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The Wolfpack Effect: Perception of Animacy Irresistibly Influences Interactive Behavior

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Abstract

Imagine a pack of predators stalking their prey. The predators may not always move directly toward their target (e.g., when circling around it), but they may be consistently *facing* toward it. The human visual system appears to be extremely sensitive to such situations, even in displays involving simple shapes. We demonstrate this by introducing the *wolfpack effect*, which is found when several randomly moving, oriented shapes (darts, or discs with "eyes") consistently point toward a moving disc. Despite the randomness of the shapes' movement, they seem to interact with the disc—as if they are collectively pursuing it. This impairs performance in interactive tasks (including detection of actual pursuit), and observers selectively avoid such shapes when moving a disc through the display themselves. These and other results reveal that the wolfpack effect is a novel "social" cue to perceived animacy. And, whereas previous work has focused on the causes of perceived animacy, these results demonstrate its effects, showing how it irresistibly and implicitly shapes visual performance and interactive behavior.

Keywords

event perception, social perception, perception of animacy, intention, agency, goal-directed behavior, chasing

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Imagine a pack of predators stalking their prey. Such events appear to be richly animate, but why? An obvious cue is objective pursuit: The predators continually move toward their target. But not always: In some circumstances (e.g., when chasing a larger animal), they may have to circle around their prey, in which case they may frequently be moving orthogonally to it (or even temporarily retreating), but still facing it. In other words, there may sometimes be a dissociation between the direction in which a predator is *facing* and the direction in which it is *moving*. Inspired by such natural phenomena, we predicted that the coordinated orientations of a group of moving shapes would yield a percept of animacy when the shapes continually pointed toward a single target shape—even if their actual motions were random.

Perceiving Animacy

People typically think of visual perception in terms of properties such as color, shape, and motion. In addition, however, visual percepts can involve seemingly higher-level properties such as animacy, as when simple moving shapes irresistibly appear to engage in intentional and goal-directed movements (Dasser, Ulbaek, & Premack, 1989; Heider & Simmel, 1944; Michotte, 1950/1991). As a phenomenon at the intersection of vision science and social cognition, the perception of animacy has attracted the interest of cognitive psychologists and vision researchers (e.g., Blythe, Todd, & Miller, 1999; Gao, Newman, & Scholl, 2009; Tremoulet & Feldman, 2000), social and developmental psychologists (e.g., Gergely, Nádasdy, Csibra, & Bíró, 1995; Klin, 2000; Mar & Macrae, 2006; Wheatley, Milleville, & Martin, 2007), cognitive neuroscientists and neuropsychologists (e.g., Blackemore et al., 2003; Heberlein & Adolphs, 2004; Schultz, Friston, O'Doherty, Wolpert, & Frith, 2005), anthropologists (e.g., Barrett, Todd, Miller, & Blythe, 2005), and computer scientists (e.g., Crick & Scassellati, 2008; Gaur & Scassellati, 2006).[1]

Previous work in these domains has typically treated the perception of animacy as a potential end state of visual processing, and has correspondingly focused on the cues that reliably give rise to such percepts—for example, self-propulsion (Dasser et al., 1989) and apparent violations of Newtonian physical principles (Gelman, Durgin, & Kaufman, 1995; Tremoulet & Feldman,

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2000). This strategy implicitly treats the perception of animacy as a sort of epiphenomenon, such that there has been a considerable amount of research into the causes of perceived animacy, but very little research on the systematic effects of such processing on downstream perception and action.

The Wolfpack Effect

Here we demonstrate that perception of animacy influences not only the character of conscious visual experience, but also implicit interactive behavior. In the displays used in our experiments, several oriented shapes (darts, or discs with "eyes") consistently pointed toward a moving disc. The shapes moved randomly, but seemed to interact with the disc—as if they were collectively pursuing it. This type of display—which we call the *wolfpack* configuration—is intrinsically dynamic, but a static frame from such a display is depicted in Figure 1a.[2]

We show here that the wolfpack configuration dramatically influences several types of visual performance and interactive behavior—for example, impairing the ability to detect actual pursuit in dynamic displays, and leading observers to selectively avoid such shapes when moving a disc through the display themselves. All such effects disappeared, however, when the oriented shapes were simply rotated by 90°—a control that eliminated the perception of animacy while retaining all other motion characteristics. These effects reveal a novel type of cue to perceived animacy and demonstrate its effects, showing how it can irresistibly and implicitly shape visual performance and interactive behavior.

