform particular actions across that area. The management of one's energetic output is known as the economy of action (Proffitt, 2006b). Secondly, the social environment in which humans evolved resulted in selection pressure to be able to accurately detect and utilize functional, social information (McArthur & Baron, 1983). Both of these adaptations will be discussed more fully before their implications are considered in an experimental situation where they necessarily intersect.

Cognition as Embodied

To say that cognition is *embodied* simply means that states of the physical body play a central role in mental activity (Barsalou, 2003; Barsalou, Niedenthal, Barbey, & Ruppert, 2003). Research pointing to the close relationship between motor and cognitive processes has accumulated over the last three decades, the sum of which suggests a reciprocal dynamic. On the one hand, mental states produce automatic, unconscious changes in one's bodily state. For example, Wiesfeld and Beresford (1982) found that receiving positive feedback on a test produced not just improved cognitive and affective states, but also a change in the receiver's bodily state. Those receiving a high grade adopted a more erect posture than those receiving a lower grade. Importantly, more subtle perceptual cues also produce bodily reactions. Bargh, Chen, and Burrows (1996) famously found that participants' walking speed from the laboratory to an elevator was slower if they completed a word task with items consistent with an elderly stereotype (e.g., "grey," "Florida," and "wrinkle"). Thus, the priming of a particular social group produced an associated bodily response, an effect that has been demonstrated in several other related experiments (e.g., Aarts & Dijksterhuis, 2002; Dijksterhuis, Spears, & Lépinasse, 2001).

Cognitive appraisals of immoral behavior have also been linked to comparable reactions to physical contamination (Rozin, Haidt, & Fincher, 2009). Chapman, Kim, Susskind, and Anderson (2009) found that facial muscles related to disgust activate when individuals witness an unfair distribution of money. Similarly, threats to one's own sense of moral purity produce a desire to cleanse physically. In Zhong and Liljenquist's (2006) study, participants asked to recall previous unethical behavior were more likely to accept a free antiseptic wipe while exiting the laboratory than those who recalled a positive experience. Schaller (2006) has suggested that the behavioral immune system, a set of mechanisms adapted to allow individuals to detect the presence of parasites in objects and other people, evolved to be oversensitive to such cues and therefore likely to result in frequent false positives. Thus, this association between physical disgust and purely mental aversion can be understood as an adaptation for self-protection.

The effect mental processes have on physical ones is particularly evident in social contexts, as overt physical reactions are made in response to perceiving and interacting with social partners. Specifically, the bodily states of others often produce automatic and unconscious mimicry by the perceiver. Such effects in dyadic interactions have been found for yawning (Provine, 1986), rubbing one's nose (Chartrand & Bargh, 1999), and gesturing while speaking (Maxwell, Cook, & Burr, 1985). Interestingly, recent neuroscientific research suggests that certain brain regions are specialized for just such mimicry. These "mirror-neurons" have been shown to fire both when the perceivers themselves act as well as when they simply observe others perform these same actions (Gallese, Keysers, & Rizzolatti, 2004; Rizzolatti & Craighero, 2004). Even when not mirroring per se, partners in social dyads often unintentionally coordinate their rhythmic behavior with one another. In Schmidt and O'Brien (1997) and Richardson, Marsh, and Schmidt (2005), participants asked to swing a wrist-pendulum at their own tempo nevertheless synchronized with co-actors. This same unintentional coordination has also been found in partners sitting in rocking chairs (Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007), an effect moderated by the visual information available about the partner.

In addition to the effects mental states have on the body, the embodied cognition perspective points to the bi-directionality of the relationship: one's bodily state also produces changes in cognitive and affective states. Holding a particular posture, for example, acts as a trigger to a variety of mental responses. Duclos et al. (1989) found that when inducing subjects to hold postures associated with anger, sadness, and fear, participants actually reported feeling those respective emotions more strongly. Similarly, upright posture produces a greater sense of self-confidence (Riskind & Gotay, 1982) and pride (Stepper & Strack, 1993), an effect that can actually improve task performance. Embodiment effects influence evaluative judgments as well. Cacioppo, Priester, and Berntson (1993) suggested that certain arm motions relevant to approach/avoidance behavior have become coupled with particular affective states. On encountering desirable objects, individuals are more apt to use their arms to pull the object towards them, whereas undesirable objects would be pushed away. They tested this empirically by having participants who could not read Chinese view neutral Chinese ideographs while either pushing upward (flexion/approach) or downward (extension/avoidance) on an exercise bar or table surface. As hypothesized, those images viewed during arm flexion were later rated more positively than those viewed during extension. Neumann and Strack (2000) used a similar experimental paradigm to show that response time is faster for classifying positively or negatively valenced words when participants are performing the congruently valenced arm movement.

Head movements are also coupled with evaluative cognitive states. Wells and Petty’s (1980) participants who were asked to nod their heads vertically were more likely to support a message they were listening to than those shaking their head horizontally. Tom, Pettersen, Lau, Burton, and Cooke (1991) replicated this study by inducing head shaking, only to then offer participants either a pen that was present during their movements or one that was not visible. Those nodding vertically were more apt to accept the pen that was visible whereas those who were shaking their head were more likely to take the new pen. Moreover, Förster and Strack (1996) found that vertical and horizontal head movements enhanced recognition memory for positive and negative words, respectively. This suggests that bodily actions influence both attitudes as well as actual cognitive performance. Numerous studies have also demonstrated that facial expressions produce complementary affective responses (Adelmann & Zajonc, 1987). For example, frowning increases aggression (Laird, 1974), smiling improves mood (Rhodewalt & Comer, 1979), and furrowing one’s brow increases the feeling of mental effort (Larsen, Kasimatis, & Frey, 1992). Again, these embodiment effects extend beyond just producing relevant affective states. Instead, higher level cognitive and evaluative processes are also influenced. Strack, Martin, and Stepper (1988) facilitated or inhibited the muscles necessary for smiling by asking participants to hold a pen in their mouth while reading cartoons. Cartoons were rated as funnier when smiling was facilitated.

Ultimately, the findings made across these diverse research paradigms all point to the essential and necessary role the body plays in cognition. Because humans evolved from organisms whose mental activity was devoted to immediate, on-line perception and action, present-day cognition should be understood as being strongly tied to and influenced by these basic sensorimotor processes. As a result, even presumed high-level cognitive abilities, such as language (Lakoff & Johnson, 1980) and moral reasoning (Rozin, Haidt, & McCauley, 2008), are grounded in the physical reality of one's body. Thus, in order to understand what is taking place in the head, one must consider what is taking place in the body on which it is located.

Cognition as Situated

Just as cognition necessarily takes place within a body, this body is itself necessarily located within a physical, social, and temporal context. To say that cognition is *situated* means that there is interdependence between the person and this immediate context, and therefore cognitive activity is best understood as arising from the relationship between the individual and this socio-physical setting (Clark, 1997; Smith & Semin, 2004; 2007). Recent theorizing has pointed out the limitations found in traditional dualistic conceptions of the organism-environment relationship, in which the organism is generally viewed as an active agent and the environment merely the background supporting its actions (Järvilehto, 2009). In contrast to this, the theory of the organism-environment system suggests that an organism and its environment are ultimately inseparable, forming one unitary system (Järvilehto, 1998; Lewontin, 1991). As

Järvilehto (1998) notes, “The organism cannot exist without the environment and the environment has descriptive properties only if it is connected to the organism” (p. 329).

Viewing individuals as radically embedded (Marsh, Johnston, Richardson, & Schmidt, 2009) in this way requires reconceptualizing traditional approaches to understanding many types of cognitive phenomena. For example, attitudes have long been viewed as stable, dispositional mental constructs: “a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor” (Eagly & Chaiken, 1993, p. 1). However, people’s actual explicit reports of these attitudes are extremely malleable, highly sensitive to current social situations, and only weakly predictive of actual behavior (Wicker, 1969). Defending this traditional view of latent attitudes, Eagly and Chaiken (2005) argue that this observed variability merely highlights the variability of attitude reporting, not the nature of the mental construct itself. Thus, context sensitivity is seen merely as noise preventing the study of presumed invariant representations. In contrast, a situated approach to cognition views this variance as a sign of the mutuality of the person and the socio-physical environment, thereby making context sensitivity not a barrier to understanding attitudes, but a central component of all evaluative processes (Schwarz, 2007; Schwarz & Bohner, 2001). The situated perspective is supported by the failure of implicit attitudinal measures to provide evidence for more stable constructs, a method once thought to provide a clear means of avoiding strategic responding and contextual consideration. Instead, implicit attitudes are similarly dependent on the physical, social, and temporal context (Blair, 2002). For example, Wittenbrink, Judd, and Park (2001) found that Black face primes produced more negative automatic responses when shown in an urban setting relative to a church setting.

Additionally, both the immediate goals (Ferguson & Bargh, 2004) and current physiological state (Seibt, Häfner, & Deutsch, 2007) of the individual have been shown to impact these implicit measures. Thus, even implicitly measured attitudes appear designed to facilitate action within a given context.

In much the same way, the activation of stereotypes, traditionally conceived of as stable schematic knowledge structures, has been shown to be a process highly sensitive to the local context and goals of the perceiver (Smith & Semin, 2007). For example, receiving praise from an African American physician activates positive stereotypes related to doctors, whereas receiving criticism from this person triggers the activation of negative race-based stereotypes (Sinclair & Kunda, 1999). Importantly, this difference does not occur when the perceiver observes the target praising or criticizing someone else. Thus, the effect appears to arise because of the participants' motivation to believe praise and disregard criticism.

In addition to cognitive processes performed on-line, memory is also a mental capacity that is inherently situated (Yeh & Barsalou, 2006). The environment in which people learn information influences their ability to remember it, with recall better if in the original location it was learned (Godden & Baddeley, 1975; Tulving & Thomson, 1973). The ability to remember specific objects is also in part dependent on the setting where that object is located. For example, Mandler and Stein (1974) had children view a set of objects arranged as they would be in a real-world scene (e.g., furniture in a room) or arranged randomly. Recall was found to be superior when objects were in meaningfully organized sets. Similar effects are found for auditory word recognition, with words heard in sentences more accurately identified than those heard in isolation (Miller & Isard, 1963). Consistent with this basic premise that memory operates with a dependence on contextual meaning, Biederman (1981) proposed a situated theory of scene processing that argues that the ease of recalling and identifying an object is dependent on the appropriateness of its position in the scene. In support of this argument, Bar and Ullman (1996) found that identification speed was faster when objects were shown in the correct relative position (e.g., hat above a leg) than for in incorrect positions (e.g., leg above a hat). This evidence suggests that mental concepts are not abstract schemata pulled from situations; rather, they are situated phenomena.

From an evolutionary perspective, the context dependency of these cognitive processes should not be surprising. Cognition developed so as to facilitate behavior, so its adaptive benefit is based primarily on its functionality in the immediate context. Thus, cognitive processes are an asset specifically because they are highly sensitive to the specifics of the current situation, are influenced by the actor's current motivations, and overweight recent experience at the expense of more distant experience (Schwarz, 2007). These findings serve to point out the fact that what takes place in the head can only be understood in light of the physical, social, and temporal location in which the entire person is situated.

