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Distance perception warped by social relations: Social interaction information compresses distance

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ABSTRACT

Though distance perception feeds the fundamental input that constructs a visual structure of the world, the suggestion has been made that it is constrained by this constructed structure. Instead of focusing on the physically defined structure, this study investigates whether and how social relations, especially the quality of social interaction (how individuals interact) rather than its content (what type of social interaction), precisely influences distance perception. The quality of social interaction was framed as an actor's intent and incurred outcome regarding another individual, whether helpful or harmful. Through visual animations, intent was operationalized as an agent's (i.e., actor's) intentional or unintentional act having an influence on another agent (i.e., affectee). Two experiments were conducted. In Experiment 1, the act was helpful, resulting in small or great beneficial consequences to the affectee. In Experiment 2, the act was harmful and resulted in small or great losses to the affectee. We found that when the help or harm had a large effect on others (the great-benefits or great-losses conditions), distance was perceived as shorter than when help or harm was minor, and the actor's intent did not affect distance perception. This suggests that, regardless of the type of social interaction, distance perception is mainly influenced by the outcome of an act not by the actor's intent. It implies that the perceived quality of social interaction creates a social constraint on distance perception. These findings are consistent with the idea that the intent and outcome of an action are assessed differently, and they help us understand how social relation penetrates the perceptual system.

1. Introduction

The human visual system relies heavily on the structure behind discrete visual elements to understand the world (Todd, 2004). Distance perception (spatial or physical) as a form of spatial perception and a central conundrum in psychology feeds the fundamental input to construct a visual structure of the world (Proffitt, 2006). Given the dependence of structural representation on distance perception, it seems unlikely that visual structure could subsequently alter that very perceived distance. Whereas it had been reported that the visual structure surrounding two dots affects the perceived distance between them, and spatial distances between objects are perceived to be greater than spatial distances in the ground regions of a scene (Vickery & Chun, 2010). Many studies have concluded that distance perception is influenced by the visual structure of scenes (Coren & Girgus, 1980; Liverence & Scholl, 2011; Tudusciuc & Nieder, 2010; Vickery & Chun, 2010; Vickery & Jiang, 2009). These studies have focused more on the physical relationship between discrete elements or objects than on the visual structure. Nevertheless, besides the physical structure, social relations are a universal organization of social objects, and social interaction, as a behavioral instantiation of social relation, defines how objects (or individuals) are connected and interact with each other and is often part of a visual scene (Stahl & Feigenson, 2014; Yin, Xu, Duan, & Shen, 2018). However, whether and how social interaction information precisely influences distance perception has received little, if any, attention.

Historically, the relationship between social interaction and the concept of distance has been largely investigated by emphasizing social distance instead of physical distance (Bogardus, 1933; Boguñá, Pastor-Satorras, Díaz-Guilera, & Arenas, 2004; Jones & Rachlin, 2006; Krackhardt & Kilduff, 1999; Vekaria, Brethel-Haurwitz, Cardinale, Stoycos, & Marsh, 2017). Social distance describes the psychological

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distance between different individuals and/or groups, as opposed to physical distance, and is generally treated as a parameter of social relations (Aron, Aron, & Smollan, 1992; Kidwell & Booth, 1977; Rummel, 1975). For instance, the closer two individuals feel towards each other (e.g., friends vs. strangers), the shorter the social distance between them (Sundstrom & Altman, 1976). This is not to say that social distance is unrelated to physical distance. In fact, social distance can be represented and measured by physical distance. In a typical observation, the more people interact socially, the closer they stand to each other (Hall, 1966; Sorokowska et al., 2017). Moreover, a series of studies from the perspective of construal level theory found that these two kinds of distances produced identical effects on how we think about an event, person, or idea (Liberman & Trope, 2008; Maglio, Trope, & Liberman, 2013; Trope & Liberman, 2010; Wakslak & Trope, 2009). Generally speaking, regardless of whether the distance is social or physical, the farther an object is from the individual, the more abstract it will be considered to be, while the closer the object is the more concrete it will be considered to be. The conceptual relationship between social and physical distance was explored by functional magnetic resonance imaging studies, which concluded that social distance and physical distance rely on shared processing regions in the human parietal cortex (Parkinson, Liu, & Wheatley, 2014; Yamakawa, Kanai, Matsumura, & Naito, 2009). Hence, social distance and physical distance are thought to be conceptually related and functionally equivalent.

As discussed above, physical distance and social distance are functionally equivalent in the mind. As such, the social relations between (or among) individuals that are implied by social distance should have an impact on the perceived distance between them. This idea is supported by several studies (Bar-Anan, Liberman, Trope, & Algom, 2007; Matthews & Matlock, 2011; Thomas, Davoli, & Brockmole, 2014). For instance, Bar-Anan et al.(2007) found that, when asked to either indicate the spatial location of a presented word or verify a word's presence, participants responded more quickly when the word "friend" (a close relation) was displayed in a spatially proximate versus a spatially distant location and when the word ""others" "(distant relations) was displayed in a spatially distant versus a spatially proximate location. Additionally, Matthews and Matlock (2011) reported that imagining friends resulted in shorter perceived physical distances than did imagining strangers. Specifically, when asked to draw a route on a map, people tend to draw routes closer to friends they pass along the way and further away from strangers. Thomas et al. (2014) investigated how the social interaction context impacts the space people perceive between themselves and others. They asked participants to play a ball-toss game with a partner until they reached a target score, either competitively (i.e., one player earned more points), or cooperatively (i.e., they together earned the total cumulative score beyond a set score), or individually (i.e., one player solely earned the total cumulative score beyond a set score). Results revealed that participants who have a competitive interaction with the partner perceived him or her to be more distant than participants who cooperated with the partner or who played alone. Hence, a socially distant relation such as in a competitive relationship leads to perceptual distancing between actors. Besides these perceptual phenomena, the spatial distortion can be found in memory task, such as, interacting individuals (versus noninteracting individuals) are physically closer in memory (Vestner, Tipper, Hartley, Over, & Rueschemeyer, 2019).