Experiment 1: The Wolfpack Trumps Other Cues to Animacy

We first demonstrated the power of the wolfpack effect by showing that it can trump the perception of actual pursuit, which is one of the most salient types of perceived animacy (Dittrich & Lea, 1994; Gao et al., 2009). Participants attempted to detect whether one object in a display was chasing another object. The local orientations of the shapes were irrelevant to this task, but we predicted that they would nevertheless influence performance. In particular, we predicted that the wolfpack effect would impair the detection of actual pursuit, by introducing misleading interpretations about how the shapes' movements mapped onto their "intentions."

Method

Participants. Twelve Yale University undergraduates participated in individual 45-min sessions in exchange for course credit.

Design and procedure. The displays were presented via custom software written with MATLAB using the Psychophysics Toolbox libraries (Brainard, 1997; Pelli, 1997). Observers sat without head restraint approximately 50 cm from the monitor. The visible black background subtended 16° × 16°. Each display contained one green outlined square (0.8°) and six white shapes (one sheep, one wolf, and four distractors, whose shapes varied across trials as described later in this section; see Fig. 1a). On each trial, however, one shape (either a distractor or the sheep) was not visible. At the beginning of each trial, each shape was assigned a random location and began moving at a constant speed (9.6°/s). The sheep and each distractor moved haphazardly: They initially moved in random directions, and each shape randomly changed its direction within a 90° window (centered on its current heading) roughly every 333 ms.

The wolf did not move haphazardly: On each frame of motion, it moved in the direction of the (moving) sheep—a form of objective pursuit (Nahin, 2007). This pursuit was not perfectly heat seeking: Instead, the displacement of the wolf

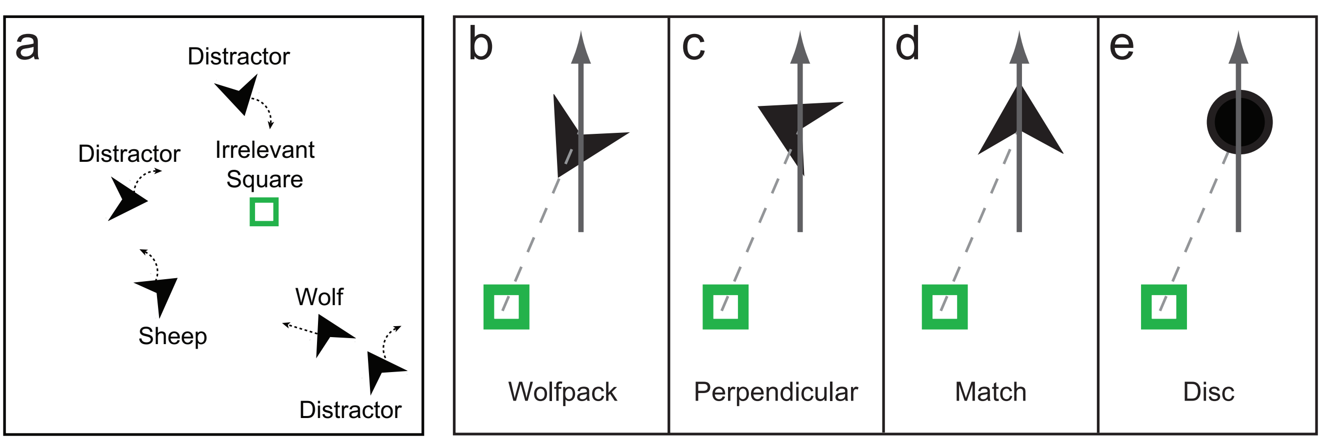

Fig. 1. Sample display (a) and manipulations (b–e) from Experiment 1. The task was to detect whether one shape (the wolf) was chasing another (the sheep). Arrows indicate motion and were not present in the displays. In the wolfpack condition (a, b), all darts stayed oriented toward the task-irrelevant green square, regardless of their motion directions. This condition generated the wolfpack effect. In the perpendicular condition (c), each dart was always oriented orthogonally to the square. In the match condition (d), each dart was always oriented in the direction in which it was moving at that moment. And in the disc condition (e), the objects had no visible orientation.

on each frame was in a randomly chosen direction within a 60° window centered on the current location of the sheep. Thus, the average deviation between the wolf's heading and the sheep's location on any frame was 15°. On *chasing-present* trials, both the wolf and the sheep were visible (and a distractor was invisible). On *chasing-absent* trials, the sheep was not visible, and all distractors were visible. Because the wolf's motions were always generated by the same algorithm, these two trial types could be discriminated only by noticing the wolf-sheep interaction. The wolf-sheep distance always exceeded 5° throughout each animation.