The Ecological Approach to Perception

The key principle unifying the situated and embodied approaches to cognition described above is the emphasis placed on action. The chief priority for any organism is to successfully function within its given environment, and so evolutionary pressures will have favored the natural adaptations that best facilitated functional behavior. The research reviewed thus far demonstrates these effects on cognition, but visual perception is another product of these same evolutionary pressures. The earliest appearance of visual organs some 530 million years ago came about in the transition between small, slow Precambrian organisms and the more mobile creatures of the Cambrian explosion (Land & Nilsson, 2002). The former fauna, worm-like animals which crawled along the surface of the seafloors, had little need for fully developed spatial vision. However, as these organisms became larger and increasingly ambulatory, selection came to favor those organisms that could most effectively navigate and adapt to their environments (Land & Nilsson, 2002). Perception, then, developed specifically so as to allow these organisms to better traverse and act within their particular ecological niches.

As with these earliest animals, modern day vision for human eyes reflects this relationship between the organism’s anatomy, its environment, and its behavior within this environment. Gibson’s (1979) ecological approach to perception has provided a theoretical framework that accounts for this animal-environment reciprocity by tying perception directly to action. As a result, this account is inherently embodied and situated. Gibson’s (1979) definition of perception clearly highlights these components: Perception is “to be aware of the surfaces of the environment and of oneself in it” (p. 255). It is a situated approach in that vision is argued to involve not merely sensations experienced from isolated stimuli, but instead it is an awareness of an entire environment resulting from being within an ambient optic array consisting of multiple sources of light and reflecting surfaces. People do not experience empty space; rather, vision is necessarily grounded to invariant frames of reference, such as the horizon, which are provided by the environment in which we inhabit (Gibson, 1950). Moreover, perception is embodied because awareness of this environment is necessarily dependent on an active perceiver moving within this ambient optic array. As Gibson (1947, 1950) famously discovered with his studies on aircraft landing, permitting observers to move makes many of the supposed problems of spatial perception disappear. Moving one's eyes, head, or feet alters the structure of the optic array, all while the person's body acts as an invariant across these changes. It is through the combination of both variants and invariants that knowledge about the world comes about.

Thus, according to the ecological approach, perception is inherently an activity involving the picking up of information about one's environment in relation to one's body (Mace, 1986). One of the key principles emerging out of this perspective is the concept of *affordances*. Gibson (1979) defined the affordances of an environment as "what it offers the animal, what it provides or furnishes, either for good or ill" (p. 127). This concept seeks to account for the fact that perception involves not only the discernment of the structure of the objects in one's surroundings, but also an awareness of the functional opportunities for action provided by these objects. For example, one perceives both an apple's structural properties (e.g., red and spherical) as well as its functional properties (e.g., graspable, edible, throwable). These functional properties are not subjective projections from the perceiver onto the world, nor are they inherent properties of the objects. Rather, they exist as a result of the relationship between the perceiver and the target. Steps are perceived to be climbable (Warren, 1984), seats "sit-onable" (Mark, 1987), and doorways passable (Warren & Whang, 1987) only when both the physiology of the perceiver and the physical characteristics of the target allow for such an action.

The ability to detect such affordances reflects the functionally adaptive nature of perception itself. Vision is attuned to this action-oriented information because it is only through an awareness of the environment's possibilities that organisms are actually able to survive within them. A comprehensive understanding of present-day visual perception therefore requires consideration of the different non-optical factors that would have influenced its evolutionary development. Two such factors influencing the ability of humans, as perceiving organisms, to successfully act in their environments will be discussed in the following sections.

The Economy of Action

One key capacity necessary for evolutionary survival is the ability to effectively manage energy expenditure (Proffitt, 2006b). That is, energy consumption must be greater than energy output. For example, a predator cannot expend more energy chasing its prey than it would acquire by eating it. The degree to which an organism effectively manages this economy of action has significant implications on its survival.

Proffitt (2006a, 2006b) has argued that the economy of action is a principal law of survival and, as such, has played a formative role in the development of visual perception. Consistent with Gibson's (1979) position that perception is for the facilitation of action, this view of perception is functional. Growing out of adaptive pressures, perception of the spatial layout of one's environment is the product of not only optical information but also the perceiver's potential to act on that environment. As a result, affordances can be understood not only in terms of the perceiver's functional relationship with specific objects, but also in terms of the perceiver's relationship with the entirety of the environmental space. In other words, how one perceives his or her surroundings is influenced by the energetic costs associated with performing particular actions across it, such as walking.

Research conducted over the last two decades has found support for conceptualizing perception in utilitarian terms. For example, judgments of hill slant, measured with both verbal assessments and with visual matching tasks, have been found to be grossly overestimated: 5° hills are judged to be about 20° and 10° hills judged to be about 30° (Proffitt, Bhalla, Gossweiler, & Midgett, 1995). These “errors” are actually useful, as perception is distorted for the purpose of more effectively guiding locomotion through the environment. Importantly, slant judgments have been found to conform to ratio scales, meaning that people show higher sensitivity to incremental changes in smaller slants than they do to larger ones. Because environmental awareness informs the selection of planned action, heightened sensitivity to small differences in smaller slants has a great deal of utility (Proffitt, 2006b). Walking up a 7° hill requires considerably more effort than walking up a 3° hill, and perceptual awareness of this difference will have an impact on how one chooses to traverse it (e.g., speed of locomotion, bipedal walking or quadrupedal climbing). Attunement to the difference between a 77° and a 73° incline, on the other hand, has little or no behavioral significance.

Moreover, these judgments of slants have been found to be influenced by the particular physiological potential of the perceiver. Fatigued participants, asked to run for one hour in between slant judgments, perceived hills to be much steeper than they did prior to running (Proffitt et al., 1995). Physical fitness was also found to be negatively correlated with perceived hill steepness (Bhalla & Proffitt, 1999). Similar results were found among a sample of elderly adults, with verbal and visual measures of slant positively correlated with age and declining health (Bhalla & Proffitt, 1999). Manipulating anticipated effort by having participants wear a heavy backpack also had perceptual implications, with those heavily encumbered judging hills to be steeper than those not (Bhalla & Proffitt, 1999).

In addition to judgments of slant, perceptions of distance have likewise been found to be influenced by the effortful costs associated with performing a particular action across that distance. Distance judgments are overestimated when looking either uphill or downhill compared to across flat terrains (Stefanucci, Proffitt, Banton, & Epstein, 2005). Participants expecting to walk to various targets judged these objects to be farther away while wearing a heavy backpack (Proffitt, Stefanucci, Banton & Epstein, 2003), and chronic pain patients have been shown to similarly perceive target distances to be greater than control groups (Witt et al., 2008). Consistent results have also been found for tasks unrelated to walking. For example, participants asked to throw a heavy ball judged their distance from the target to be greater than those throwing a lighter ball (Witt, Proffitt, & Epstein, 2004).

This relationship between energy expenditure and perceptual outcomes is a learned one. That is, the anticipated optic flow experienced while walking is associated with the effort typically expended to produce this rate of optic flow, and several studies have been able to temporarily alter this relationship. Reiser, Pick, Asmead, and Garing (1995), for example, had participants walk on a treadmill that was being pulled by a tractor, with the treadmill set to speeds incongruent with the participants’ expected speed based on expended walking energy. This mismatch produced an after-effort when participants were next asked to walk blindfolded to a target. Those whose adjusted optic flow was faster than the normal rate of walking undershot the targets, while those whose optic flow rate was slower overshot the targets. In related research, Anstis (1995) found that after participants ran on a treadmill while blindfolded (and thus experienced zero optic flow), they would drift forward when asked to jog in place with their eyes closed. Additionally, creating this mismatch between energy expenditure and perceptual outcome has been shown to affect verbal distance judgments. Proffitt et al. (2003) had participants wear virtual reality goggles, which provided either zero optic flow or appropriate optic flow while walking on a treadmill. Those experiencing no optic flow while walking came to associate some energy expenditure with going nowhere. As a result, distance estimates following this exercise were greater than for those trained with congruent optic flow.

Importantly, the effects of effort on perception appear to be action-specific (Witt, Proffitt, & Epstein, 2004). That is, effort's influence on perceived distance is dependent upon the perceiver's intended action. Altering anticipated optic flow rate by walking on a treadmill influences the apparent distance to an object when the participant anticipates walking to it. However, if the intention is to throw an object to that target, apparent distance is unaffected. In the same way, throwing a heavy ball to a target influences perceived distance when participants expect to throw again, but not if they expect to walk to it (Witt et al., 2004). This is consistent with Heft's (1989) treatment of affordances as necessarily involving the intentions of the perceiver. Whether an object affords grasping, for example, requires assessment relative to the intentional act, not merely the scaling of one's body to the environment. Similarly, the influence of anticipated effort on perceptions of the environment is moderated by how the perceiver intends to act across this environment.

These studies all support the position that one’s perception of the world is a function of not only optical information, but it is also influenced by one’s potential for action in it (i.e., what the environment affords the perceiver), the purposeful intentions of the perceiver, and the effortful costs associated with these actions.

The Detection of Social Affordances

The key premise of the ecological approach is that perception serves an adaptive function for the organism (Heft, 2001; Reed, 1996). Because of this, the external world must provide the perceiver with information that successfully guides functional behavior. Though the emphasis of the field has primarily been on how people pick up on the action possibilities that inanimate objects afford, the environments in which humans belong are inherently social. Physical and socio-cultural factors are intertwined and experienced concurrently (Heft, 2007). As Gibson (1979) himself noted, other people are for humans the “richest and most elaborate affordances of the environment” (p. 135). In light of this, humans’ evolutionary history implies the ability to successfully perceive *social affordances*, or the functional meaning found in interactions with other people.

Baron (1980, 1981; McArthur & Baron, 1983) first introduced the ecological perspective to social psychology, proposing that social perception – the act of perceiving traits and attributes in others – can be conceptualized as detecting veridical, functional information about how to interact with the target. For example, observing that someone is smiling and friendly to the perceiver suggests that particular interactions are available that would not exist if the individual were frowning. Conceptualizing psychological attributes (i.e., personality traits) as affordances, researchers have since attempted to find whether individual characteristics could be perceived directly without requiring inferential processes (e.g., Zebrowitz, 2006; Zebrowitz & Collins, 1997). Such social invariants, just like the physical invariants of objects, should be available for detection and functional application by all members of the species. Research has found some support for social consensus on traits that are particularly relational, such as extroversion (Kenny, 1994) and sexual availability (Gangestad, Simpson, DiGeronimo, & Biek, 1992). Additionally, use of point-light videos has demonstrated how movement provides kinematic information that specifies particular attributes, such as gender (Cutting & Kozlowski, 1979; Runeson & Frykholm, 1983), deceptive behavior (Runeson & Frykholm, 1983), carefulness (Hodges & Lindheim, 2006), and even vulnerability to mugging (Gunns, Johnston, & Hudson, 2002).

Being able to recognize what another person offers a perceiver requires the capacity to detect the opportunities for action this person has. Therefore, perceiving the affordances for others in their environments would be another crucial adaptive capacity for humans. In support of this, individuals have been shown to be able to detect the critical boundaries for particular actions not only for themselves but also for others, such as the maximum height one can sit on a surface (Stoffregen, Gorday, Sheng & Flynn, 1999), whether an object is reachable (Ramenzoni, Riley, Davis, & Snyder, 2005), and whether a gap can be crossed (Mark, 2007). This research suggests that perceivers are capable of alternating from an egocentric perspective to an allocentric perspective when making judgments about others' capabilities. Judgments of others' action potentials are therefore based not on one's own physiological capabilities, but on those detected in the target.