In all the studies cited so far, social interaction was characterized by different kinds of relationships between individuals, which falls into cognitive schema about content, or what the individuals are doing together (e.g., friend vs. stranger, cooperation vs. competition; Hinde, 1976). The social interaction between individuals is characterized in terms such as "A does X to B" or "A does X to B and B responds with Y." (Brinkerhoff, Ortega, & Weitz, 2013) Hence, describing an interaction requires specifying both what the individuals are doing together (content) and how they do it (quality) (Hinde, 1976). For instance, A cooperates with B but also decides how much effort to invest. Hence, whether and how the quality of social interaction influences distance perception appears to expand social constraints on the perception of physical distance, but the extent to which it does so remains unclear.

Social interaction is patterned by the observable constituents of an individual's actions (Knoblich & Sebanz, 2008). Typically, an action is explained within the framework of the underlying intent of that action, which describes the actor's mental states (e.g., intentional or unintentional), as well as its outcome, which describes the effects of that action (Ames & Fiske, 2013; Ames & Fiske, 2015). As such, knowledge of both the intent and outcome is crucial for characterizing the quality of an action (Malle, 2004). Hence, this study focused on how the intent and outcome of a social interaction affect the perception of distance.

In previous studies, the operationalization of intent and outcome of an action were usually embedded in verbal descriptions of social events (Ames & Fiske, 2013; Ames & Fiske, 2015). This method may lead to ambiguity in understanding action, and importantly, is difficult to use to study questions related to visual perception. As such, following the research of Wu et al. (2018), we adopted visual animations as stimuli in order to manipulate the intent and outcome of an act. Notably, in visual animations, constructing conditions in which the intent and outcome are antithetical is almost impossible, as inferences of intent generally rely on the outcome of the act (Baker, Goodman, & Tenenbaum, 2008; Gergely & Csibra, 2003). Thus, we operationalized intent as an intentional or unintentional act in a social interaction and manipulated the outcome's impact on the affected agent as small or great. Two experiments with different social interaction contents were conducted: Experiment 1 was a helpful action, and Experiment 2 was a harmful action. This design helped us examine whether the influences of intent and outcome on distance perception can be generalized to different kinds of social interactions.

Because the intent and outcome of an action are accessed or attributed differently (Cushman, 2015; Gergely & Csibra, 2003; Malle, 2004), they might have distinct influences on distance perception. Specifically, an action's outcome is an observable reality and is acquired directly without explicit conscious reasoning; but the intent behind an action is an attributed mental state and needs to be explicitly reasoned about and inferred by the mentalistic interpretation system (Malle, 2004). Similarly, physical distance perception as a parameter of reality is perceived without explicit reasoning by primarily using distance receptors (Foley, 1980; Loomis, Da Silva, Philbeck, & Fukusima, 1996). In this case, in understanding distance perception, the influence of the mental states behind individuals' actions may be very low, because vision implicitly relies more on the percept of reality (Malle, 2004). Hence, we predicted that the outcome of a social interaction would be the main (possibly only) factor influencing distance perception. Furthermore, some have suggested that the two interacting agents should be represented as one unit within a social structure (Shen, Yin, Ding, Shui, & Zhou, 2016; Yin et al., 2018). Due to such a social constraint, the psychological distance between two interacting agents may be compressed, and a stronger social interaction should result at a shorter perceived distance. If this is the case, since larger effects on one individual caused by another results in a stronger social interaction between them (Hinde, 1976), we expected to observe that, when an actor bestowed great benefits upon the affected agent, the distance between the two interacting agents would be perceived as shorter than when the actor bestowed small benefits.

2. Experiment 1: helpful actions

2.1. Methods

2.1.1. Participants

The sample size was determined by a power analysis based on a predicted effect using G*Power 3 (Faul, Erdfelder, Buchner, & Lang, 2009). To achieve a medium effect size (f = 0.25, according to Cohen,

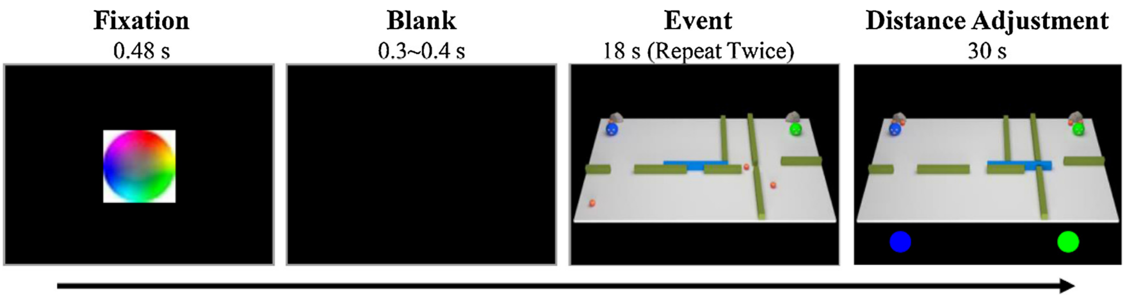

Fig. 1. Illustration of the experimental procedure.

1988) with 80 % statistical power, we needed to recruit 24 individuals using a repeated two-way analysis of variance against an alpha of 0.05. Ultimately, 25 paid participants took part in this experiment. We analyzed the data of 24 participants (13 males and 11 females, aged 18–25, mean age 20), and one participant was removed due to operating errors by the experimenter. For consistency, Experiment 2 also used 24 participants. All participants had normal or corrected-to-normal vision and no history of neurological disorders. The study was approved by the Research Ethics Board of the Department of Psychology at Ningbo University, and it was performed in accordance with relevant guidelines and regulations. Information sheets were distributed to all participants before the experiment, and after learning of the purpose of and procedure for the experiment, they gave their written informed consent.