In three of the four primary conditions, the white shapes were drawn as oriented darts, whose "nose" and right and left "wings" were located on the perimeter of an invisible 1.9°-diameter disc (see Fig. 1a). The angle between each wing and the nose was 120°. In the *wolfpack* condition (Fig. 1b; Animations 2.1 and 2.2 online), each dart was always oriented with its nose toward the green square throughout the motion. In the *perpendicular* condition (Fig. 1c; Animations 2.3 and 2.4 online), each dart was always oriented with its nose rotated 90° clockwise from the green square. In the *match* condition (Fig. 1d; Animations 2.5 and 2.6 online), each dart was always oriented with its nose facing the direction in which it was currently moving (relative to the previous frame). Finally, in the *disc* condition (Fig. 1e; Animations 2.7 and 2.8 online), each shape was drawn as a 1.1° disc. Note that the orientation of each dart was correlated with the movement of the green square to exactly the same degree in the wolfpack and perpendicular conditions.

The animation on each trial lasted 10 s, after which participants pressed one of two keys to indicate whether or not a chase had been present on that trial. Chasing was explicitly defined in terms of one shape being consistently displaced over time in the direction of another shape, and participants were explicitly informed that (a) the green square could never be the wolf or the sheep, and (b) the shapes' orientations were always task irrelevant and could (and should) be ignored. Participants completed 96 randomly ordered trials, including 12 chase-present trials and 12 chase-absent trials for each of the four conditions.

Results and discussion

The wolfpack effect impaired detection of chasing: Performance was significantly worse on wolfpack trials (62%, *SD* = 7.8%) than on perpendicular (72%, *SD* = 9.0%), match (75%, *SD* = 9.1%), or disc (72%, *SD* = 9.4%) trials, and nearly all observers showed this pattern (for statistical tests, see Table 1). Thus, the wolfpack effect is strong enough to trump actual chasing—impairing observers' ability to detect actual pursuit, even when orientation is not task relevant.

Experiment 2: Don't Get Caught

To demonstrate that the wolfpack effect influences interactive behavior, we moved from a third-person display (in which participants observed one object chase another) to a first-person display, in which participants directly controlled the motion of the sheep to avoid a wolf that was chasing *them* (Fig. 2a). In the Don't Get Caught task, we again contrasted wolfpack and perpendicular conditions, predicting that the wolfpack effect would impair participants' ability to "escape" from the wolf.

Method

This experiment was identical to Experiment 1 except as noted here. Eight Zhejiang University undergraduates participated in exchange for a monetary payment. The wolf was one of seven white discs (0.8°) in the display, and the user-controlled sheep was a green disc (0.6°). Participants' task was to use a computer mouse to move the sheep about the display, attempting to avoid coming into contact with the wolf (which they first had to detect). Trials ended either when the wolf-sheep distance became less than 2° (caught!) or after 10 s (escape!). There were also seven white darts (1.2°) in the display. Participants were explicitly instructed that the wolf could never be a dart, and that the darts were irrelevant to the task. All darts and all but one of the discs (the wolf) moved haphazardly; the wolf pursued the user-controlled sheep as in Experiment 1. Across trials, the darts were oriented to face either directly toward the user-controlled sheep (*wolfpack* trials; Animations 3.1 and 3.2 online) or orthogonally to it (*perpendicular* trials; Animations 3.3 and 3.4 online). The maximum speed of the user-controlled sheep was always 1.5 times the speed of the wolf and all other items.[3] Participants completed 48 randomly ordered trials, 24 for each condition.