Being able to detect veridical information about others (McArthur & Baron, 1983) and their potential for action in the environment (e.g., Stoffregen et al., 1999) is useful chiefly because this information allows for successful interaction. Importantly, more than just being aware of one another, humans cooperate and co-act. Individuals acting together form a social synergy (Marsh, Richardson, Baron, & Schmidt, 2006), a wholly new perception-action system that is distinct from the mere individuals constituting it. As a result, the presence of another person provides new possibilities for joint-action within their shared environment. For example, a high wall may afford little to a lone individual, but, if provided with a partner, the pair's possible coordinated behavior may now make the wall afford climbing.

Once a part of a social synergy, individuals have been shown to detect opportunities for joint action following laws similar to how one detects intrapersonal affordances. For example, Richardson, Marsh, and Baron (2007) found that transitioning from using one hand, two hands, a tool, and working cooperatively with a partner when moving wooden planks of varying sizes followed the same, lawful patterns. The emergence of joint activity resulted from the relationship between the actors' particular physiologies (i.e., hand and arm length) and the object (i.e., plank length). Moreover, these affordances for cooperation come about in relation to the fit between the actors' shared capabilities, such as matching or mismatched arm length, as well as the strength of the contextual pull to work in concert (Isenhower, Richardson, Carello, Baron, & Marsh, 2010). Thus, there is evidence that individuals are able to perceive interpersonal affordances as part of a social unit in much the same way intrapersonal affordances are detected when acting alone.

The Effortful Implications of Joint Action on Spatial Perception

In sum, cognition necessarily involves an awareness of one's body and one's current physical, social, and temporal environment. For humans, this awareness comes about in large part through visual perception, which, according to the ecological approach, is attuned to functional information about how one can act in this environment. This attunement is the result of evolutionary pressures favoring those adaptations that allowed for successful survival within the organisms' particular ecological niche.

The goal of the current research was to test the implications of the two particular perceptual attunements outlined above – the influence effort has on distance perception and the ability to accurately detect social affordances as part of a synergy – in a situation in which they overlap: carrying an object either with or without a partner. Though prior research has shown that judgments of distance are influenced by the observer's purposes and the behavioral abilities of the observer's body, the experiments reported here sought to see whether this holds true not only when individuals act alone, but also when they take part in joint-action with a partner. By forming a social unit, two individuals become a new perception-action system. Just as this system has new environmental affordances available to the unit, it should also have its own energetic economy to which its members are attuned. Thus, this research was interested in exploring whether the perceptual consequences of anticipated effort previously demonstrated for solo behavior follow a similar pattern when individuals are part of a dyadic unit.

In the following experiments, participants were asked to judge the distance between themselves and a target location when expecting to carry a heavy object either with or without a partner who affords helping. With another person present to share a portion of the load, anticipated physical, energetic costs should be lower among those in the joint carrying condition. In light of the prior literature demonstrating the costs of required energetic expenditure on perceived distance, it was hypothesized that participants' ability to detect the possibility for and implications of joint action afforded by their partner would lead to the perception of smaller distances relative to those expecting to carry alone.

Experiment 1

Method

Participants. Thirty-three University of Connecticut undergraduate students (17 male, 16 female) participated in the experiment. Participants were recruited as part of a requirement for their introductory course. All had normal or corrected-to-normal vision, and were without any physical impairment that would hinder their ability to lift objects.

Apparatus and stimuli. The experiment was conducted in a basketball gym, which contained a tarp covering about half the court. The tarp's dimensions were 7.62 m x 14.94 m (≈ 25 ft x 49 ft). Thread was sewn into the tarp at distances of 4 m, 6 m, 8 m, 10 m, and 12 m from a set point along five rows, placed flush to the ground so they were unobservable to the participant (see Figure 1). An orange cone was placed on one of the 21 locations for each trial.

The box being lifted by participants was made of cardboard and had hand-slits on either side. Its dimensions were 61 cm x 45.72 cm x 30.48 cm (≈ 24" x 18" x 12"). The box was weighted to be approximately 25% of the participant's reported weight, acquired prior to the experiment during participant pre-screening. Five pound weights were used to incrementally weight the box. For each participant, insulation foam was placed on the bottom of the box and five weights were placed on top (one in each corner, one in the center). Another layer of insulation foam was then placed on top of these, and any additional weights were placed on this layer. A final, third layer of insulation foam was then placed on top. Construction goggles were covered with black duct tape to serve as the blind-fold.

A questionnaire filled out at the completion of the study asked participants to rate the confederate on physical and interpersonal characteristics using Likert-type 9-point scales. Though carrying a heavy object with another person is inherently less physically difficult than carrying alone, variation in anticipated difficulty within groups were hypothesized to result from differing judgments of how useful one's partner would actually be. Thus, the purpose of these impression measures was to gauge whether the degree to which one views the confederate as a helpful and welcome aid in carrying the box would impact distance estimates among those in the joint condition. Perceptions of the confederate's physical characteristics were assessed with two items: strength and athleticism. Interpersonal characteristics were assessed with three items: how much they liked the confederate, how much interaction they had with the confederate, and how similar to themselves they thought the confederate was. Additionally, the final item asked participants how accurate they thought their judgments of distance were.

Design. Participants were randomly assigned to either the solo-carrying or the joint-carrying condition. Each participant was presented with five trials at distances of 4 m, 6 m, 8 m, 10 m, and 12 m, consistent with those used by Proffitt et al. (2003). The five distances and rows were presented in a randomized order. On each trial, two dependent measures of judged distance were taken: the participant first provided a verbal estimate of distance in feet and then blind-walked to the target.

Procedure. Participants volunteered to participate in a study called "object carrying across environments." They arrived at the gym and were met by a same-sex confederate acting as another participant. In the solo-carrying condition, they were told that they would be taking turns carrying a heavy box to different locations on the tarp. In the joint-carrying condition, participants were told that they would be working together to carry the box to each location. However, both groups were told that before they actually carry the box, the experimenter would first have them estimate how far they thought the target locations were to which they would be carrying.

The participant was brought to stand at the convergence point of five rows of distances (see Fig. 1) and picked up the box. They were then asked to turn while the experimenter placed a cone in one of the five set distances. The participant then turned, was shown a yard stick as a scale reference, and was asked to estimate in feet and inches the distance they would be carrying to that cone while holding the box. The experimenter then told the participant that before they carry the weight, they will be asked to walk that distance without it. The participant then put on the blackened goggles and tried to walk to the cone (without the weight). Their stopping location was marked, and the participant was guided back to the starting location. So as to allow the participant on opportunity to get used to the procedure and reduce the variability of estimates, participants were first given two practice trials, consistent with past research (e.g., Proffitt et al., 2003). Practice trials were made at distances of 5 m and 9 m. These were completed without holding the box, and the participant received feedback on their accuracy on each. On the five critical trials, participants received neither visual nor verbal feedback on their accuracy.

After the five trials were completed, participants were given the questionnaire to fill out while the confederate ostensibly began the procedure for the distance estimates. Once the questionnaire was completed, the experimenter informed the participant that they would not actually be carrying the box, ended the study, and debriefed the participant.

Results

Descriptive statistics and correlations for the primary dependent measures of verbal and behavioral estimates of distance are presented in Table 1. Consistent with prior research (Loomis, da Silva, Fujita, & Fukusima, 1992; Loomis, da Silva, Philbeck, & Fukusima, 1996), participants in both groups generally underestimated distance to the target. However, participants tended to slightly overestimate their verbal estimate in the farthest trial. Importantly, participants demonstrated the ability to detect the variations in distance across the five trials. Correlations between the actual trial distance and each participant's verbal and behavioral estimates indicated an extremely high range for both conditions, with participant *r*'s all above .90 and often approaching 1.00. Correlations between verbal and blind-walking estimates indicate that the two measures were significantly related for the farthest three trials (rs $\geq .47$, ps $< .01$), but largely unrelated for the 4 m and 6 m trials ($r = .15$ and $.16$, respectively).

To test the hypothesis that expectations regarding solo versus joint action would affect perceived distance, separate MANOVAs for verbal estimates and blind-walking distances were conducted. Condition was the between-subjects factor and trail distance was the repeated measure. Not surprisingly, variance increased as the trial length increased; thus, Mauchly's test indicated that the assumption of sphericity had been violated on both measures (Verbal: $\chi^2(9) = 46.88$, $p < .001$; Blind-walking: $\chi^2(9) = 47.34$, $p < .001$), therefore justifying the use of MANOVA instead of a repeated measures ANOVA. For the verbal estimate, a significant within-subjects main effect was found for trial distance, $F(4, 28) = 177.01$, $p < .001$, again demonstrating participants' capacity to distinguish the varying lengths used across the five trials. However, the main effect for condition was nonsignificant, $F(1, 31) < 1$. Moreover, no interaction was found between condition and trial distance, $F(4, 28) = 1.41$, $p = .26$. For the blind-walking measure, a significant within-subjects main effect was again found for trial distance, $F(4, 28) = 278.77$, $p < .001$. As in the verbal measure, however, no effect for condition on blind-walking was found, $F(1, 31) < 1$. The interaction between condition and trial distance was also not significant, $F(4, 28) = 2.02$, $p = .12$.

As discussed earlier, the object participants anticipated carrying was a box sized to be approximately 25% of their weight, using five pound increments. This method was used chiefly so as to be roughly equivalent to the procedure used in prior work (e.g., Proffitt et al., 2003). However, as an inexact measure of participant strength, it was unclear whether this linear proportioning would actually ensure an equivalent experience of *heaviness* across participants of various sizes. Therefore, to check for the possibility that the weight of the box itself affected distance judgments, further analyses were conducted including box weight as a covariate across both verbal and blind-walking estimates using a linear mixed-effects model. Condition (solo carrying = 0, joint carrying = 1), type of estimate (verbal = 1, blind-walking = -1), box weight (centered on grand mean), and trial distance (centered on 8 m) were entered first as main effects, and all two-way, three-way, and four-way interactions were added in second, third, and fourth successive blocks, respectively (see Table 2 for estimates at each block). A significant main effect was found for type of estimate, $t(32) = 3.71$, $p < .01$, with verbal estimates larger than blind-walking distances. The main effect was not statistically significant for condition, $t(30) < 1$, or for box weight, $t(30) = 1.38$, $p = .18$. However, a significant interaction was found between trial distance and box weight, $t(129) = 3.77$, $p < .001$, with greater box weight predictive of larger distance estimates for the farthest trial, but not for shorter ones. The interaction between trial distance and type of estimate was also significant, $t(131) = 9.68$, $p < .001$, indicating that verbal estimates were greater than blind-walking distances on the largest trials, but not for shorter ones. Although none of the three-way interactions were significant, a significant four-way interaction was found, $t(128) = -2.33$, $p < .05$, indicating that box weight had the strongest positive effect on verbal estimates on the largest trials for those in the solo condition. Significant random effects were found for verbal estimates, Wald's Z = 2.50, $p < .05$, and blind-walking, Wald Z = 2.67, $p < .01$, indicating significant variability among participants in their estimates. Surprisingly, the correlation between these two effects was not statistically significant, Wald Z = 1.56, $p = .12$.