2.1.2. Apparatus and stimuli

The stimuli were all presented on a black background using a 19-inch cathode ray tube (CRT) monitor (1024 × 768 pixels resolution; 100 Hz refresh rate) at a 60-cm viewing distance, using custom software written in MATLAB with the Psychophysics Toolbox libraries (Brainard, 1997). The visual stimuli were created using the free open-source 3D creation suite Blender (https://www.blender.org/), and they consisted of 9-s computer-animated events of a size of 27.2° × 20.5° (the full area of screen was 34.0° × 25.6°, please see the supplementary videos for details).

Each event involved two cartoon agents of different colors: blue and green. The blue agent (the actor) is initially positioned in the upper left corner of the screen and then approaches an apple positioned in the lower left corner of the screen to pick it up and place it in front of a stone near the actor's starting position. When approaching the apple, the blue agent must pass through one of two gaps in the wall: one is unobstructed, and the other is blocked by a movable obstacle. The path to the apple is shorter through the unobstructed gap compared to the blocked gap. However, the width of the unobstructed gap differs depending on whether the condition represents intentional or unintentional help: in the intentional-help condition, the gap is the width of the blue agent and therefore the agent can pass through it easily; in the unintentional-help condition, the gap is narrower than the blue agent, forcing the agent to move the obstacle in the other gap to reach the apple. In both conditions, the blue agent moves the obstacle to take the apple (i.e., pass through the gap with the movable obstacle), but the former is considered (more) intentional and the latter is considered (more) unintentional. This manipulation of intent is the same as used by Wu et al. (2018).

The green agent (affectee) is positioned in the upper right corner of the screen and also moves to take an apple positioned in the lower right corner. Upon obtaining the apple, the green agent returns to near its starting position to place the apple in the front of the stone. This action illustrates to the observers the green agent's intention to take the apple. Continuing, the green agent moves again, this time to an apple between the two walls almost at the center of the screen. This apple is visible through a gap in the wall on the green agent's side. The green agent attempts to cross through this gap to retrieve the apple but does not take it and then moves slightly upwards before remaining still. During this period, the obstacle moved by the blue agent forces the apple to almost in front of the green agent, acting like a helping action; this allows the green agent to pick up the apple and move it to the stone. As with the blue agent, the gap that the green agent attempts to pass through is either wider or narrower than the green agent's body. When the gap is wider, the blue agent's helping action is not as necessary because the green agent can fetch the apple by itself; hence, it is considered less beneficial for the green agent than when the gap is narrower.

There were a total of four conditions in a two (helpful intent: unintentional help vs. intentional help) by two (action outcome: great benefits vs. small benefits) within-subjects design. All of the motions outlined above were presented at a 24.2° viewing distance and at a 3D perspective view of 57°.

2.1.3. Procedure and design

In each trial, a dynamic fixation stimulus was first presented at the center of the screen for 480 ms and then replaced by a blank background for 300 ms–400 ms. Thereafter, one animation, randomly sampled from four different events, was replayed twice at the center of the screen, lasting for 18 s. Finally, the last frame of the animation stayed on the screen, and two dots (radius: 1°)—one blue and one green—were displayed below the area occupied by the animation on the screen (see Fig. 1). Participants were asked to perceive the distance between the two agents in the last frame of the presented animation (i.e., actual distance), and adjust the distance between the two dots to the actual distance (i.e., perceived distance) in 0.5-pixel increments. The actual distance was 568.0 pixels (about 18.9°) in all conditions. Participants were told that they were being monitored by a camera and could not use their hands or other tools to measure the distance (a post-hoc examination confirmed that all participants followed the instructions). The initial distance between two dots was either shorter or longer than the actual distance by between1.89° to 3.78° (i.e., the adjusted distance was 1.1–1.2 [or 0.8 to 0.9] times as long as the actual distance), to allow participants to easily detect the difference between the actual distance and the adjusted distance. Participants pressed the spacebar to proceed to the next trial. If the response time exceeded 30 s, this trial was not considered in the analysis, as our pilot test showed that 30 s was sufficient for participants to finish the adjustment. Participants completed 20 trials for each condition, resulting 80 trials in total. To evaluate how the social structure influences distance perception, we measured the perceived distance for each trial as the dependent variable (in pixels).

After completing the above task, each participant had to answer one question for each event: "Do you think that the blue agent intentionally influenced the green agent?" (rated from 1 = completely disagree to 7 = completely agree). This question was designed as a manipulation check to elucidate how the blue agent's intent was perceived (note that the question used the word "influence" instead of "help" to maintain consistency between the experiments).

Table 1
Descriptive Results of the Evaluations of the Actor's Intent in Both Experiments ($M \pm SE$).

	Experiment 1: Helpful Action		Experiment 2: Harmful Action	
	Great Benefits	Small Benefits	Small Losses	Great Losses
Unintentional Action	2.8(0.3)	2.9(0.3)	2.4(0.2)	2.4(0.3)
Intentional Action	5.0(0.4)	5.2(0.4)	5.8(0.3)	5.7(0.3)

2.1.4. Results and discussion

2.1.4.1. Intent. The overall results for the evaluations of intent are presented in Table 1. A two-way analysis of variance (ANOVA) with helpful intent and action outcome as factors revealed a significant main effect of helpful intent ($F(1, 23) = 44.97$, $p < 0.001$, $\eta_p^2 = .66$). Neither the main effect of action outcome ($F(1, 23) = 0.30$, $p = 0.592$, $\eta_p^2 = 0.01$) nor the interaction effect of action outcome and helpful intent ($F(1, 23) = 0.08$, $p = 0.775$, $\eta_p^2 < 0.01$) was significant. These results thus confirm that participants perceived the actor's action as more intentional in the intentional-help condition than in the unintentional-help condition (95%CI = [1.6 3.0]), suggesting that our manipulation of intent was valid.