Results and discussion

The wolfpack effect impaired participants' ability to detect and evade the real wolf: They escaped on fewer wolfpack

Table 1. Results of Paired *t* Tests From Experiment 1

Condition	Comparison condition: Perpendicular	Match	Disc
Wolfpack	$t(11) = 2.383, p = .036$	$t(11) = 3.083, p = .010$	$t(11) = 2.767, p = .018$
Perpendicular		$t(11) = 0.655, p = .526$	$t(11) = 0.147, p = .886$
Match			$t(11) = 0.627, p = .544$

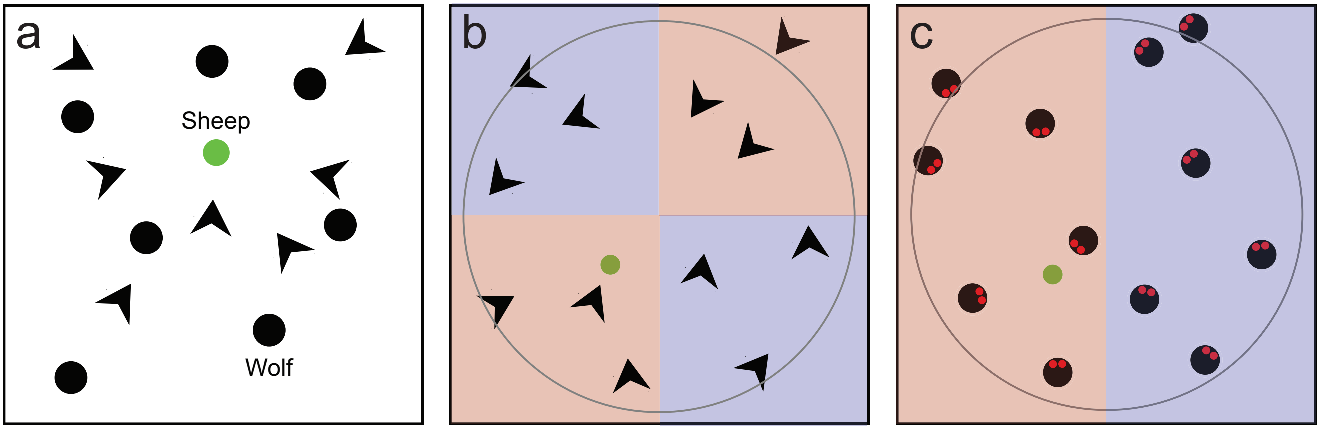

Fig. 2. Sample displays from the Don't Get Caught task (Experiment 2) and Leave Me Alone task (Experiments 3a and 3b). In the interactive Don't Get Caught task (a), participants used a computer mouse to control the movement of the green disk (the sheep), attempting to avoid being touched by the wolf—a disc that consistently moved toward the sheep. All other discs and darts moved randomly and were task irrelevant. In the wolfpack condition (depicted here), each dart was always oriented toward the user-controlled green disc. In the interactive Leave Me Alone task used in Experiment 3a (b), each quadrant contained three darts. In wolfpack quadrants (marked in light red here, but not in the actual displays), each dart was always oriented toward the user-controlled green disc. In perpendicular quadrants (marked in light blue here), each dart was always oriented orthogonally to the user-controlled disc. Participants moved a green disc about the display, attempting to avoid contact with any of the darts. In Experiment 3b (c), orientation was depicted not by a sharp contour (as with darts), but by the placement of two small circles (which appeared to be eyes).

trials (46.2%, SD = 3.9%) than perpendicular trials (54.4%, SD = 3.9%), $t(7) = 3.03$, $p = .019$ (all tests reported are two-tailed), and this pattern held true for all participants individually. These results indicate the power of the wolfpack effect during interactive behavior when all of the darts themselves (not only their orientations) were task irrelevant and should have been ignored.

Experiment 3a: Leave Me Alone (Darts)

Our phenomenology when viewing such animations suggested that the wolfpack effect was not only salient, but also *aversive*—perhaps similar to the sensation of being in a crowd of people all staring at you. To explore this experimentally, we developed a novel interactive Leave Me Alone task: Participants simply moved a disc about a display filled with other randomly moving objects and attempted to avoid contacting any of them. In this experiment, we were not interested in participants' objective performance, however; rather, we measured *where* participants moved—and whether they preferentially avoided wolfpack regions of the display.