Perceptions of the confederate. Exploratory analyses of participants' perceptions of the confederate were also conducted. Participants in the two conditions had similar impressions of the confederate, all $|t|$s ≤ 1.50, ps $> .14$. The confederate was generally rated above the midpoint in terms of strength (*M* = 6.03, *SD* = 1.09), athleticism (*M* = 6.39, *SD* = 1.17), and being likable (*M* = 6.66, *SD* = 1.45). Confederates were rated at about the midpoint for similarity (*M* = 4.87, *SD* = 1.68). Participants generally did not believe there was much interaction between themselves and the confederate (*M* = 3.31, *SD* = 2.09). Interestingly, though participants always rated a same-sex confederate, both genders were rated equivalently in terms of strength, athleticism, and likability, all $|t|$s ≤ 1.27, *p*s > .21. However, the female confederate was rated higher in similarity by female participants than the male confederate was by male participants, $t(30) = 2.21$, $p < .05$ (Women: *M* = 5.53, *SD* = 1.35; Men: *M* = 4.29, *SD* = 1.75).

As would be expected, ratings of confederate strength and athleticism were highly correlated, $r = .63$, $p < .01$. Rating of similarity was correlated with amount of interaction, $r = .54$, $p < .01$, and liking, $r = .56$, $p < .01$, and liking and amount of interaction were also significantly correlated, $r = .37$, $p < .05$. Surprisingly, ratings of athleticism were also correlated with similarity, $r = .48$, $p < .01$, and liking, $r = .37$, $p < .05$. Correlations within conditions were also examined to determine if anticipating joint action would lead to stronger associations amongst impressions. One difference in correlation patterns was found. For those expecting to carry with the confederate, ratings of similarity were correlated with both perceived strength, $r = .56$, $p < .05$, and athleticism, $r = .73$, $p < .01$. In contrast, there was no such relationship in the solo condition (*r*s = -.07 and -.02, *p*s > .05), suggesting that those expecting to work with the confederate associated similarity at least in part with physical similarity, whereas those expecting to work alone did not.

Analysis of first verbal trial. One possible reason for the lack of main effect for condition on either of the dependent variables was the length of the procedure. That is, though participants were instructed that they would eventually be carrying to these locations, participants would naturally have become aware that their next, immediate action in either condition would be to simply walk to the cone. It was therefore possible that the manipulation of carrying alone or jointly lacked salience as the experiment proceeded. Therefore, it seemed advisable to look specifically at participants' first verbal trial, which would be when the anticipation of carrying would presumably be most pronounced.

Additionally, an analysis of this dependent variable allows for an exploration of the possible moderating role that perceptions of the confederate may have had on these distance estimates. Although the conditions did not differ in terms of how participants rated the confederate, the ratings themselves may differ in importance depending on the condition the participant is in. For those expecting to work with the confederate, this other person's characteristics will be much more relevant, for it will directly alter the difficulty of the task. In contrast, for those not expecting to carry with the confederate, this person's perceived traits are unrelated to the participants' ability to complete the task. One would expect that perceptions of the confederate's strength and athleticism, as *physical* characteristics, would be particularly important, as they would have a direct role in the anticipated energetic costs required for joint carrying. In light of this, partial correlations between these variables and verbal estimates of the first trial were explored, controlling for the actual distance of the first trial (see Table 3). Though athleticism was unrelated to the distance estimate among joint carriers ($pr = .15$, $p > .05$), a significant correlation was found for strength judgments. Interestingly, perceived strength was significantly correlated with the first verbal trial for those in the joint carrying condition, $pr = .62$, $p < .05$, but not for those in the solo condition, $pr = .18$, $p =.56$. Surprisingly, the direction of this correlation indicates that the stronger participants believed their carrying partner to be, the larger was their distance estimate.

To estimate the role perceptions of partner strength uniquely contributed to distance estimates, a three-step hierarchical regression analysis was conducted, using the participants' first verbal trial as the dependent variable. In the first step, the actual distance of the first trial was entered. On the second step, the condition (solo carrying = 0, joint carrying = 1) and confederate strength ratings (centered on grand mean) were entered. Finally, on the third step, the interaction between condition and perceived strength was included. The results of this analysis are shown in Table 4. Not surprisingly, the actual distance of the first trial explained the vast bulk of the variance ($R^2 = .92$). Condition and perceived strength were both positively related to distance estimates, with the latter being a statistically significant predictor, $\beta = .12$, $t(28) = 2.33$, $p < .05$. However, this main effect was qualified by a statistically significant interaction, as including the condition by perceived partner strength interaction in the third step also produced a significant change in the model's explained variance, $\Delta R = .01$, $F(1, 27) = 4.63$, $p < .05$. This interaction was statistically significant, $\beta = .16$, $t(27) = 2.15$, $p < .05$. The simple slopes of this interaction can be seen in Figure 2. Estimated values for participants one standard deviation above and below the mean on perceived partner strength are graphed. It shows that the effect of perceived partner strength is exclusive to those in the joint carrying condition; that is, those expecting to actually carry the object with this person ($b_{\text{joint}} = .62$; $b_{\text{solo}} < .01$). Again, surprisingly, participants in the joint-carrying condition reported their first distance to be *farther* when they judged the confederate to be stronger.

Discussion

Based on the previous work of Proffitt and colleagues (Proffitt et al., 2003; Witt et al., 2008), it was expected that participants who anticipated having to perform a more strenuous task would judge the distance this task would be done over to be larger. Because of this, those expecting to carry a heavy box with a partner were predicted to perceive their distance to the target locations to be shorter than those expecting to carry this same weight alone. However, the results of the experiment failed to support this hypothesis. Over five trials, participants did not differ across conditions in either verbal estimates or in blind-walking distances.

Do these results call into question the impact effort has on spatial perception? If they do, they would not be alone in doing so. The claims made by Proffitt (2006b) about the role anticipated energetic costs play on distance perception have been challenged by several researchers. For example, Hutchinson and Loomis (2006) sought to replicate Experiment 1 of Proffitt et al. (2003), wherein participants wore heavy backpacks and reported egocentric distance to various target locations. In the original study, those wearing a backpack reported distances to be farther than those unencumbered. In contrast, Hutchinson and Loomis (2006) failed to find any differences resulting from the backpack manipulation, using both between and within-subject designs and measuring verbal estimates, indirect blind-walking, and target size as the critical dependent variables.

Woods, Philbeck, and Danoff (2009) also report a series of experiments failing to find results consistent with an economy of action prediction. Closely replicating the procedure of Proffitt et al. (2003), they too found no difference in verbal distance estimates resulting from wearing a backpack. Additionally, over three studies they sought to repeat the findings reported in Witt et al. (2004), who found that distance estimates were larger after participants threw a heavy ball than after they threw a lighter ball. Again, Woods et al. (2009) failed to find a difference by condition. However, in a fifth experiment, the authors found that explicitly instructing participants to focus on non-visual factors did lead to larger estimates for those in the more effortful condition. They therefore suggest that the results finding support for the influence of energetic costs are not due to actual perceptual differences, but rather post-perceptual response bias. Durgin et al. (2009) make a similar claim, arguing that the differences found by manipulating anticipated effort are merely the result of the differing social demands of the experimental context, not the actual manipulation. In their experiment, they sought to test the findings of Bhalla and Proffitt (1999) by varying the apparent demand characteristics that result from being asked to wear a backpack. Participants judged the slant of a ramp either without a backpack, while wearing a backpack, or while wearing the backpack after being told it contained electromyographic (EMG) equipment meant to measure muscle strain. Participants wearing the backpack without being given this back-story gave larger slant estimates, whereas those in the EMG condition did not differ from the control. The authors argue that participants who are naïve to the experimenter's hypothesis that energy impacts spatial perception will not be affected by energetic manipulations.

Proffitt and colleagues (Proffitt, 2009; Proffitt, Stefanucci, Banton, & Epstein, 2006) have responded to these critiques. They argue that methodological and theoretical limitations explain the failures of these attempted replications. First, Proffitt et al. (2006)

note that Hutchinson and Loomis' (2006) use of three dependent variables for each trial is an important difference from the procedure of Proffitt et al. (2003), which used only verbal estimates. Part of the theory proposed in Witt et al. (2004) is that the impact energy has on perception is dependent on intention. That is, the environment and distances across it are seen in terms of the perceiver's next anticipated action. If the next anticipated action is not to walk with a heavy backpack, but instead to provide another measure of the dependent variable unrelated to direct walking, it would not be predicted that difficulty walking with this weight would be a factor on distance estimates.

Secondly, Proffitt (2009) specifically questions the relevance of energy levels in the experimental design constructed by Durgin et al. (2009). The slant used in this study is 14.5°, constructed from a 1 x 2 m ramp, and presented to participants indoors. Proffitt (2009) argues that this setup is insufficient to produce a difference in energetic consequences. Wearing a backpack or not has little consequence if only expecting to walk a few feet. In contrast, the slant used in Bhalla and Proffitt (1999) was a real hill at 31° and of significant length. The backpack manipulation is only meaningful if it would have an actual consequence on one's ability to perform the particular behavior of interest while in the perceived environment.

Finally, Proffitt (2009) argues that experimental demands cannot fully explain the robustness and variety of contexts in which the effect of action capabilities on distance perception has been found. For example, the third experiment reported in Bhalla and Proffitt (1999) did not use an experimental manipulation: physical fitness was assessed independently and found to be negatively correlated with slant judgment. Similarly, Witt et al. (2008) found differences in distance judgments based on patient's pre-existing medical conditions. Moreover, Schnall, Zadra, and Proffitt (2010) have found that varying levels of blood glucose, the energetic resources of the body, produce expected differences in slant judgment. These results suggest that experimental demands fail to provide a comprehensive account of the sum of the findings derived from the economy of action theory.

Does this defense of the energetic economy's role in spatial perception provide some explanation for the present experiment's inability to find a significant difference between conditions? Most relevant is Proffitt et al.'s (2006) critique of Hutchinson and Loomis (2006), wherein participants' actual anticipation of walking was called into question. Following Witt et al. (2004), he argues that distances are seen in terms of the very next intentional action expected to be performed. Though the goal of the present experiment was to make participants anticipate carrying, multiple trials of verbal estimates followed by blind-walking would likely have made this anticipated action much less salient and much less immediate. Thus, when participants perceived the target cone in front of them, the distance to it could be understood as being judged in terms of blind-walking rather than solo or joint carrying. If this is true, finding no difference between the two groups would not be surprising.