2.1.4.2. Perceived distance. The perceived distances under all conditions were not significantly different from the actual distances ($ts < 1.72$, $ps > 0.095$), but the distances differed between conditions, as shown in Fig. 2a. The ANOVA with helpful intent and action outcome as factors revealed that only the main effect of action outcome was significant ($F(1, 23) = 7.46$, $p = 0.012$, $\eta_p^2 = 0.25$); neither the main effect of intent ($F(1, 23) = 0.03$, $p = 0.859$, $\eta_p^2 < 0.01$) nor the interaction effect was significant ($F(1, 23) < 0.01$, $p = 0.963$, $\eta_p^2 < 0.01$). These results suggest that the perceived distance between two agents in the great-benefits condition ($M = 576.2$) was shorter than that in the small-benefits condition ($M = 580.0$; 95%CI = [−6.7 −0.9]), and this effect was not modulated by the helpful intent.

3. Experiment 2: harmful actions

3.1. Methods

Another 24 paid adult volunteers (10 males and 14 females, aged 18–25, mean age 19) participated in this experiment. The stimuli and procedure were the same as those outlined in Experiment 1, with the following exception: when the blue agent moved the obstacle, it prevented the green agent from retrieving the apple, thus performing a harmful action. The green agent therefore returned to its starting point without the apple. Regarding the manipulation of the severity of the harmful outcome, we used two conditions: either the green agent had the ability to retrieve the apple before it was blocked by the blue agent's action (referred to as the great-losses condition) or the green agent could not retrieve the apple (the small-losses condition). As in Experiment 1, there was a total of four conditions constructed in a two (harmful intent: unintentional-harm vs. intentional-harm) by two (action outcome: great-losses vs. small-losses) within-subjects design.

3.2. Results and discussion

3.2.1. Intent

Table 1 shows the overall results regarding participants' evaluations of the blue agent's intent. The ANOVA revealed that only the main effect of harmful intent was significant ($F(1, 23) = 56.00$, $p < 0.001$, $\eta_p^2 = 0.71$). As expected, the results confirmed that the intentional-harm condition had higher evaluations of intentionality compared to the unintentional-harm condition (95%CI = [2.3 4.1]). Neither the main effect of action outcome ($F(1, 23) = 0.34$, $p = 0.567$, $\eta_p^2 = 0.01$) nor the interaction effect ($F(1, 23) < 0.01$, $p = 1.000$, $\eta_p^2 < 0.01$) was significant.

3.2.2. Perceived distance

The overall results for the perceived distance between the two agents are shown in Fig. 2b. The perceived distances under all conditions were not significantly different from the actual distances ($ts < 1.88$, $ps > 0.075$). An ANOVA with harmful intent and action outcome as factors was conducted on perceived distance. This revealed that the main effect of action outcome was significant ($F(1, 23) = 6.65$, $p = 0.017$, $\eta_p^2 = 0.23$), showing that the condition with great losses to the recipient ($M = 578.1$) led to a perception of shorter distance between the two agents than the condition with small losses to the recipient ($M = 581.5$; 95%CI = [−6.1 −0.7]). The main effect of harmful intent was not significant ($F(1, 23) = 2.03$, $p = 0.168$, $\eta_p^2 = 0.08$), nor was the interaction effect ($F(1, 23) = 0.11$, $p = 0.744$, $\eta_p^2 < 0.01$). As with Experiment 1, the perceived distance between the two agents when one of the agents brought about great losses to the other was shorter, compared to that when one of the agents brought about small losses to the other, and this effect remained the same between different intents.

4. Replication

Without a doubt, the effect of spatial distortion caused by social interaction information was weak but consistent in our study. In fact, previous studies revealed that the effect of spatial distortion resulting from the physical structure of a visual scene was weak as well (Coren & Girgus, 1980; Liverence & Scholl, 2011; Tudusciuc & Nieder, 2010;

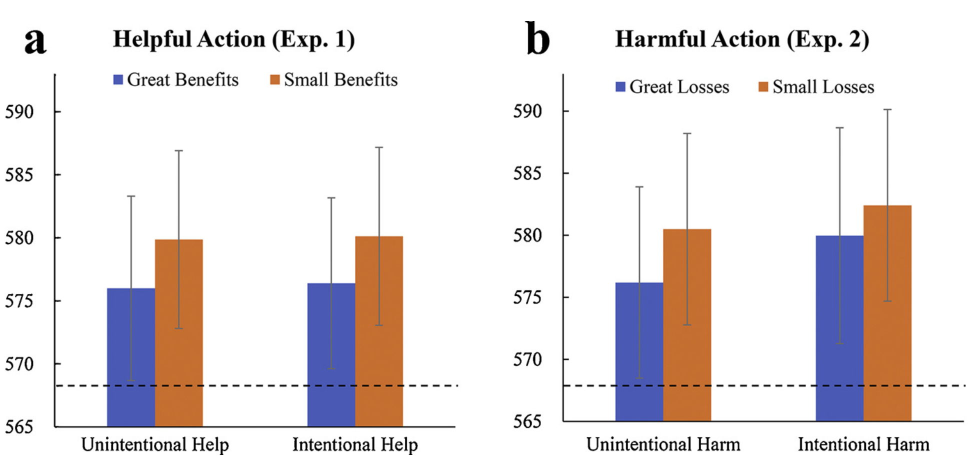

Fig. 2. Perceived distance between the actor (blue agent) and the influenced affectee (green agent) under different acting conditions in Experiment 1 (a) and Experiment 2 (b). The units in the Y-axis are pixels measured on the screen. The dashed line represents the actual distance between two agents (568 pixels). The error bar indicates the standard error.

