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# Visual perception of intentional motion

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Winand H Ditttrich<sup>†</sup>, Stephen E G Lea

Department of Psychology, Washington Singer Laboratories, University of Exeter, Exeter  
EX4 4QG, UK

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**Abstract.** A series of experiments were performed to investigate how motion sequences provide information about the intentional structure of moving figures or actors. Observers had to detect simulations of biologically meaningful motion within a set of moving letters. In the first two experiments a factorial design was used, with type of instruction as a between-subject factor and six movement parameters (number of items, speed and directness of target and distractors, and 'relentlessness' of target movement) as within-subject factor; in the final two experiments, the visibility of the goal towards which the target moved and the use of a tracking movement to distinguish the target were varied. In such displays search time increases with increasing number of stimuli. It was found that (a) the more direct the motion, the more likely it was to be interpreted as intentional; (b) intentional motion was much easier to detect when the target moved faster than the distractors than when it moved more slowly; (c) recognition of intentionality was impaired but not abolished if the goal towards which the target was moving was invisible; and (d) participants did not report intentional movement when the target was distinguished by brightness rather than the manner in which it moved. We argue that the perception of intentionality is strongly related to observers' use of conceptual knowledge, which in turn is activated by particular combinations of features. This supports a process model, in which intentionality is seen as the result of a conceptual integration of objective visual features.

## 1 Introduction

The understanding of motion is important both for biological and for artificial perceptual systems. Most investigations have been concentrated on the perception of motions of biological systems, with an emphasis on movements resembling those of individual ambulating humans or animals (Johansson 1973, 1976). However, movement cues are also important for recognising patterns of interaction between individuals, since changes in movement are one of the main characteristic features during social interaction.

Consider first the question of body language. While the form of communicative patterns such as facial expressions probably cannot be changed very much, their time course is a major candidate for modification and variation. The interpretation of communicative expressions such as laughing is closely dependent on the perception and interpretation of the time course of the expression: the basic facial expressions (Ekman and Friesen 1976) can be recognised on the basis of movement cues alone (Bassili 1978, 1979; Ditttrich 1991). Interestingly, the highest recognition rates were found for the emotional expressions surprise and happiness, which show the most facial movements and have the richest variety of shade of expression.

Much less detailed movement information can also be interpreted in social terms. An early demonstration of this was performed by Heider and Simmel (1944), in a study which is usually interpreted as an example of attributional processes in perception. They showed observers a film in which simple geometrical figures, two triangles of different size and one disc, moved about an enclosure with a moveable flap in one side (a 'door'). All but one of their thirty-four subjects described these motions in

<sup>†</sup> Present address: Psychology Division, University of Hertfordshire, Hatfield, Herts AL10 9AB, UK

terms generally applied to social interactions of animate beings. With high consistency observers mentioned functional relationships between the figures like chasing or fighting. Subjects tended to ascribe particular genders and dispositions (motives or intentions) to the objects. The classic experiments of Michotte (1963) on the perception of causality provide another demonstration of the extraction of functional relationships between geometrical figures on the basis of their movement.

Apart from some work on the Michotte effects (eg Gordon et al 1990; Schlottman and Shanks 1992), there has been little research on our tendency to interpret movement in functional terms. In the only systematic study following up the work of Heider and Simmel (1944), a film with five different kinds of movements with a black and a white circle was used (Bassili 1976). The computer-generated movement patterns differed in the temporal and spatial characteristics with which the two circles moved in relation to each other. Bassili reported that temporal contingency between the changes in direction of the two figures was relevant for the impression of interaction between them, while the perception of intentionality attributed to the circles was influenced by spatial contingencies.

Unlike Bassili (1976), we argue that absolute motion kinematics (spatiotemporal trajectories) and relative ones (relations between trajectories) are both likely to be relevant for the interpretation of motion displays as intentional. We hypothesise that the perception of motion displays like those of Heider and Simmel or Johansson is a two-stage process. The immediate impression of intentionality (or causality) is given by a 'bottom-up' process of selecting specific motion features, and at a later stage these are visually encoded and conceptually integrated in such a way that intentional percepts are activated through a 'top-down' process. In the present experiments we mainly investigated whether the perception of intentionality can be manipulated by varying motion features alone, but we also varied the participants' instructions to see whether the integrative processes could be manipulated.