Analyzing the first verbal trial in isolation was a post hoc attempt to address this concern by assessing the role of effort when carrying would have been most salient. Surprisingly, however, the results of this analysis show effects in the opposite direction from what a purely effortful account would predict. Expecting to receive help from someone judged to be strong led to larger distance estimates than those judging their partner to be weaker. Furthermore, the direction of the condition effect indicated that expecting to carry jointly was itself predictive of larger estimates, not shorter ones. These results begin to suggest that social, coordinated action may involve additional, perceptually relevant factors beyond just physical effort that makes joint action qualitatively different from the experience of doing something alone. For example, being in the presence of another person is often enough to lead individuals to make automatic and unconscious social comparisons (Wood, 1996). Importantly, these judgments are most likely to be made with similar, readily comparable others (Festinger, 1954). Thus, expecting to work with another person on a task, as in the joint condition, will make such comparisons particularly relevant and meaningful. However, comparisons to those in one's immediate context are quite capable of negatively impacting task performance, as in the case of stereotype threat (Steele, Spencer, & Aronson, 2002). For those judging their partner to be very strong, this comparison may have a deleterious effect on one's own sense of strength and adequacy. Feeling weaker as a result of this contrast may actually produce a purely psychological effect similar to the direct effortful manipulations employed by Proffitt et al. (2003).

However, due to the present study's design, the results found remain difficult to interpret. The actual salience of anticipated carrying relative to anticipated walking is unknown, even in this first trial. Therefore, isolating it from the rest of the experiment as the sole instance where carrying was top of mind for the participants may not be a fair assumption. It is certainly possible that, even in this first trial, participants were judging the task in terms of walking rather than joint or solo carrying. Moreover, ratings of the partner only took place after their completion of all five trials, and were therefore far removed from their first verbal estimate. Allotting predictive power to such post-experimental interpersonal perceptions must therefore be done with a great deal of caution.

In light of the methodological weaknesses of this first experiment, a second study was designed to address these concerns. The chief goal of the new design was to heighten the salience of the carrying manipulation so as to ensure that, while participants observed the target cone in front of them, the very next action they anticipated making would be carrying the box to it. To accomplish this, the procedure was changed in several ways. Rather than being told at the beginning of the experiment that they would make distance estimates to the targets on all trials and then carry the box to each location, participants were instructed that for each trial they would make a verbal estimate of distance and then immediately carry the box to it while blindfolded. By doing so, participants would no longer have any reason to anticipate walking to the target; rather, their only expected action in relation to the cone would be blind-carrying to it. Only after their blindfold was donned did the experimenter then tell the participants that they would first walk to the target.

Because of this change in procedure, it was deemed necessary to reduce the experiment to only a single trial. Though a lack of multiple trials risks increasing the noise resulting from individual variability, it was decided that the immediacy of anticipated carrying would be lost after this initial trial. The distance of 10 meters was chosen to be the single trial in this second study, for it was at this distance that verbal estimates and blind-walking distances were most strongly correlated ($r = .61$, $p < .01$) and also the distance where the largest differences between groups were observed for both measures.

Experiment 2

Method

Participants. Thirty-eight University of Connecticut undergraduate students (21 male, 17 female) participated in the experiment. Participants were recruited as part of a requirement for their introductory course. All had normal or corrected-to-normal vision, and were without any physical impairment that would hinder their ability to lift objects.

Apparatus and stimuli. The stimuli used in this experiment were identical to those used in Experiment 1.

Design. Once again, participants were randomly assigned to either the solo-carrying or the joint-carrying condition. As before, participants first provided a verbal estimate of distance and then subsequently blind-walked to the target. However, this experiment involved only a single trial.

Procedure. As in Experiment 1, participants arrived at the gym and were met by a same-sex confederate acting as another participant. Those in the solo-carrying condition were told that they would be taking turns carrying a box to different locations on the tarp, while those in the joint-carrying condition were told that they would be working together.

The participant and the confederate were weighed on a scale and informed that the object they would be carrying would be weighted proportionately. They were then each given duct-taped goggles to act as a blindfold. The experimenter told them that he wanted them to have practice walking with the goggles on before the experiment started. Those in the solo condition took turns walking to the end of the tarp and back with their goggles on. Those in the joint condition walked alongside the confederate. This addition to the procedure was done for two reasons. First, it was hoped that giving participants the opportunity to walk the length of the tarp with their goggles on would give them a rough sense of their traveling distance while wearing them, thereby providing them with some practice blind-walking without actually including practice trials. Secondly, it was hoped that having joint carriers walk together would lead to a subtle increase in feelings of connectivity and group identity. After this practice walking, participants were given a questionnaire that asked them to rate the confederate in terms of strength, athleticism, likeability, similarity, and amount of interaction. While they did so, the experimenter weighted the box to a quarter of the participant's weight.

The participant was then brought to the convergence point on the tarp and asked to pick up the box while the confederate stood nearby. While turned, the experimenter placed an orange cone 10 m behind them (location D, center row on Fig. 1). The participant then turned and estimated how far they would be carrying to the cone. The participant was then instructed to place the box down in front of them. They were told that after they put their goggles on, the experimenter would go remove the cone, return, lift the box up to them, and they would try to carry the box to where the cone used to be with their goggles on. However, after the experimenter returned, he said "actually, before you carry the box [together], I would like you to try to walk to the cone first without the weight." Once the participant stopped, their location was marked. Distance from the starting location to their stopping point was then measured.

Results

The means and standard errors for the key dependent measures of verbal and behavioral estimates of distance are shown in Figure 3. As in the first experiment, participants in both groups underestimated the actual distance of 10 meters on both measures. The verbal estimates and blind-walking distances were significantly correlated, $r = .46$, $p < .01$. However, blind-walking distances were significantly larger than verbal estimates, $t(37) = 3.16$, $p <.01$. Additionally, blind-walking estimates were more accurate, as the absolute difference between the correct distance of 10 meters and the participants' blind-walking estimate was significantly smaller than the absolute difference of their verbal estimates, $t(37) = 5.62$, $p < .001$.

To test the hypothesis that expecting to carry a heavy object either with another person or alone would lead to differing judgments of distance, ANCOVAs were conducted on the verbal and blind-walking estimates. In light of the effect box weight had on distance estimates in the largest trial of Experiment 1, it was included in these analyses as a possible covariate. For the verbal estimate, the effect of condition was statistically significant, $F(1, 35) = 5.10$, $p < .05$, $r = .36$. Surprisingly, those in the joint carrying condition reported farther distances than did those expecting to carry alone, replicating the trend found in the first trial of Experiment 1. Box weight also had a statistically significant effect on verbal estimates, $F(1, 35) = 10.63$, $p < .01$, $r = .48$, with larger weights predictive of greater distance judgments. An additional analysis including the box weight by condition interaction revealed no violation of the homogeneity of regression assumption, $F(1, 37) = 1.07$, $p = .31$. For the measure of blind-walking, however, the effect of condition was nonsignificant, $F(1, 35) = 1.71$, $p = .20$, $r = .22$. Box weight, on the other hand, again had a statistically significant effect, $F(1, 35) = 3.95$, $p = .05$, $r = .32$. As with verbal estimates, larger box weight led to greater blind-walking distances. Again, an analysis including the box weight by condition interaction did not reveal a violation of the homogeneity of regression assumption, $F(1, 37) < 1$.

Perceptions of the confederate. As in Experiment 1, participants in the two conditions formed similar impressions about the confederate, all $|t|$s ≤ 1.16, ps $> .26$. Once again, the confederate was rated well above the midpoint in terms of strength ($M = 6.24$, $SD = .90$), athleticism ($M = 6.16$, $SD = 1.24$), and being likable ($M = 6.73$, $SD = 1.19$). Confederates were rated at about the midpoint for similarity ($M = 4.76$, $SD = 1.53$). However, participants in the joint carrying condition tended to say there was slightly more interaction between them and the confederate, $t(35) = 1.75$, $p < .10$, though amount of interaction was still viewed as relatively low (Joint: $M = 3.83$, $SD = 2.26$; Solo: $M = 2.63$, $SD = 1.92$). Unlike Experiment 1, men and women rated their same-sex confederate differently in several key ways. Men rated the confederate higher in terms of strength, $t(35) = 2.41$, $p < .05$ (Women: $M = 5.88$, $SD = .99$; Men: $M = 6.55$, $SD = .69$), whereas women rated their confederate higher in terms of similarity, $t(35) = 3.16$, $p < .01$ (Women: $M = 5.53$, $SD = .26$; Men: $M = 4.10$, $SD = .36$), and in being likable, $t(35) = 2.55$, $p < .05$ (Women: $M = 7.24$, $SD = .66$; Men: $M = 6.30$, $SD = 1.38$).

Consistent with Experiment 1, ratings of confederate strength and athleticism were highly correlated, $r = .59$, $p < .001$. Similarity ratings were correlated with amount of interaction, $r = .48$, $p < .01$, and liking, $r = .51$, $p < .01$. Liking and amount of interaction was also significantly correlated, $r = .38$, $p < .05$. No difference in the pattern of these correlations or pattern of gender differences was found between conditions.

The relationship between perceptions of the confederate and the participants' distance estimates were also examined between conditions to see if differences in judgments led to variations in verbal and blind-walking reports. These correlations are shown in Table 2. Importantly, unlike in the first experiment, these interpersonal ratings were completed prior to the distance trial. As in Experiment 1, ratings of the confederate had no relationship with the distance measures among those in the solo carrying condition ($|r|$s $\leq .26$, ps $> .05$). However, in the joint carrying condition, ratings of their partner's athleticism were positively correlated with both their verbal estimate, $r = .46$, $p = .05$, and blind-walking, $r = .47$, $p = .05$. Additionally, ratings of partner strength were marginally correlated with the verbal estimate, $r = .40$, $p < .10$. Consistent with Experiment 1, more positive appraisals of the anticipated partner's physical abilities surprisingly related to larger perceived distances. Notably, judgments of similarity, likability, and amount of interaction were all negatively correlated with distance estimates for those in the joint condition, though these were nonsignficant, rs $\geq -.31$, ps $> .21$.

Discussion

In Experiment 2, participants were told that they would be carrying a heavy box while blindfolded, either alone or jointly with a partner. Surprisingly, participants expecting help carrying gave larger verbal estimates of distance to the target than those expecting to carry alone. Blind-walking results did not significantly differ, though they showed a trend in the same direction as the verbal measure. Moreover, ratings of the confederate's physical characteristics were positively correlated with distance estimates among those in the joint carrying condition, a finding consistent with the first trial of Experiment 1.

These results cannot be easily squared with a strict interpretation of Proffitt's (2006b) theory of the economy of action, as it is unlikely that a purely physical account can explain the direction of the found effect. On the one hand, Naylor and Amazeen

(2004) have demonstrated that judgments of object heaviness can be greater when lifting with another individual than when lifting alone. They argue that this effect is due to additional physical forces present only when holding jointly. Specifically, there is an additional horizontal force resulting from pulling the object towards oneself, thus making the object feel more unwieldy. Nevertheless, it does not follow that joint carrying is therefore actually perceived to be a more difficult physical task than carrying alone. Estimating a weight to be heavier when holding it with another person is not equivalent to actually supporting more weight. For example, a participant may estimate a load to weigh 100 lbs when lifting alone, but estimate it to be 120 lbs when holding jointly. Even so, carrying this object with another his person would entail supporting what feels like 60 lbs, whereas working alone would necessarily involve supporting what feels like 100 lbs. It is therefore unlikely that anticipating working with another person would actually result in expecting to expend more physical energy.