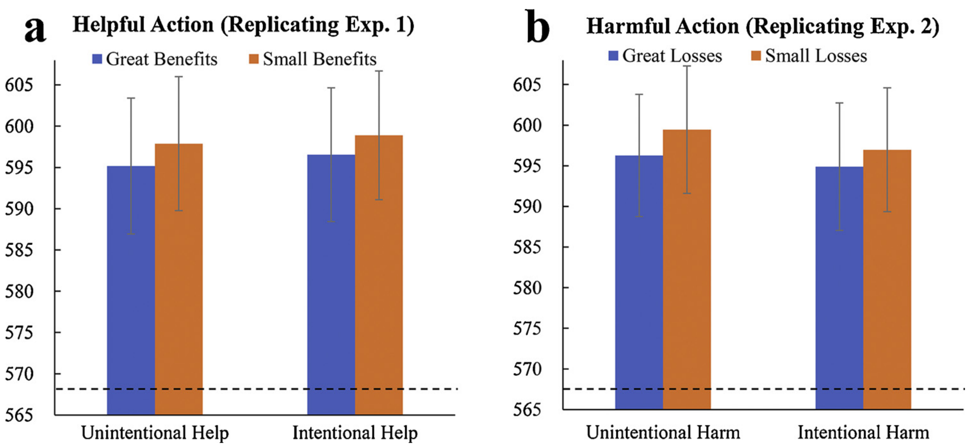

Fig. 3. Perceived distance between the actor (blue agent) and the influenced affectee (green agent) under different acting conditions, replicating Experiment 1 (a) and Experiment 2 (b). The units in the Y-axis are pixels measured on the screen. The dashed line represents the actual distance between two agents (568 pixels). The Error bar indicates the standard error.

Vickery & Chun, 2010; Vickery & Jiang, 2009). To further test the robustness of the spatial distortion effect, we replicated each experiment by presenting the animation only once in each trial on a 27-inch LCD wide screen (100 Hz of refresh rate; 47.8° × 31.3°). The remaining parameters, including the size and distance of the animations as well as the design were the same as in the other experiments.

4.1. Replication of experiment 1

Twenty-four participants took part in this experiment (10 males and 14 females, aged 19-–26, mean age 22). The overall results for the perceived distance between the two agents are shown in Fig. 3a. The perceived distances under all conditions were significantly different from the actual distances (*ts* > 3.30, *ps* < 0.003), which may be the result of the wider screen of the LCD monitor (even though the animations occupied the same spatial parameters). An ANOVA with helpful intent and action outcome as factors that was conducted on perceived distance revealed the same effects as the previous experiment. Specifically, the main effect of action outcome was significant ($F(1, 23) = 9.99$, $p = 0.004$, $\eta_p^2 = 0.30$), showing that the condition with great benefits to the recipient ($M = 595.9$) led to a perception of shorter distance between the two agents than the condition with small benefits to the recipient ($M = 598.4$; 95%CI = [−4.2 −0.9). The main effect of helpful intent was not significant ($F(1, 23) = 0.75$, $p = 0.397$, $\eta_p^2 = 0.03$), nor was the interaction effect ($F(1, 23) = 0.05$, $p = 0.825$, $\eta_p^2 < 0.01$). These replicate results of Experiment 1.

4.2. Replication of experiment 2

Twenty-four participants took part in this experiment (9 males and 15 females, aged 19–26, mean age 22). The overall results for the perceived distance between the two agents are shown in Fig. 3b. The perceived distances under all conditions were significantly different from the actual distances (*ts* > 3.43, *ps* < 0.002), which may be a result of the wider LCD monitor as discussed above. However, an ANOVA with harmful intent and action outcome as factors conducted on the perceived distance revealed the same effects as the previous experiment. In particular, only the main effect of action outcome was significant ($F(1, 23) = 9.76$, $p = 0.005$, $\eta_p^2 = 0.30$); neither the main effect of intent ($F(1, 23) = 1.85$, $p = 0.187$, $\eta_p^2 = 0.07$) nor the interaction effect was significant ($F(1, 23) = 0.21$, $p = 0.650$, $\eta_p^2 < 0.01$). These results suggest that the perceived distance between the two agents in the great-losses condition ($M = 595.6$) was shorter than that in the small-losses condition ($M = 598.2$; 95%CI = [−4.4 −0.9]), and this effect was not modulated by harmful intent, which replicates the results of Experiment 2.

5. General discussion

Instead of focusing on the content of social interaction, this study investigated how the quality of social interaction influences distance perception. The quality of social interaction was represented by the actor's intent and incurred outcome by another individual in either helpful actions or harmful actions. Consistent with our predictions, we found that, in both helpful and harmful contexts, the main factor influencing distance perception was the outcome of the action. Specifically, when the help or harm had a large effect on the other agent (great-benefits or great losses conditions), a shorter distance was perceived than when the help or harm was minor, and this effect was indifferent to both the intentional and unintentional conditions. This finding suggests that the quality of social interaction has an impact on distance perception: the higher the quality of social interaction, the shorter the perceived distance between two individuals.