Method

This experiment was identical to Experiment 2 except as noted here. Ten new undergraduates participated. Participants controlled a green disc that was initially located in the center of a 23.5° circular display. They moved the disc about the display with the mouse, with no speed limit, and their task was simply to avoid contact with all of 12 darts throughout each 17-s animation. Each quadrant of the display contained three 1.6° darts that moved haphazardly (as in the previous experiments) at a constant speed of 7.8°/s within their quadrant, but could not move to a different quadrant. The 3 darts in a quadrant were always oriented relative to the user-controlled disc, either facing it directly (in *wolfpack* quadrants) or oriented orthogonally to it (in *perpendicular* quadrants). Thus, all the darts in each quadrant had equivalent degrees of rotational motion that were equally correlated to the behavior of the sheep. Each trial included two randomly placed quadrants of each type (Fig. 2b; Animation 4.1 online). Participants completed 20 trials.

Results and discussion

In response to postexperimental debriefing questions, no observer reported having suspected that the time spent in each quadrant was being measured. Nevertheless, observers spent less time (7.99 s, SD = 0.39) in wolfpack quadrants (and more time in perpendicular quadrants; 9.01 s) than would be predicted by chance (8.5 s), $t(9) = 4.18$, $p = .002$—and this pattern held true for all participants individually. This avoidance is particularly striking given that orientation was uncorrelated with the darts' motions. On the basis of the phenomenology of the displays, we suggest that the avoidance may have been due to the fact that observers felt that darts in the wolfpack quadrants were actively pursuing them, even though the darts were in fact moving randomly.

Experiment 3b: Leave Me Alone (Eyes)

To show that the avoidance effect did not depend on the sharp angle of the darts, we replicated the Leave Me Alone results with displays in which orientation was depicted by the placement of two small dots (which appeared to be eyes) on otherwise orientationless discs (Fig. 2c; Animation 4.2 online).

Method

This experiment was identical to Experiment 3a except as noted here. Seven Yale University undergraduates participated. Each dart was replaced by a 1.9° white disc with two smaller (0.38°) red discs—"eyes"—drawn on one side (Fig. 2c). Measured from their centers, the red discs were always separated from each other by 0.48° and from the white disc's center by 0.71°. In *wolfpack* quadrants, the placement of the two red discs was updated throughout each animation so that the line connecting them was always orthogonal to the direction of the user-controlled disc (on the nearer side of the white disc, as if they were eyes looking at the user-controlled disc). In *perpendicular* quadrants, the red discs' positions were updated so that the line connecting them was parallel with the direction of the user-controlled disc (as if they were eyes looking 90° away from the user-controlled disc).

Results and discussion

Observers again spent less time (7.97 s, SD = 0.26) in wolfpack quadrants (and more time in perpendicular quadrants; 9.03 s) than would be predicted by chance (8.5 s), $t(6) = 5.291$, $p = .002$, and this pattern held true for all participants individually. This replication is consistent with the idea that the wolfpack effect is a *social* cue and not just a physical cue, as the placement of the two eye dots was otherwise arbitrary.

Experiment 3c: Leave Me Alone (Sudden Onsets)

To determine whether the Leave Me Alone results were due to the objects in the wolfpack quadrants capturing attention, we replicated Experiment 3b with featureless discs. Discs in two quadrants were constantly flashing off and on, a cue that is especially powerful at capturing attention (Yantis, 1993; Yantis & Jonides, 1984; cf. Cosman & Vecera, 2009), and discs in the other two quadrants always remained visible (Animation 4.3 online).

Method

This experiment was identical to Experiment 3b except as noted here. Fourteen new undergraduates participated. Each white shape was simply a 1.9° white disc (i.e., there were no cues to indicate the presence of eyes). In two *flashing* quadrants, each disc had a 10% chance of suddenly disappearing on each frame (successive disappearances were separated by at least 500 ms). Each disappearance lasted 83.3 ms, after which the disc immediately reappeared. The discs' positions continued to be updated during the disappearances. In the two *nonflashing* quadrants, the discs never disappeared.

Results and discussion

Observers spent no more time in the nonflashing quadrants (8.58 s, SD = 0.47) than would be predicted by chance (8.5 s), $t(13) = 0.67$, $p = 0.51$. This finding suggests that the avoidance of wolfpack quadrants in the previous experiments was not due to attentional capture.

Experiment 3d: Leave Me Alone (Attentional-Direction and Grouping Control)

Rather than capturing attention, could the wolfpack objects simply have been directing attention, leading participants to spend more time in the opposite (and frequently nonwolfpack) quadrants? To find out, we dissociated the consistent target of the wolfpack from the position of the user-controlled sheep.