Understanding the results of the present study in relation to past findings therefore requires broadening how one conceptualizes the role perception plays in guiding and constraining behavior. Rather than viewing effortful influences on distance judgments as a comprehensive account of non-optical related perceptual adaptation, Proffitt’s (2006b) findings can perhaps be better understood as just a single factor involved in perception’s role in facilitating action. Managing energetic output may be an important constraint on a perception-action system, but it is not the sole one. Rather, perception and action are guided by multiple, mutually constraining values, with energetic efficiency being only one of many factors (Hodges & Baron, 1992). Though anticipated physical exertion may be an important factor in certain contexts, in others it may play a lesser role relative to other pressures for successful self-regulation. In this experiment, the participants' anticipated activity was carrying a heavy weight across a gym while blindfolded. Though necessarily less physically taxing, carrying this heavy object with another person could be understood as more *psychologically* taxing than doing so alone. Relative to solo-carrying, coordinating with another person without the aid of vision is a difficult task, not in terms of physicality, but in terms of the additional cognitive resources and social obligations inherent in being part of a cooperative unit. Ultimately, working with or without another person is not equivalent to working with or without a heavy backpack. Becoming part of a social unit, a new perception-action system, produces not only new environmental affordances, but also new challenges. This experiment provides initial evidence that such challenges, arising from social interaction, have perceptual consequences.

Several other research programs have found evidence for the role of visual perception in self-regulation, above and beyond just energy maintenance. For example, Stefanucci (2010) has argued that emotions are a type of bodily state directly impacting perception of spatial layout. Fear in particular appears to serve a clear self-regulatory purpose, and it has been shown to influence both height and slant judgments. In one study, observers were asked to stand on a skateboard at the top of a hill. Those reporting high levels of fear descending the hill estimated the slant of the hill to be greater than those who were unafraid (Stefanucci, Proffitt, Clore, & Parekh, 2008). Stefanucci and Proffitt (2009) found that participants' judgments of height from the top of a banister were correlated with reported fear of heights. Stefanucci (2010) reports a study using a high ropes course. Height was overestimated more for students at the top of a platform when they were about to rappel down than for those not about to jump, suggesting that fear may be a particularly relevant perceptual constraint when a dangerous behavior is available.

Anxiety levels also impact perceivers' ability to detect and utilize available environmental affordances. Pijpers, Oudejans, Bakker, and Beek (2006) found that judgments of maximal overhead reachability on a climbing wall were reduced by high levels of anxiety. Similarly, Jiang and Mark (1994) found that observers increasingly underestimate the crossability of a gap as the depth increases, suggesting that the consequences of falling may play a role in such judgments. These differences in spatial judgments highlight how one's emotional state can regulate behavior through variations in perception.

Past performance and success also appear to influence perceptual judgments. For example, Witt and Proffitt (2005) asked softball players to estimate the size of the ball after winning a game. Those who hit well remembered the ball as being larger than those who hit poorly. Similar results have been found for other sports: golfers putting well judge the size of the hole to be larger (Witt, Linkenauger, Bakdash, & Proffitt, 2008), field goal kickers view goal posts to be farther apart and closer to the ground after making successful kicks (Witt & Dorsch, 2009), and better dart players report the center target to be larger than poorer players (Canal-Bruland, Pijpers, & Oudejans, 2009; Wesp, Cichello, Gracia, & Davis, 2004). Thus, the ability of the perceiver to act successfully on an object affects how that object itself is perceived.

Moreover, Balcetis and Cole (2009) have argued that perception has a regulatory function tied to motivational processes. In this way, distance perception is influenced not only by a drive to avoid dangerous actions, but also by a drive to pursue beneficial actions. Balcetis and Dunning (2010) report several experiments showing desirable objects to be judged closer than undesirable objects. For example, distance to a bottle of water was perceived to be closer for thirsty participants, and test results were judged to be closer for those believing it contained positive feedback. The motivation to reduce cognitive dissonance also appears capable of affecting perceptual judgments. Balcetis and Dunning (2007) found that participants asked to walk across campus wearing a Carmen Miranda costume judged the distance they traveled to be shorter when in a high-choice condition. That is, those who believed they had been given the choice to dress up as they did resolved the dissonance resulting from their behavior by judging their walk to be shorter. Similarly, in a second study the authors found that participants asked to push themselves up a hill on a skateboard reported shallower slants when in the high-choice condition. Thus, there is evidence that distance judgments are malleable in a number of ways, due to both motivational and environmental factors.

In much the same way, the results of the present study suggest that additional factors related to social interaction influence perceptions of distance above and beyond the physical costs necessary for completing a task. Carrying with another person requires less physical exertion than carrying alone, yet distances were reported as greater in this condition. How can this counterintuitive finding be explained? Joint-action entails becoming part of a dyadic synergy (Marsh et al., 2006), a unique perception-action system. Although this point was raised earlier to note that a dyadic synergy necessarily has its own available affordances and a distinct energetic economy, it is also important to acknowledge that this unit will necessarily have its own unique constraints on cohesiveness and potential coordination. These constraints have two sources. First, the unit's ability to successfully coordinate will necessarily depend on the nature of the task they are attempting to accomplish. The task of this experiment, carrying a heavy object with someone while blind-folded, clearly poses a challenge to cohesiveness. The direction and speed of the participant's movement is dependent upon the partner, yet this coordination must take place without the aid of vision. Being unable to see one's partner is a substantial limitation on the unit's potential to effectively coordinate. As a result, this task may very well be considered more difficult in the joint condition, for additional cognitive resources are clearly required. It would appear that this constraint on potential coordination was weighed more heavily by participants than any reduction in physical strain that would result from working with their partner.

In addition to the task itself, the characteristics of one's partner also act as a constraint on the ease with which coordination can be achieved. For example, Isenhower et al. (2010) found that people asked to move wooden planks attended to the arm length of their partner relative to their own when transitioning from solo to joint action. Thus, the pair's ability to work together was dependent on the relevant, relative physical characteristics of the participant's partner. In the present research, impressions of the confederate's physical characteristics also appeared to be information participants attended to and were affected by. Surprisingly, however, both perceived athleticism and strength were positively correlated with distance estimates. Again, it seems that the purely physical support afforded by a partner is not necessarily the key element at play within social units. Instead, interactions can be costly. Working with another person entails an inherent obligation to be a good and valuable partner. If one's partner appears to be strong and athletic enough to be capable of handling the task alone, one’s value as both a partner and a participant is necessarily diminished. Attunement to this negative social information will naturally impact both the participant’s ability and desire to form a cohesive social unit, and it may ultimately lead to regulatory strategies meant to avoid such joint activity.

The weight of the box was also found to significantly influence both verbal estimates and blind-walking distances. Though this was surprising, as it had meant to produce a controlled and equal sense of *heaviness* for all participants, the effect does indicate that physiological effort did in fact play some role in the outcomes of this experiment. Heavier weight lead to farther distance estimates. Nevertheless, there are several possible explanations for this effect. First, because the procedure included the experimenter weighting the box to the appropriate amount while in the presence of the participant, those being given a large amount would have been more likely to see the experimenter add weight, rather than remove it. Being more apt to observe this may have lead to experiencing the heaviness of the box differently. That is, watching the box be filled may lead to a greater expectation of weight, thereby producing a greater subjective experience of its heaviness. However, the experimenter adjusted the box while participants filled out their ratings of the confederate, so it is doubtful that much attention was actually being paid to the experimenter as he did this. Moreover, even if participants did notice the experimenter’s activities, evidence exists that calls into question the role of cognitive expectations on perceptions of heaviness (Masin & Crestoni, 1988). In fact, typical expectation models (Davis & Brickett, 1977) would actually predict the opposite effect: expecting the weight to be particularly heavy would lead participants to lift with greater force, thereby overshooting the actual energy needed. This mismatch should make the box feel lighter upon lifting for those expecting greater weight. Finally, this explanation cannot account for the same effect found in the largest trial of Experiment 1, in which the box was weighted before the participant arrived.

A second explanation for the effect of box weight is the possibility of a *size-weight illusion*, produced by differing distributions of weight for heavier and lighter participants. According to Amazeen and Turvey's (1996) Inertial Model, the perceived heaviness of an object is a function of its resistance to rotational forces. Though the dimensions of the box itself did not differ from participant to participant in this experiment, the distribution of the mass within the box did. All participants had a base weight of 25 lbs. at the bottom of their box. Additional weight, if needed, was then added after a second layer of insulation foam. Thus, a box used by the heavier participants would have had its weight distributed more equally on the vertical dimension than would the lighter participants. As a result, when controlling for actual weight, the box with more mass would actually be predicted to feel *less* heavy than the lighter box. The difference in weight distribution therefore fails to explain the direction of the effect found in this experiment.

Another alternative explanation involves noting that, because the box was weighted to each participant, heavier participants were the people given larger amounts to carry. Due to their greater mass, heavier participants will necessarily expend more energy traversing any large distance than will smaller people. Thus, like the chronic pain patients studied in Witt et al. (2008), this difference could be understood as the product of individual, inherent physical characteristics relevant to energy expenditure. However, this explanation is on theoretically weak footing. Even though larger participants must expend more energy, they should also have more energetic resources to draw from (e.g., muscle). One's energetic economy is not based purely on raw energy requirements, but instead on the ratio between expended and available energy.

The final and preferred explanation for the statistically significant effect found for box weight is the likelihood that basing the weight of the box purely on the participant's weight produced an inequivalent experience of heaviness for *some* of the larger participants. Though very light participants would be largely similar in terms of strength, a person can weigh a lot due to either muscle or excess fat. Asking heavy, low-muscle-mass participants to carry large amounts would necessarily require greater effort from them than would be needed for smaller participants carrying small amounts. Thus, without being able to adjust weight according to the participant's BMI, heavier participants as a group were likely by and large presented with a physically more difficult task.

The effect of condition was found for the verbal estimate, but the blind-walking measure did not significantly differ between conditions. It is worth considering then whether verbal estimates are a valid measure of distance perception. Verbal measures have been criticized previously, with some suggesting that, relative to blind-walking, it measures cognitive rather than perceptual judgments (e.g., Hutchinson & Loomis, 2006). That is, verbal reports are more the product of post-perceptual biases, such as experimental demands, whereas blind-walking is a purer gauge of actual visual processes. In the present research, participants' blind-walking distances were indeed found to be significantly more accurate than their verbal estimates. However, there are reasons to think that the verbal estimates used here are in fact valid criteria. First, in both experiments verbal estimates and blind-walking were significantly correlated with one another. This is consistent with prior comparisons between the two measures (Philbeck & Loomis, 1997), and previous work has found manipulations of effort that do affect both action-based and non-action-based distance judgments (e.g., Witt et al., 2005). This relationship suggests that there is at least some shared commonality between the two measures. Secondly, there is not a clear theoretical reason to think that blind-walking taps into actual visual processes better than verbal estimates. It is, after all, a measure of vision that is done without vision. As Proffitt et al. (2006) argue, "Only through convoluted argument could it be asserted that a measure obtained without vision is a "purer" measure of visual perception than one in which vision is unfettered" (p. 342). Importantly, blind-walking is a dynamic activity done over time that produces both haptic (feeling the floor and air) and auditory information (hearing one's footsteps) in addition to the original visual information. As a result, blind-walking is just as likely to be at least partially guided by non-visual processes as are verbal estimates. Therefore, though blind-walking was less impacted by the manipulations used here, this does not negate the claim that it was perceptual processes that were influenced by anticipated joint-action, not merely post-perceptual response biases.