Consistent with the research that social distance and physical distance are conceptually related (Maglio et al., 2013; Parkinson et al., 2014; Trope & Liberman, 2010; Yamakawa et al., 2009), an action helpful to the affectee—or a close social distance—can also result in a shorter perceived physical distance between the actor and the affectee. What differs from previous studies in the current research is that the social distance represents the quality of the social interaction (how individuals interact) rather than the content of social interaction (what type of social interaction). Hence, the functional equivalence of the physical and social distances in the mind is tenable across different social contexts. This idea, however, is seemingly contradicted by the observed effects of harmful actions. Specifically, if a harmful action means a greater social distance between the actor and the affectee, the distance between them in a harmful context should be perceived as shorter when the harm has a large effect than when the effect is minor, which is inconsistent with our findings. To address this inconsistency, we speculated that the type of social interaction would determine the social distance for different social relations, but how individuals interact would influence how close the two are perceived to be in a social relation. Specifically, inspired by the hierarchical tree-bank representation for physical object relationships (Feldman, 2003), objects can be replaced by social individuls. That is, given that two individuals are connected by social interaction in a social relation, the representation for interactive individuals can be understood in terms of a hierarchical tree-bank. Within the hierarchical tree, certain nodes are natural "joints" that connect individuals, corresponding to a single type of social interaction, and each subtree with individuals hanging from such a node defines how the individuals interact. At the "joint" level, this node defines what relationship two individuals are (i.e., content); but at the "subtree" level the strength of the linkage between the individual and the "joint" represents the intensity (i.e., quality) of the social interaction (please see Fig. 4). This concept needs further

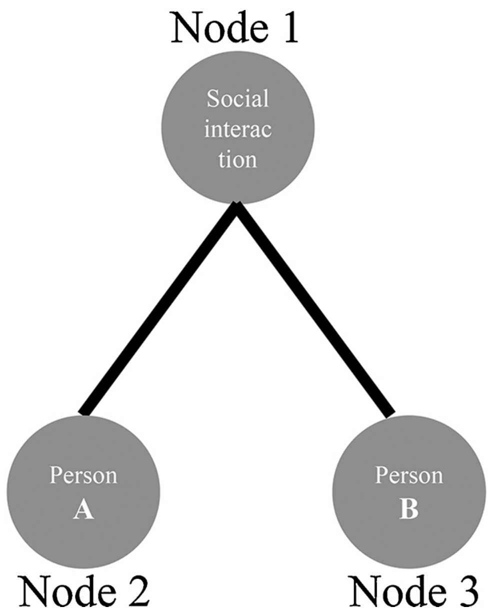

Fig. 4. Tree-bank representing social interaction. Node 1 represents the "joint" level, which defines the type of interaction. Nodes 2 and Node 3 represent two interacting individuals. The solid line represents the linkage between the individual and the "joint," and its thickness is used to describe the quality of linkage.

research.

Though it is risky to interpret a null effect, in both experiments we found, as expected, a consistent null effect regarding the influence of intent on perceived distance. In light of a recent Bayesian analysis in the context of psychological science (Cumming, 2014), we computed Bayes Factors (BF: H1/H0) with JASP 0.8.4.0 (JASP Team, 2018), in which BF < 0.33 suggests substantial evidence against between-group differences. For the main effect of intent, BF was less than 0.33 in both Experiment 1 (0.227) and Experiment 2 (0.216); and BF was no more than 0.33 in both experiments (Experiment 1: 0.278; Experiment 2: 0.282) for the interaction effect between intent and outcome. Hence, we considered that the mental state of intent in a social interaction had no crucial role in distance perception, at least in the current settings of animated actions. This finding was in contrast to theory of mind studies, which showed that the judgment of the number of dots was influenced by how many dots the other saw (Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010; Santiesteban, Catmur, Hopkins, Bird, & Heyes, 2014). This phenomenon is known as perspective-taking: that is, the mental states of other agents influencing our own perception. Such differences may be caused by the two suggested systems for mind-reading: the early-developing system is implicit and fast enough to guide social activities in rapidly changing circumstances and efficient enough to not consume more cognitive resources than necessary; and the late-developing system is as flexible as any reasoning abilities to support the explicit explanation and prediction of an action involved in understanding one's relation to other thinking agents (Apperly & Butterfill, 2009; Apperly, Riggs, Simpson, Chiavarino, & Samson, 2006; Schneider, Bayliss, Becker, & Dux, 2012). Some have suggested that perspective-taking ability is supported by the early-developing system, while intent needs to include the contents of mental states, and it has a propositional role and falls more into the framework of the late-developing system (Apperly & Butterfill, 2009). Possibly, as an implicit process of the perceptual system, perception of distance would strongly interact with the implicit early-developing system but be independent of the explicit late-developing system.

Alternatively, the null effect may be explained by the preferential interpretation of social interaction in actions regardless of the agent's intent, due to the necessity of social interaction for our survival (Knoblich & Sebanz, 2008). In both experiments, the actor's intent to interact was manipulated when pursuing an object-directed goal, but always incurred either benefits or costs by the affectee. In accordance with the principle of rational behavior, an agent's instrumental action (as a means to achieve their goals and subjective desires) is selected to maximize the agent's utility function (to minimize costs and maximize benefits; Dennett, 1989; Jara-Ettinger, Gweon, Schulz, & Tenenbaum, 2016; Ullman et al., 2009). If the attribution of social interaction for actions is preferential, for the actor in our animations, the utility of directing to the affectee (i.e., interacting) is more than the utility of the object-directed goal of carrying the apple. In this case, the incurred effects by the affectee would be the main factor in determining the intensity of social interaction, and the options for pursuing an object-directed goal would have no role, or at least less of a role in such an interpretation. In other words, such an inference may be based on the "teleological stance," which represent actions by relating relevant aspects of reality in our study when no explicit question is asked (Dennett, 1989; Gergely & Csibra, 2003). Theoretically, teleological reasoning would predict that the unintentional act of influencing another by accident should also be ascribed with a goal of social interaction. This theory was supported in one study on infants (Tatone, Hernik, & Csibra, 2014), but whether it is tenable in adults is outside the scope of this study and needs further research.