In the experiments to be reported, observers had to detect one distinctive element among an array of moving symbols. The aim in the investigation was to identify the conditions which are relevant for the perception of intentionality. The distinctive element was moved in a variety of ways, which we expected to give rise, to a variable extent, to an immediate impression of intentionality. We also tried to influence the interpretative process through the instructions the observers were given before the experiment. The displays were designed to simulate, loosely, a typical biological movement pattern, that of one animal seeking out another. This is a kind of motion which it would be adaptive for many, perhaps all, animals to perceive efficiently; the seeking animal might, for example, be a predator to be avoided, or a juvenile to be rescued. In our displays, a number of nontarget or distractor elements moved essentially at random, while a target element tended to move towards a chosen one of the other elements, though its movement, too, had random components.

The experiments were designed to investigate the questions about the perception of intention outlined above. However, since the task used involved spotting one disparate element in an array, it is also a novel kind of visual search task. We discuss this aspect of the experiments elsewhere (Ditttrich and Lea, *in press*).

## 2 Experiment 1

In the first experiment, the target element always moved faster than the distractors. This is what predators tend to do. In an attempt to see whether looking at the display as depicting some form of biological motion would influence the way it is perceived through a top-down process, some (but not all) of the subjects were given the description of the displays in which the target was called a wolf, and the distractors

were called sheep. The type of display used in this experiment is therefore referred to below as the 'wolf/sheep' condition.

## 2.1 Method

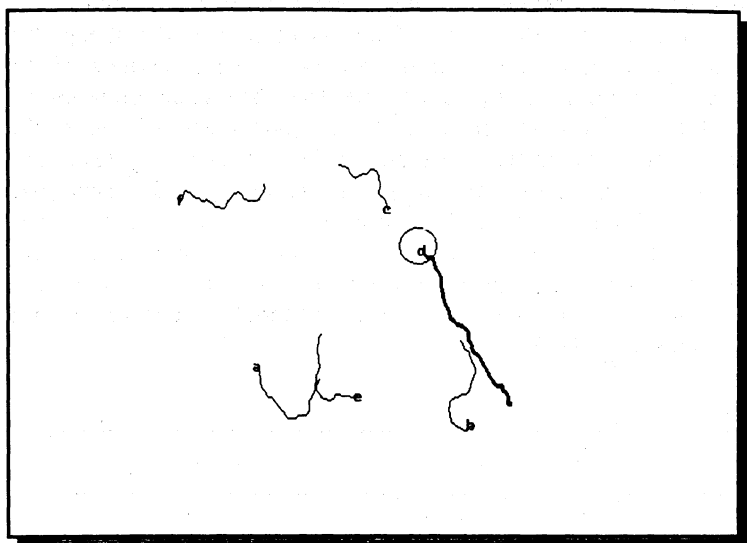
**2.1.1 Participants.** Ten Exeter University biology or psychology students volunteered to participate in the experiment. All had normal or corrected-to-normal vision, and none of them was familiar with the theoretical issues investigated or had previous experience in observing similar displays. Equal numbers were assigned, at random, to each of two experimental conditions.

**2.1.2 Apparatus.** The stimuli were presented within a 18 cm × 25 cm (height × width) rectangular region of the display screen (640 pixels × 480 pixels) on a Mitsubishi Video Monitor (EUM 1481, 14 inch) with a 60 Hz raster refresh rate, under the control of an IBM-AT-compatible personal computer (Panatek AT 204) with VGA graphics. The control program was written in Turbo Pascal 5.5. The participant viewed the display from a distance of 50 cm. The starting positions of the characters were randomly varied within a 12.5 cm × 9 cm region in the centre of the screen. The character and background brightness at the screen were approximately 5 cd m<sup>-2</sup> and 0.1 cd m<sup>-2</sup>, respectively. The computer keyboard was used as the response device, and the responses and response latencies were recorded by the computer.