Rather than being an altogether different psychological process, the difference between the findings for verbal estimates and those for blind-walking distances may be the result of the distinct methodology used in this experiment. Verbal estimates were made by participants while actually holding the box. Blind-walking, on the other hand, was done after observing the target location while the box rested on the ground between the participant and the confederate. This may be a key phenomenological difference. Receiving assistance from the confederate while giving the verbal measure would entail a shift from a solo-holding position to a joint carrying position. Therefore, joint-carrying at the point of the verbal estimate would necessarily involve a transition that may make coordination especially challenging. In contrast, when preparing to blind-carry, the experimenter told the participant that he would lift the box up to the two partners and each would take a side. Thus, no solo to joint holding transition is necessary at this stage. Prior research has found that humans' ability to measure distance through their locomotion is dependent on maintaining gait symmetry (Turvey et al., 2009). That is, asymmetric transitions from a primary gait (e.g. walking) to a secondary gait (e.g., galloping) reduces individuals' ability to accurately reproduce traveling distance. The anticipated transition from solo- to joint-carrying at the time of the verbal estimate may entail a similar process that adds an additional challenge to participants. Thus, if the effect found for condition in this experiment is in fact due to the challenges involved in coordinating, it seems possible that the different results found for the dependent variables is because such challenges would have been most pronounced at the time of the verbal estimate.

General Discussion

Two experiments tested the prediction that anticipating help from another person when carrying a heavy object would lead to shorter distance judgments relative to those expecting to carry alone. Based on Proffitt's (2006b) theory of the economy of action, it was expected that the lessened physical strain resulting from having a partner would reduce anticipated carrying distances. Nevertheless, the opposite effect was found, with reductions in the carrying task's apparent physical difficulty instead increasing distance judgments, both between and within conditions. In Experiment 1, verbal estimates of the first trial were influenced by perceptions of the partner's strength when participants expected to work with this person. However, these distance judgments actually increased when their partner was judged to be stronger. Moreover, expecting to carry jointly was itself predictive of larger verbal estimates. In Experiment 2, these effects were replicated, with participants' verbal estimates significantly shorter in the joint-carrying condition and ratings of confederate's physical traits positively correlated with perceived distance. These results suggest that alterations in physical strain alone do not predict changes in spatial perception in the context of joint action. Rather, it is argued that working as part of a social unit produces not just changes in terms of the individual's effortful requirements, but also unique interpersonal challenges, expectations, and obligations. As a means of facilitating behavior in one's environment, visual perception is sensitive to the new factors that arise from taking part in interpersonal coordination and joint action. Importantly, in certain contexts, it seems that these challenges can be more relevant and have greater influence on spatial perception than physical effort alone.

Because the results were contrary to the experimenter's original hypothesis, it is important for future research to clarify that the observed results are in fact the result of perceived task difficulty. Coordinating with another person to carry a heavy object while blindfolded is a difficult enterprise, and it seems as though this challenge is the basis for the larger distance judgments when in the joint carrying condition. Therefore, manipulating the degree to which the task is judged to be difficult would likely be the most fruitful means of validating this explanation. Doing so can be done two ways. First, the constraints on the unit’s ability to coordinate resulting from the task itself can be manipulated. This would entail altering the task so as to make the joint condition significantly easier in all respects, rather than just in terms of physical effort, as in the experiments above. For example, varying the length of the object to be carried may make the value of working with another person more or less apparent. If expecting to have to work another person, distance estimates should be inversely related with the degree to which that person needs the other to move the object comfortably.

The alternative approach would instead involve altering the constraints on the pair’s ability to coordinate that result from the participant’s perceptions of and relationship with the partner. This would entail manipulating the perception of interpersonal effort required for the task by either strengthening the sense of cohesiveness within the dyad, or by altering the valence of the participant’s attitude towards the other person. As Marsh et al. (2006) have suggested, individuals acting together are a synergy. The nature of this social synergy (along with its behavioral potential) is dependent upon their sense of connectedness, or entitativity (Campbell, 1958). High degrees of connectedness would have behavioral consequences for the synergy, such as “high awareness of the other’s movements, easy anticipation, and responsiveness to the other, much as teammates on a well honed basketball team can show immediate awareness of the motions of teammates” (Marsh et al., 2006, p. 25). It seems reasonable to predict that greater entitativity will also have an impact on anticipated physical and psychological effort, as participants should be able to accurately detect the synergy of their social unit.

In support of this hypothesis, Schnall, Harber, Stefanucci, and Proffitt (2008) found that judgments of hill slant were reduced when participants were accompanied by a friend, an effect that was mediated by relationship quality (i.e., duration, closeness, and warmth). They hypothesize that psychosocial resources such as social support are able to reduce one's sense of physiological load. However, while their study speaks to how perceived sense of effort in solo action can be influenced by social factors, it does not address the dynamics of taking part in a task *with* another person. It would be in this context that one's sense of entitativity should have the strongest impact. Such manipulations could include giving the participant a personality test which will imply similarity with their partner, or by manipulating confederate behavior so as to create a rude or disagreeable partner persona. It would be hypothesized that the greater the degree of entitativity experienced by the participant towards his or her dyadic unit, the lesser the anticipated effort of a joint-task will be. As a result, distance targets they expect to carry an object to with this partner would be predicted to be perceived as shorter.

The results of the current research and the proposed new hypotheses highlight the complicating and often counterintuitive social factors that ultimately guide and influence all aspects of human activity, including perception. Recently, there have been calls for ecological researchers to take more seriously the role human sociality plays as a component of our basic perception-action cycles (e.g., Hodges & Baron, 2007). At the same time, there has been a renewed push for social psychologists to better grapple with the consequences of ecological theory in their understanding of social perception (e.g., Baron, 2010; Good, 2007). The main aim of this research program has been to provide several small steps towards just such integration.

For ecological researchers, these findings should spur on further thought in two ways. First, they emphasize the need to move beyond studying affordances simply in terms of human-object interaction. Instead, more focus should be given to the possibilities for action within an environment as a whole, as can be found by adopting a theory of behavior settings (Heft, 2001). Distances, the space for movement within a medium, can and should be understood and defined in terms of the action possibilities for the perceiver. Although there has been a tradition within ecological psychology of understanding object perception as inherently involving the detection of affordances, distance perception has often been described simply in terms of detecting law-governed, invariant information. By emphasizing the accuracy of distance perception (which is, in fact, supported by the results of these experiments), what is lost is an appreciation for how behavioral opportunities and intention also guide these judgments of whole environments.

Secondly, these experiments emphasize the need for ecological researchers to better understand the unique perceptual consequences resulting from being within a dyadic system. Traditionally, how affordances are perceived and actualized has been described almost exclusively with reference to individual body scaling. For example, whether a surface affords sitting is determined by the perceiver's relevant body dimension (e.g., leg length) relative to the object (e.g., surface height). This is, however, an impoverished account of how people actually look and act in their environments. As Heft (1989) pointed out over two decades ago, affordances are indentified only when they are a means of expressing the perceiver's goals and intentions. People are always doing and planning to do something, and these behavioral intentions are the units by which the world is seen, not universally applied body-object ratios. Acknowledging that the detection of affordances necessarily involves intention, an ecological account of perception must address the unique goals, consequences, and constraints of social behavior. As has been shown, being asked to share half the load of a heavy object by carrying with another person is not equivalent to a single person being asked to carry half the original weight alone. Social coordination has unique challenges, not just in terms of overall task difficulty, but also in terms of other types of social psychological phenomena worth investigating (e.g., self-presentation, social loafing, social facilitation). These phenomena impact the intentions and motivations of a perceiver. Therefore, an ecological approach to perception that seeks to account for how one actively perceives the environment in terms of behavioral possibilities must seriously grapple with the social factors that either guide or constrain the intentions of perceivers.

Similarly, for social psychologists, it is hoped that this line of research will help to broaden current conceptions of what social perception actually entails. Historically, social psychologists have largely limited their study of perception to the question of how people form impressions about others. Even ecological forays into the field of social psychology have been chiefly interested in just this question (e.g., McArthur & Baron, 1983; Zebrowitz, 2006). However, this is too narrow a focus to fully address the important intersection between social phenomena and perceptual processes. All perception is social. The environments in which we live and act are socially constructed, being the product of cultural and historical development (Heft, 2007). Goals and intentions are the result of not only individual agency, but local and chronic social norms, customs, and obligations. Thus, how one relates to even inanimate objects (i.e., how we detect affordances) is necessarily saturated with both the perceiver's and the larger society's social history. Moreover, the experiments described here have sought to show how even spatial perception, a process that seems among the most basic and objective we perform, is socially influenced. Working with someone has ramifications for how the world itself is seen. These findings highlight the importance of social relationships on one of the most basic of human processes: Being embedded in a functional social unit alters one's perception of his or her immediate surroundings.

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Tables

Table 1

Average Estimates of Distances for Solo and Joint Conditions, Experiment 1

	Distances					
Estimates	4 m	6 m	8 m	10 m	12 m	Range of *r*'s[a]
Verbal						
Solo	2.97 (0.55)	5.32 (0.82)	7.68 (1.32)	10.89 (1.71)	13.40 (3.00)	.97 - 1.00
Joint	3.13 (0.34)	5.21 (0.92)	7.82 (1.74)	9.86 (1.34)	13.02 (1.92)	.93 - 1.00
Blind-Walking						
Solo	3.44 (0.32)	5.20 (0.65)	7.42 (0.76)	9.42 (1.00)	11.01 (2.10)	.94 - 1.00
Joint	3.70 (0.45)	5.40 (0.65)	7.18 (1.15)	8.90 (1.07)	11.47 (1.60)	.91 - 1.00
r's between DVs	.15	.16	.49*	.61*	.47*	

Note. Standard deviations are shown in parentheses.

[a] Ranges reflect the correlations between actual distances and estimates across the five distances within participants.

*p < .01.

Table 2

Prediction of Centered Distance Estimates in Experiment 1

		b	Std. Error	*t*	*p*
Fixed Effects					
Block 1:	Intercept	-.34	.18	-1.92	.06
	Estimate Type	.31	.08	3.71	**
	Condition	-.07	.24	-.31	.76
	Box Weight	.03	.02	1.38	.18
	Trial Distance	1.02	.02	41.14	**
Block 2:	Estimate Type x Condition	-1.54	.17	-.92	.37
	Estimate Type x Box Weight	.01	.01	.80	.43
	Estimate Type x Trial Distance	.16	.02	9.68	**
	Condition x Box Weight	-.06	.04	-1.37	.18
	Condition x Trial Distance	-.05	.05	-1.09	.28
	Box Weight x Trial Distance	.02	.01	3.71	**
Block 3:	Estimate Type x Condition x Box Weight	-.04	.03	-1.17	.25
	Estimate Type x Condition x Trial Distance	-.05	.03	-1.40	.16
	Estimate Type x Box Weight x Trial Distance	.00	.00	.51	.61
	Condition x Box Weight x Trial Distance	-.01	.01	-1.45	.15
Block 4:	Estimate Type x Condition x Box Weight x Trial Distance	-.01	.01	-2.33	.02

		b	Std. Error	*Wald Z*	*p*
Repeated Measures	Verbal Estimate	.79	.10	8.00	**
	Blind-Walking Distance	1.54	.19	8.00	**
Random Effects	Verbal Estimate	.61	.24	2.50	.01
	Blind-Walking Distance	.38	.14	2.67	.01

Note. Dependent variable is distance estimate centered on 8 m.