Our findings have important implications for understanding how visual structure modulates distance perception. Previously, the perceived physical structure of a visual scene was found to constrain distance perception (Coren & Girgus, 1980; Liverence & Scholl, 2011; Tudusciuc & Nieder, 2010; Vickery & Chun, 2010; Vickery & Jiang, 2009). Though it was also suggested that social relations constrain distance perception, this was limited to the content of social interaction and manipulated by top-down explicit instructions (Bar-Anan et al., 2007; Matthews & Matlock, 2011; Thomas et al., 2014). The contribution of the current study to the literature is to expand the boundary conditions of social relations to include the quality of social interaction as immediately perceived from a visual scene. Such an expansion suggests that social information, at least social interaction information, can set top-down signals to constrain distance perception. Social interaction information is processed primarily in mirror neurons and mentalizing systems (e.g., posterior superior temporal sulcus; Isik, Koldewyn, Beeler, & Kanwisher, 2017), which differs from the parietal cortex's processing of the distance between objects and physical structure (Parkinson et al., 2014; Yamakawa et al., 2009). The pathway of this top-down modulation may start in the frontal cortex (Corbetta & Shulman, 2002), which is thought to generate top-down signals when activated by social interaction information. Then, the pathway continues into the parietal cortex to add a new constraint to distance perception beyond the physical structure. Hence, more than information about physical structure, the top-down information about social interaction may introduce a new social link between objects that modulates distance perception. In this case, distance perception that is constrained by a physical structure may function complementarily from distance perception that is constrained by social relations.

6. Conclusion

In summary, we demonstrated that distance perception is primarily influenced by the outcome of an act rather than by an actor's intent within a social interaction, suggesting that the perceived quality of social interaction adds a social constraint on distance perception. Further investigations are needed regarding why intent and outcome in a social interaction have dissociable impacts on distance perception, and how the top-down information of social interaction penetrates the visual process of perceiving distance.

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Author contributions

J. Yin conceived and designed the experiments. M. Shao, H. Ji, Y. Yang, and F. Song performed the experiments and analyzed the data. M. Shao, J. Yin, and H. Ji wrote the manuscript.

Declaration of Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.actpsy.2019.102948.