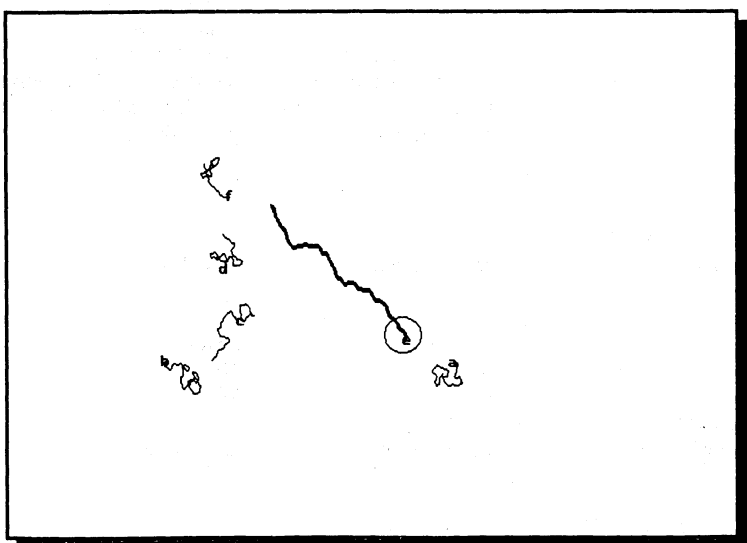
**2.1.3 Stimuli.** The stimuli consisted of arrays of moving letters. All letters were lowercase, drawn within 8 pixel × 8 pixel regions of the display screen by using the graphics mode of the computer. All but one of the letters were designated as non-target elements (distractors) or 'sheep' and these moved essentially at random. One letter was designated as the target of 'wolf', and moved so as to track a particular distractor. At the beginning of each trial, the letters were randomly distributed within the central quarter of the display area and one letter was randomly chosen as wolf. One letter in the opposite quadrant of the screen was randomly selected as the goal for the wolf's movement. The movements of the sheep and wolf were as follows. In each cycle, each sheep moved by a number of pixels that was randomly varied from 0 to a maximum. Its direction of movement was given by its direction of movement in the previous cycle plus a random element which was also determined from a rectangular distribution, from plus a maximum value to minus the same maximum. The wolf similarly moved by a random number of pixels, though, unlike the sheep, in some conditions it had a nonzero minimum step size. Its major difference from the sheep was in the direction of its movement, which was always towards the current position of its goal, though a random element ranging from plus some maximum to minus the same maximum was added to this direction. Figure 1 shows a snapshot of two of the displays, with the histories of each element traced on. These histories did not, of course, appear on the screen during the experiment.

The program moved each element of the display in turn. After moving each element, it paused for a brief period (calculated in a calibration test carried out at the beginning of each trial), to ensure that a complete cycle through all stimuli would take 62.5 ms. Thus in each condition all elements were moved sixteen times each second. All random selections were performed separately and independently, by using rectangular distributions.

**2.1.4 Experimental design.** The task was given under two conditions. In the neutral condition, the instructions to the participant referred only to moving letters, while in the story condition, the instructions referred to a wolf trying to stalk a sheep. Each participant experienced only one of these conditions, in a single session. We examined seven additional independent variables: the trial block (first half of the session versus second half), and six movement parameters. These were the number of moving



(a)



(b)

**Figure 1.** Stills of two displays of the kind used in experiment 1, with the histories of the elements since the beginning of the trial traced (these histories did not appear on the screen). In (a), letter d is the target or 'wolf'; its goal is letter e, while in (b) the wolf is letter e and its goal is letter a. In these displays the speed of the distractors was a maximum of 5 pixels cycle<sup>-1</sup>, and the target had a speed advantage of 2 pixels cycle<sup>-1</sup> and a relentlessness (minimum step) of 1 pixel cycle<sup>-1</sup>. In (a), the directness of distractor movement was set at a maximum of 45° deviation cycle<sup>-1</sup>, while the target had a maximum 90° deviation cycle<sup>-1</sup>; in (b) these parameter values were reversed. The displays used in the experiment were of slightly higher resolution than shown in this figure (480 pixels vertically rather than 350). The circles around the 'wolf' appeared when the observer detected it.