Method

This experiment was identical to Experiment 3a except as noted here. Nine new undergraduates participated. On each trial, one quadrant was randomly selected as the *target* quadrant, whose center was the target of the darts in two wolfpack quadrants, which were always both adjacent to the target quadrant. Darts in both of the nonwolfpack quadrants (including the target quadrant) were always oriented perpendicular to the center of the target quadrant.

Results and discussion

Observers spent no less time in wolfpack quadrants (8.63 s, SD = 0.55) than would predicted by chance (8.5 s), $t(8) = 0.708$, $p = 0.499$, and spent no more time in the target quadrant (3.98 s, SD = 0.76) than in the other nonwolfpack quadrant (4.39 s, SD = 0.59), $t(8) = 1.001$, $p = 0.356$—and in fact the latter numerical difference trended in the opposite direction. This suggests that the wolfpack effect in the Leave Me Alone task is truly a social effect and is not simply mediated by some new form of attentional direction or grouping by the wolfpack items.

Experiment 4: Varying the Social Significance of the Wolfpack

To show that the wolfpack makes a functional difference to interactive performance in such situations, in the final experiment we employed a hybrid of the Don't Get Caught and Leave Me Alone tasks: Participants again moved a disc about a dart-filled display, attempting not to contact any other darts. In addition, the display contained a second disc, which served as a real wolf (as in Experiment 2) that continually chased the participant-controlled disc about the display. This manipulation served two purposes. First, it forced the participant to

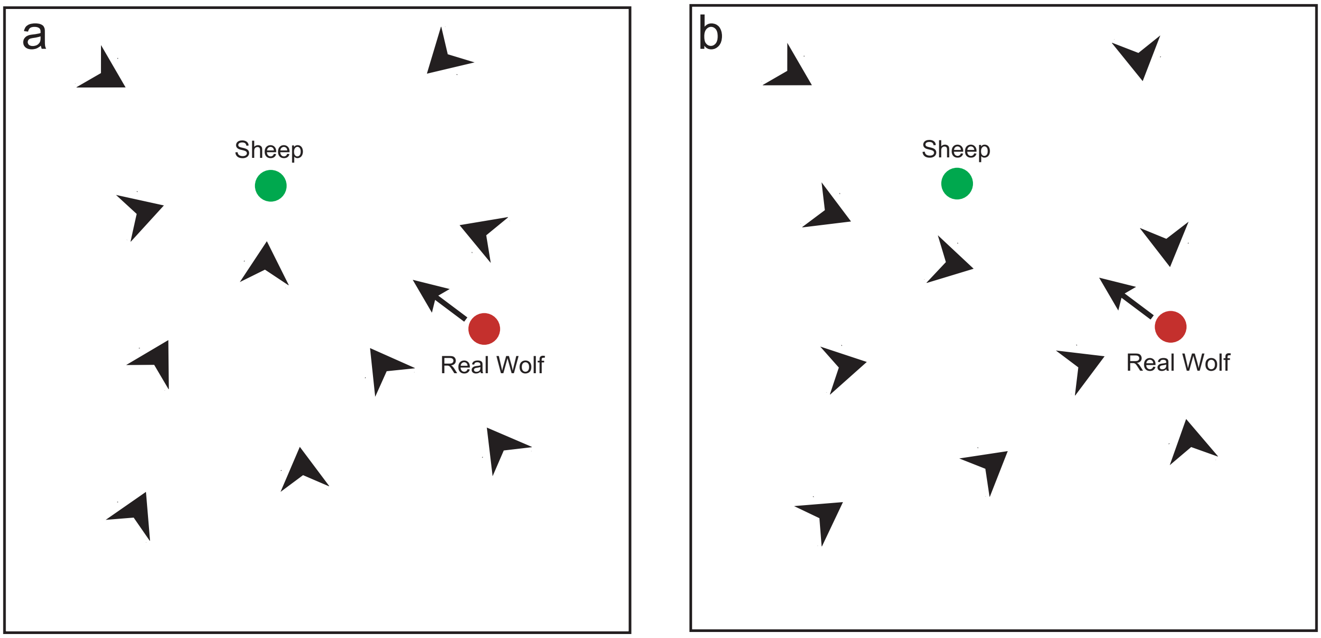

Fig. 3. Screenshots from the interactive displays used in the hybrid of the Don't Get Caught and Leave Me Alone tasks in Experiment 4. Participants had to use the mouse to move the green disc across the display in order to avoid touching the display border, the darts, or a red wolf disc. In dynamic wolfpack-to-sheep trials (a), each dart was always oriented toward the user-controlled green disc. In dynamic wolfpack-to-wolf trials (b), each dart was always oriented toward the red wolf disc.