References

Ames, D. L., & Fiske, S. T. (2013). Intentional harms are worse, even when they're not. *Psychological Science, 24*(9), 1755–1762.
Ames, D. L., & Fiske, S. T. (2015). Perceived intent motivates people to magnify observed harms. *Proceedings of the National Academy of Sciences of the United States of America, 112*(12), 3599–3605.
Apperly, I. A., & Butterfill, S. A. (2009). Do humans have two systems to track beliefs and belief-like states? *Psychological Review, 116*(4), 953–970.
Apperly, I. A., Riggs, K. J., Simpson, A., Chiavarino, C., & Samson, D. (2006). Is belief reasoning automatic? *Psychological Science, 17*(10), 841–844.
Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of other in the self scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology, 63*(4), 596–612.
Baker, C. L., Goodman, N. D., & Tenenbaum, J. B. (2008). Theory-based social goal inference. *Proceedings of the Thirtieth Annual Conference of the Cognitive Science Society,* 1447–1452.
Bar-Anan, Y., Liberman, N., Trope, Y., & Algom, D. (2007). Automatic processing of psychological distance: Evidence from a Stroop task. *Journal of Experimental Psychology: General, 136*(4), 610–622.
Bogardus, E. S. (1933). A social distance scale. *Sociology & Social Research, 17*, 265–271.
Boguñá, M., Pastor-Satorras, R., Díaz-Guilera, A., & Arenas, A. (2004). Models of social networks based on social distance attachment. *Physical Review E, 70*(5), 56122.
Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision, 10*(4), 433–436.
Brinkerhoff, D. B., Ortega, S. T., & Weitz, R. (2013). *Essentials of sociology.* Cengage Learning.
Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd edn.). Hillsdale, NJ: Lawrence Earlbaum Associates.
Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*(3), 201–215.
Coren, S., & Girgus, J. S. (1980). Principles of perceptual organization and spatial distortion: The gestalt illusions. *Journal of Experimental Psychology: Human Perception and Performance, 6*(3), 404–412.
Cumming, G. (2014). The new statistics: Why and how. *Psychological Science, 25*(1), 7–29.
Cushman, F. (2015). Deconstructing intent to reconstruct morality. *Current Opinion in Psychology, 6*, 97–103.
Dennett, D. C. (1989). *The intentional stance.* MIT press.
Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*(4), 1149–1160.
Feldman, J. (2003). What is a visual object? *Trends in Cognitive Sciences, 7*(6), 252–256.
Foley, J. M. (1980). Binocular distance perception. *Psychological Review, 87*(5), 411–434.
Gergely, G., & Csibra, G. (2003). Teleological reasoning in infancy: The naïve theory of rational action. *Trends in Cognitive Sciences, 7*(7), 287–292.
Hall, E. T. (1966). *The hidden dimension.* New York, NY: Doubleday.
Hinde, R. A. (1976). Interactions, relationships and social structure. *Man,* 1–17.
Isik, L., Koldewyn, K., Beeler, D. L., & Kanwisher, N. (2017). Perceiving social interactions in the posterior superior temporal sulcus. *Proceedings of the National Academy of Sciences of the United States of America, 114*(43), E9145–E9152.
Jara-Ettinger, J., Gweon, H., Schulz, L. E., & Tenenbaum, J. B. (2016). The naïve utility calculus: Computational principles underlying commonsense psychology. *Trends in Cognitive Sciences, 20*(8), 589–604.
Jones, B., & Rachlin, H. (2006). Social discounting. *Psychological Science, 17*(4), 283–286.
Kidwell, I. J., & Booth, A. (1977). Social distance and intergenerational relations. *The Gerontologist, 17*, 412–420.
Knoblich, G., & Sebanz, N. (2008). Evolving intentions for social interaction: From entrainment to joint action. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 363*(1499), 2021–2031.
Krackhardt, D., & Kilduff, M. (1999). Whether close or far: Social distance effects on perceived balance in friendship networks. *Journal of Personality and Social Psychology, 76*(5), 770–782.
Liberman, N., & Trope, Y. (2008). The psychology of transcending the here and now. *Science, 322*(5905), 1201–1205.
Liverence, B. M., & Scholl, B. J. (2011). Selective attention warps spatial representation: Parallel but opposing effects on attended versus inhibited objects. *Psychological Science, 22*(12), 1600–1608.
Loomis, J. M., Da Silva, J. A., Philbeck, J. W., & Fukusima, S. S. (1996). Visual perception of location and distance. *Current Directions in Psychological Science, 5*(3), 72–77.
Maglio, S. J., Trope, Y., & Liberman, N. (2013). Distance from a distance: Psychological distance reduces sensitivity to any further psychological distance. *Journal of Experimental Psychology: General, 142*(3), 644–657.
Malle, B. F. (2004). *How the mind explains behavior: Folk explanations, meaning, and social interaction.* MIT Press.
Matthews, J. L., & Matlock, T. (2011). Understanding the link between spatial distance and social distance. *Social Psychology, 42*(3), 185–192.
Parkinson, C., Liu, S., & Wheatley, T. (2014). A common cortical metric for spatial, temporal, and social distance. *Journal of Neuroscience, 34*(5), 1979–1987.
Proffitt, D. R. (2006). Distance perception. *Current Directions in Psychological Science, 15*(3), 131–135.
Rummel, R. J. (1975). *The dynamic psychological field. Understanding conflict and war, Vol. 1*. Thousand Oaks, CA: Sage.
Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., & Bodley Scott, S. E. (2010). Seeing it their way: Evidence for rapid and involuntary computation of what other people see. *Journal of Experimental Psychology: Human Perception and Performance, 36*(5), 1255–1266.
Santiesteban, I., Catmur, C., Hopkins, S. C., Bird, G., & Heyes, C. (2014). Avatars and arrows: Implicit mentalizing or domain-general processing? *Journal of Experimental Psychology: Human Perception and Performance, 40*(3), 929–937.
Schneider, D., Bayliss, A. P., Becker, S. I., & Dux, P. E. (2012). Eye movements reveal sustained implicit processing of others' mental states. *Journal of Experimental Psychology: General, 141*(3), 433–438.
Shen, M., Yin, J., Ding, X., Shui, R., & Zhou, J. (2016). Deployment of attention on handshakes. *Frontiers in Psychology, 7*, 681.
Sorokowska, A., Sorokowski, P., Hilpert, P., Cantarero, K., Frackowiak, T., Ahmadi, K., et al. (2017). Preferred interpersonal distances: A global comparison. *Journal of Cross-Cultural Psychology, 48*(4), 577–592.
Stahl, A. E., & Feigenson, L. (2014). Social knowledge facilitates chunking in infancy. *Child Development, 85*(4), 1477–1490.
Sundstrom, E., & Altman, I. (1976). Interpersonal relationships and personal space: Research review and theoretical model. *Human Ecology, 4*(1), 47–67.
Tatone, D., Hernik, M., & Csibra, G. (2014). Socially meaningful outcomes influence infants' goal attribution. *Talk Presented at the XIX Biennial International Conference on Infant Studies*.
Thomas, L. E., Davoli, C. C., & Brockmole, J. R. (2014). Competitive interaction leads to perceptual distancing between actors. *Journal of Experimental Psychology: Human Perception and Performance, 40*(6), 2112–2116.
Todd, J. T. (2004). The visual perception of 3D shape. *Trends in Cognitive Sciences, 8*(3), 115–121.
Trope, Y., & Liberman, N. (2010). Construal-level theory of psychological distance. *Psychological Review, 117*(2), 440–463.
Tudusciuc, O., & Nieder, A. (2010). Comparison of length judgments and the Müller-Lyer illusion in monkeys and humans. *Experimental Brain Research, 207*, 221–231.
Ullman, T., Baker, C., Macindoe, O., Evans, O., Goodman, N., & Tenenbaum, J. B. (2009). Help or hinder: Bayesian models of social goal inference. *Advances in Neural Information Processing Systems,* 1874–1882.
Vekaria, K. M., Brethel-Haurwitz, K. M., Cardinale, E. M., Stoycos, S. A., & Marsh, A. A. (2017). Social discounting and distance perceptions in costly altruism. *Nature Human Behaviour, 1*(5), 100.
Vestner, T., Tipper, S. P., Hartley, T., Over, H., & Rueschemeyer, S. A. (2019). Bound together: Social binding leads to faster processing, spatial distortion, and enhanced memory of interacting partners. *Journal of Experimental Psychology: General, 148*(7) 1751–1268.
Vickery, T. J., & Chun, M. M. (2010). Object-based warping: An illusory distortion of space within objects. *Psychological Science, 21*(12), 1759–1764.
Vickery, T. J., & Jiang, Y. V. (2009). Associative grouping: Perceptual grouping of shapes by association. *Attention, Perception, & Psychophysics, 71*(4), 896–909.
Wakslak, C., & Trope, Y. (2009). The effect of construal level on subjective probability estimates. *Psychological Science, 20*(1), 52–58.
Wu, X., Hua, R., Yang, Z., & Yin, J. (2018). The influence of intention and outcome on evaluations of social interaction. *Acta Psychologica, 182*, 75–81.
Yamakawa, Y., Kanai, R., Matsumura, M., & Naito, E. (2009). Social distance evaluation in human parietal cortex. *PloS One, 4*(2), e4360.
Yin, J., Xu, H., Duan, J., & Shen, M. (2018). Object-based attention on social units: Visual selection of hands performing a social interaction. *Psychological Science, 29*(7), 1040–1048.