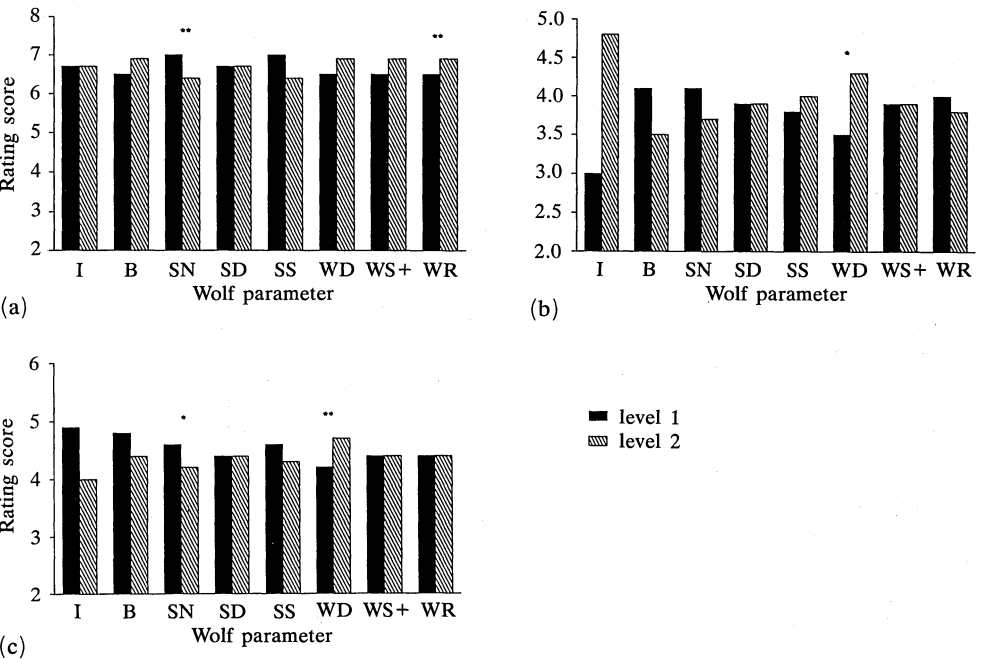
elements, the directness of the movement of the sheep (ie maximum change of direction for a sheep between cycles), the speed of the movement of the sheep (the maximum number of pixels they could move between cycles), the directness of the wolf's movement, its speed relative to the sheep (ie the difference between its maximum movement and that of the sheep), and the 'relentlessness' of the wolf's movement (the minimum number of pixels by which it moved between cycles). The levels used for each stimulus parameter are shown in table 1. Each participant experienced all sixty-four combinations of the six movement parameters within each trial block. The order in which they occurred was determined by random sampling without replacement, except that if the observer failed to spot the wolf before it collided with the sheep on any trial, the parameter combination concerned was replaced in the sampling pool up to twice.

**Table 1.** Levels of stimulus parameters.

Parameter	Level 1	Level 2
Instructions	neutral	story:
Experiment 1		about wolf
Experiment 2		about lamb
Experiment 3a		about wolf
Experiment 3b		about lamb
Experiment 4		about wolf
Trial block	start of session	end of session
Experiment 1, 2, 4	first half of session	second half of session
Experiment 3a, 3b	first third of session	last third of session
Number of distractors	fewer sheep	more sheep
Experiments 1, 2	6	12
Experiment 3	-	10
Experiment 4	5	10
Directness of distractor movement (maximum angle of turn)	more direct	less direct
All experiments	45°	90°
Speed of distractor movement (maximum pixels/cycle)	slower	faster
Experiments 1, 2, 4	5	10
Experiment 3	-	10
Directness of target movement (maximum angle of deviation)	more direct	less direct
All experiments	45°	90°
Target speed advantage (pixels/cycle more than distractor)		
Experiment 1, 3a	+1	+3
Experiment 2, 3b	-1	-3
Experiment 4	0	+3
Target relentlessness (minimum pixels/cycle)	less relentless	more relentless
All experiments	0	2
Visibility of goal		
Experiments 1, 2, 4	-	visible
Experiment 3	invisible	visible
Goal orientation of target movement		
Experiments 1, 2, 3	-	goal directed
Experiment 4	random	goal directed

**2.1.5 Procedure.** Participants were seated in front of the video monitor with their hands above or in direct contact with the computer console. At the beginning of the experiment, each was given either the ‘neutral’ or the ‘story’ instruction on the computer screen. They were told that on detecting the target letter they had to press the corresponding key on the keyboard. If they pressed the wrong key, nothing happened. After a correct response, a tone was sounded, the movement of the letters ceased, and a circle was drawn round the target letter. After one second, the screen was erased, and the message “Well spotted” appeared. The subject was then asked to make ratings [from 1 (not at all) to 9 (very strongly)] in answer to three questions: (1) ‘How much was the letter you spotted trying to do something?’ (2) ‘How much did the letter you spotted interact with any other letters?’ (3) ‘To what extent did the letter you spotted simulate an animate creature?’ The questioning process resulted in intertrial intervals of between 5 and 15 s. If the wolf came within 1 pixel of the goal without being spotted then the trial was terminated; a lower-pitched tone was sounded, circles were drawn round both letters, and after a pause of 1 s the screen was erased and the message “Sorry, you missed that one” was displayed, after which the next trial began.

Before the experiment proper, there were ten practice trials with the same instructions. A block of sixty-four experimental trials was then given, followed by a pause of 3 min and a second sixty-four-trial block. The number of errors (ie inappropriate keys pressed) within a trial, the search time (ie the time to identify the target correctly), and the latency (ie the time to the first response) were recorded, in addition to the ratings given in answer to the three questions. In this paper attention is focused on three ratings; for search times see Dittrich and Lea (in press).