keep moving constantly and allowed us to greatly amplify the magnitude of the wolfpack-induced impairment. Second, and more important, the wolf could also serve on some trials as the target of the wolfpack (with the darts all continually pointing to the wolf rather than to the participant-controlled disc). This manipulation (depicted in Figs. 3a and 3b) allowed us to essentially vary the social significance of the wolfpack while equating all visual factors.

Method

This experiment was identical to Experiment 3a except as noted here. Twelve new undergraduates participated. Each display contained 10 white darts (1.3° × 1.3°), a bright red 0.65° disc (the wolf), and a green 0.65° user-controlled disc (the sheep); all were initially randomly placed (without overlapping) within in a black square (18°) background. Participants had to freely move the user-controlled disc (with unlimited speed) for 8 s to avoid touching the display border, the darts, or the wolf disc. The darts again moved haphazardly, while the wolf disc always moved toward the user-controlled sheep, as in Experiment 2. Note that this task was unlike the initial Don't Get Caught task, in which the wolf was camouflaged by being drawn in the same color as the other items. In this experiment, the presence and identity of the wolf was always continually apparent (as can be seen online in Animations 5.1–5.3). Speeds were calculated as in Experiment 2 (except that the initial speed was 5.1°).

There were three types of trials. On *wolfpack-to-sheep* trials, the white darts were always oriented toward the user-controlled sheep (Fig. 3a; Animation 5.1 online). On *perpendicular-to-sheep* trials, the darts were always oriented orthogonally to the user-controlled sheep (Animation 5.2 online). On *wolfpack-to-wolf* trials, the white darts were always oriented toward the red wolf disc (Fig. 3b; Animation 5.3 online). Participants completed 90 trials in a randomized order (30 for each of the three conditions).

Results and discussion

Participants were significantly worse at this task—by more than 20%—when the darts were consistently oriented to face the user-controlled disc (the wolfpack-to-sheep condition; 55.3%, SD = 5.6%) than when they were oriented orthogonally to the disc (the perpendicular-to-sheep condition; 75.4%, SD = 4.3%), $F(1, 9) = 48.519$, $p < .001$, and this pattern held true for all participants individually. This effect may arise because the wolfpack effect irresistibly distracts participants from the actual wolf. It is striking that the wolfpack effect was strengthened in this experiment, given that the prevailing perceptual load was much higher than in the previous experiments.

This impairment was attenuated, however, when the wolfpack pointed at the wolf rather than at the user-controlled sheep. In fact, performance in the wolfpack-to-wolf condition (69.4%, SD = 5.6%) was both significantly better than performance in the wolfpack-to-sheep condition, $F(1, 9) = 20.857$, $p = .001$, and significantly worse than performance in the perpendicular-to-sheep condition, $F(1, 9) = 7.078$, $p = .026$.

This finding that the wolfpack's target makes a difference is another indication that the wolfpack effect is a type of social cue. In addition, it again demonstrates that the influence of the wolfpack effect cannot simply stem from any general sort of grouping or attention capture, as these factors were always equated in this experiment; rather, it seems to matter in such situations whether the wolfpack is facing *you* or a third party.

General Discussion

These studies introduce a new cue to perceived animacy—the wolfpack effect—that is based on the coordinated orientations of a group of moving objects. When asked informally to describe such displays (interactive versions of Animation 1.1 online) without any prompting, naive observers frequently invoked notions of animacy and chasing: for example, "Many white arrows were chasing after the green dot"; "The triangles . . . follow the green dot wherever it goes"; and "There were triangles trying to hit me." In contrast, when asked informally to describe perpendicular control displays that were otherwise identical (interactive versions of Animation 1.2 online), observers never invoked notions of pursuit, chasing, or intentionality—instead using descriptions such as "arrows that went in random directions," "chaotically floating white chevrons," and "a bunch of white snow flakes or jacks swirling tumultuously around my green circle."