Table 3

Correlations and Partial Correlations Between Confederate Ratings and Distance Estimates

	Experiment 1		Experiment 2			
	Verbal Estimate		Verbal Estimate		Blind-Walking	
	Solo Carriers	Joint Carriers	Solo Carriers	Joint Carriers	Solo Carriers	Joint Carriers
Athleticism	-.36	.15	-.06	.46*	.04	.47*
Strength	.18	.62**	.26	.40*	-.02	.34
Amount of Interaction	.08	.31	.12	-.17	.19	-.05
Likable	-.23	.33	-.05	-.17	-.04	-.02
Similarity	.33	.19	.10	-.31	.22	-.08

Note. Values shown for Experiment 1 are partial correlations for the first trial, controlling for actual distance. Zero order correlations are shown for Experiment 2.

*p < .10, **p < .05.

Table 4

Prediction of Verbal Estimates of Distance in Experiment 1 for First Trial

		b	Std. Error	*β*	*t*	*p*
Model 1	Intercept	-1.37	0.48		-2.84	.01
	Actual Distance	1.10	0.06	0.96	18.40	**
Model 2	Intercept	-1.45	0.46		-3.19	**
	Actual Distance	1.08	0.06	0.94	18.50	**
	Condition	0.42	0.33	0.07	1.30	.20
	Perceived Strength	0.34	0.15	0.12	2.33	.03
Model 3	Intercept	-1.11	0.46		-2.42	.02
	Actual Distance	1.05	0.06	0.91	18.23	**
	Condition	0.45	0.31	0.07	1.46	.16
	Perceived Strength	0.00	0.21	0.00	0.01	.99
	Condition x Perceived Strength	0.62	0.29	0.16	2.15	.04

Figures

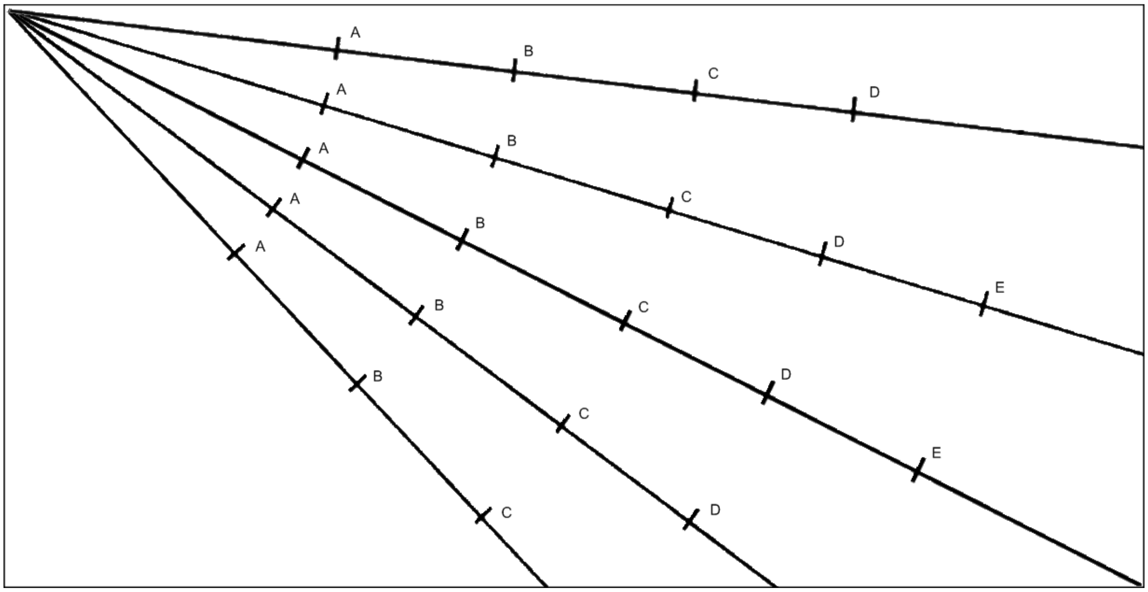

Figure 1. Bird's-eye view of the target space in Experiment 1. Stimuli were positioned four meters (A), six meters (B), eight meters (C), ten meters (D), and twelve meters (E) from the observer along the five radial directions.

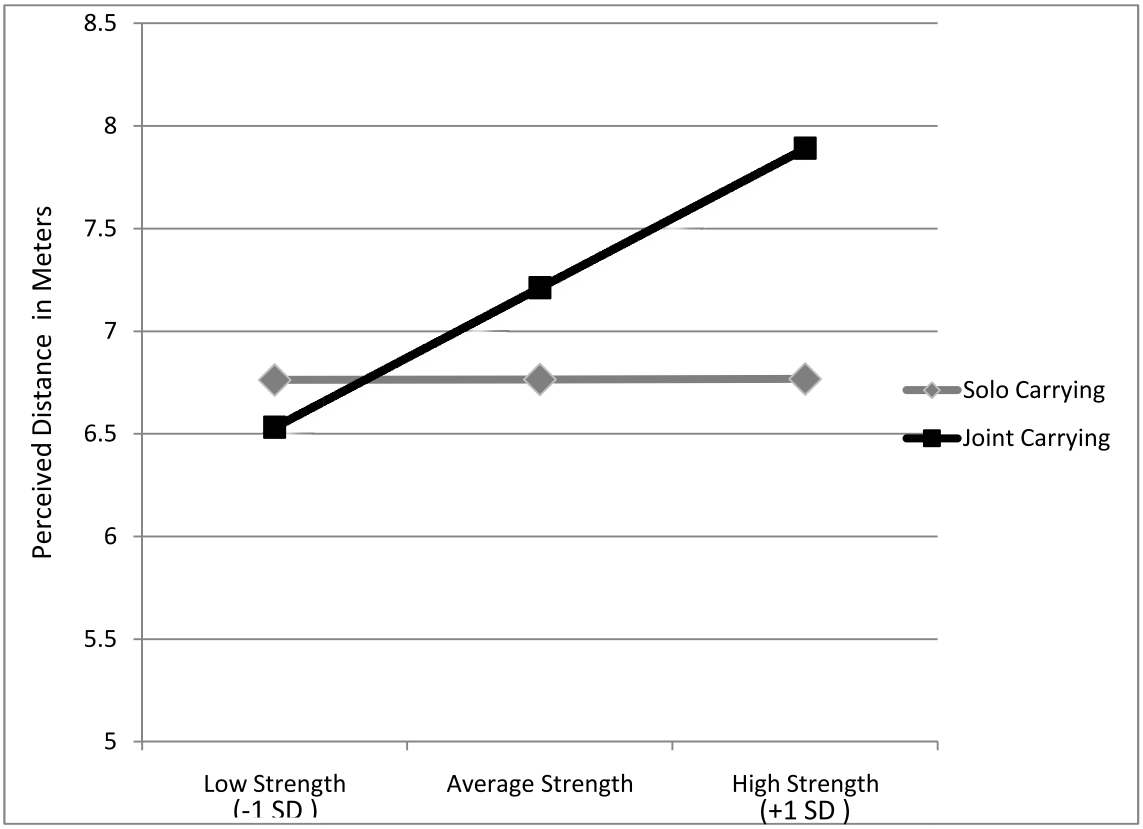

Figure 2. Simple slopes for perception of confederate strength on verbal estimate of participants' first trial, Experiment 1.

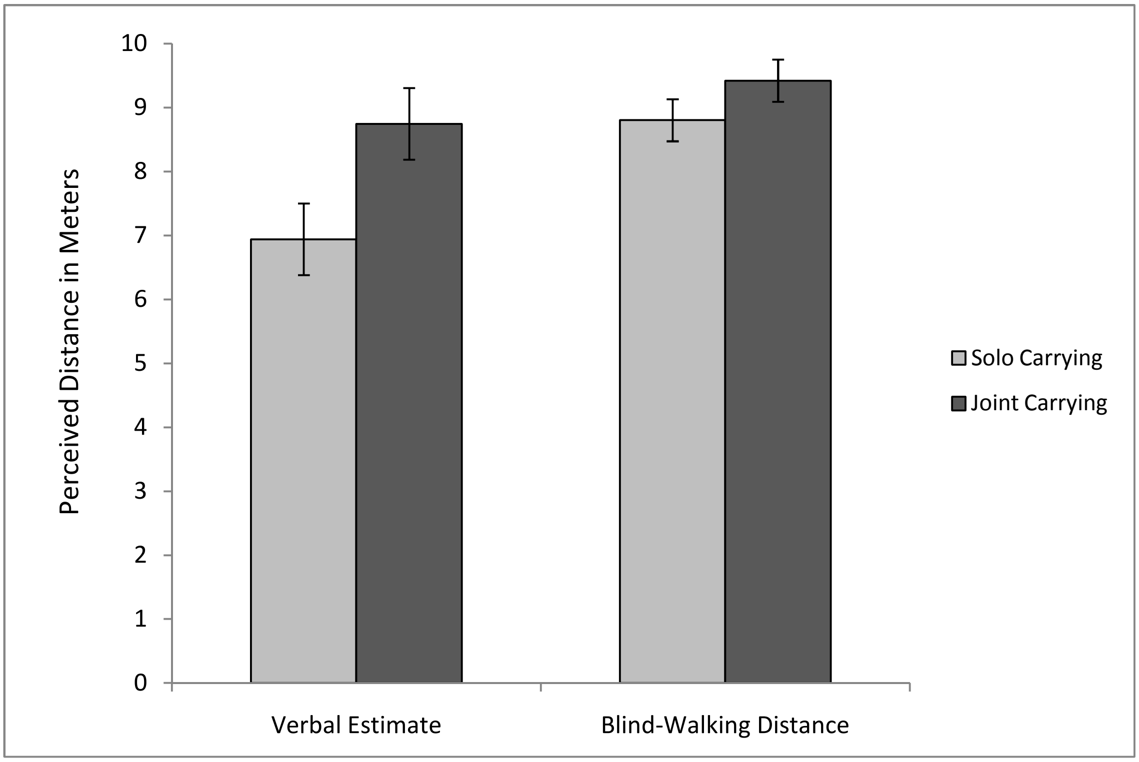

Figure 3. Distance estimates, Experiment 2.

Appendix

Current age (please be accurate) ______________

Indicate your gender: Male Female

Indicate your ethnicity background (Circle all that apply):

White American African-American Hispanic-American Asian-American Native American Other

Below are a number of questions that relate to the experiment you are about to participate in. Please circle a number for each statement.

1. How would you characterize the other student in terms of their strength?

1	2	3	4	5	6	7	8	9

Extremely weak Extremely strong

2. How would you characterize the other student in terms of their athleticism?

1	2	3	4	5	6	7	8	9

Extremely unathletic Extremely athletic

3. How likable do you find the other student?

1	2	3	4	5	6	7	8	9

Extremely unlikable Extremely likable

4. How much interaction was there between you and the other student?

1	2	3	4	5	6	7	8	9

Not much interaction at all Lots of interaction

5. How similar to yourself do you find the other student to be?

1	2	3	4	5	6	7	8	9

Extremely dissimilar Extremely similar