The design of our experiments tapped the perception of animacy in wolfpack displays, isolating it from any more general influence of correlated motion by always contrasting wolfpack displays with perpendicular control displays. In addition, note that the wolfpack effect cannot be explained by appeal to any sort of prioritized attention, as was directly tested in the Leave Me Alone paradigm (Experiments 3c–3d). Nor can the wolfpack effect be explained by appeal to any form of perceptual grouping without invoking animacy. Perhaps the most salient demonstration of this was in the final, hybrid experiment (Experiment 4), in which the effect was more powerful when the wolfpack pointed at the observer-controlled disc than when the wolfpack pointed at the wolf. We explain this by noting that although these two displays had equivalent amounts of grouping (because in fact the wolfpack objects behaved identically in all trials), they differed in terms of their social content (because what varied was only whether the wolfpack's target was the observer or not).

The primary purpose of these studies, beyond establishing this new wolfpack cue, was to explore the downstream effects of this form of perceived animacy. Nearly all previous studies of the perception of animacy have focused on the features that trigger it (e.g., Bassili, 1976; Blythe et al., 1999; Dasser et al., 1989; Dittrich & Lea, 1994; Gao et al., 2009; Gelman et al., 1995; Michotte, 1950/1991; Santos, David, Bente, & Vogeley, 2008; Tremoulet & Feldman, 2000, 2006), on its neural bases (Blakemore et al., 2003; Castelli, Happé, Frith, & Frith, 2000; Schultz et al., 2005; Schultz, Imamizu, Kawato, & Frith, 2004; Wheatley et al., 2007), or on the degree to which animacy is robustly perceived by different populations (e.g., Abell, Happé, & Frith, 2000; Barrett et al., 2005; Heberlein & Adolphs, 2004; Klin, 2000; Rochat, Striano, & Morgan, 2004). In this way, the perception of animacy has previously been treated as a type of end result in visual processing, and no previous studies to our knowledge have ever explored whether or how the perception of animacy influences subsequent perception and action. This was the primary goal of the current study, which demonstrated several ways in which the perception of animacy influences interactive behavior.

Note that the particular novel cue to animacy that we employed in this project (i.e., the wolfpack effect) was never relevant to participants' overt tasks: The orientations of the objects were irrelevant for (a) determining whether actual pursuit was present (Experiment 1), (b) detecting the presence of a wolf (Experiment 2), (c) determining which quadrants of the display had more easily avoidable shapes (Experiments 3a and 3b), and (d) traveling efficiently through a flock of darts while avoiding a pursuing wolf (Experiment 4). Nevertheless, the wolfpack effect robustly influenced all of these behaviors. This is consistent with the possibility that such effects represent a form of reflexive, automatic perception (see Gao et al., 2009; Scholl & Tremoulet, 2000)—and one that has important implications for further perception and action.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Notes

1. Research in this domain is variously referred to in terms of the perception of animacy (e.g., Gelman, Durgin, & Kaufman, 1995; Tremoulet & Feldman, 2000), intentionality (e.g., Dasser et al., 1989; Dittrich & Lee, 1994), goal directedness (e.g., Csibra, 2008; Opfer, 2002), social causality (e.g., Rochat, Morgan, & Carpenter, 1997; Rochat, Striano, & Morgan, 2004), or social meaning (e.g., Tavares, Lawrence, & Barnard, 2008). Sometimes these distinctions are important, as when researchers wish to attribute one property but not another—for example, goal directedness without other aspects of mental-state reasoning (Gergely & Csibra, 2003)—but few of these categories have clear objective definitions. Throughout this article, we describe our studies in terms of the perception of animacy, which strikes us as perhaps the most general and theoretically neutral term.
2. Dynamic animations of all of the conditions reported here are available online at http://www.yale.edu/perception/wolfpack/. Readers are strongly encouraged to view the online demonstrations to appreciate the effect (Animations 1.1 and 1.2).
3. The shapes initially moved at 9.3°/s, but this speed was adjusted subject by subject on the basis of performance: If the average

percentage of successful escapes on each subsequent group of eight trials (always containing four of each condition) was greater than 75%, then the shapes' speeds (and the sheep's maximum speed) increased by 0.15°/s; if the percentage of escapes was less than 50%, the speed was decreased by 0.15°/s. Over the 8 participants, the average speed per trial was 9.43°/s (range: 8.73–9.9°/s).

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