**Figure 2.** Experiment 1: main effects of all factors on ratings of (a) purposefulness, (b) interaction, and (c) animateness under the ‘wolf’ condition. Parameters are coded as follows: I, instructions; B, block; SN, number of distractors; SD, directness of distractor movement; SS, speed of distractor movement; WD, directness of target movement; WS+, target speed positive advantage; WR, relentlessness of target motion. For parameter levels, see table 1. Asterisks above pair of columns indicate significant main effects as reported in table 2.

**2.1.6 Statistical procedure.** Only the data from trials with a correct response were used, except that for parameter combinations where the participants made three errors (and so had no further chance to make a correct response) the time taken for the wolf to catch the sheep on the last of the three trials was taken as a conservative estimate of trial duration, and ratings were treated as missing values. The data were examined by means of eight-way ANOVAs. Because of the large number of possible interactions, only main effects are presented in full here, although all interactions were extracted in the analyses, and significant interactions are mentioned where they alter the interpretation that would emerge from the main effects alone.

**2.2 Results and discussion**

Over all conditions, the target was not spotted even after three attempts in 8.2% of parameter combinations. These were of course concentrated in the most difficult conditions, but they were few enough not to have more than a minor influence on the main effects of the variables.

Figure 2 shows the mean values of each of the three rating measures at each value of the experimental parameters. *F*-values for significant main effects are included in table 2. The displays produced a strong impression of purposefulness, which was affected significantly by the number of distractors and the directness and relentlessness of the movement of the target. Conditions that made it more difficult to identify the goal for the target tended to produce lower purposefulness ratings. For example, there

**Table 2.** *F*-values for significant main effects of stimulus parameters on ratings of the target movement (degrees of freedom 1, 8 for experiments 1, 2, and 4, and 1, 6 for experiments 3a and 3b).

Parameter	<i>F</i>		
	purposefulness	interaction	animateness
Instructions	not significant in any experiment		
Trial block	not significant in any experiment		
Number of distractors			
Experiment 1	19.45**		6.18*
Experiment 2	21.87***		13.80**
Experiment 4	9.10*		
Directness of distractor movement			
Experiment 2	15.17**	16.89**	16.01**
Speed of distractor movement			
Experiment 2		8.97*	
Directness of target movement			
Experiment 1		10.25*	19.23**
Experiment 2		39.18***	
Experiment 3a	31.08***		9.36**
Experiment 3b		29.56***	
Experiment 4		16.98**	
Target speed advantage			
Experiment 3a	5.27*		
Target relentlessness			
Experiment 1	15.79***		
Experiment 3a	45.12***		32.75***
Experiment 4	7.11*		
Visibility of goal			
Experiment 3a	16.79**	9.35**	10.60**
Experiment 3b	6.99*	5.96*	6.95*
Goal orientation of target movement			
Experiment 4	25.31***	28.87***	13.79**

Note: \* *p* < 0.05; \*\* *p* < 0.01; \*\*\* *p* < 0.001.

was a significant interaction between number of distractors and their speed, with the lowest purposefulness ratings on trials with a large number of fast-moving distractors.

Ratings of interaction were somewhat lower though still substantial. They were less affected by the stimulus parameters than were purposefulness ratings. Only relentlessness of the target had a significant main effect, though there were a number of significant interactions. The impression of interaction was strongest with fast-moving elements whose direction of motion was variable.

Table 2 shows that significant main effects on ratings of animateness tended to occur for the same parameters as for ratings of purposefulness. However, comparison of the three panels of figure 2 suggests a more complex picture: the largest effects on animateness occurred for those variables where effects on purposefulness and interaction went in the same direction.

Instructions had no significant effect on any of the rating measures. This is surprising given that, in most accounts of the perception of intentionality, context or foreknowledge of the situation is seen as the most important factor (cf Bruce and Green 1985). The experimental design was, of course, less powerful as a test of the between-subjects instructions factor than for the movement parameters, which were varied within subjects, and the substantial but nonsignificant effect of instructions on ratings of interaction illustrates this. But all three ratings were high even with the neutral instructions, showing that the participants provided their own interpretations (or were prompted to do so by the questions) even when we did not.

None of the dependent variables showed a significant effect of trial block, although search time and latency did decrease slightly from the first to the second block of trials. This result suggests that the results are not affected by practice to any great extent. The experimenters' own experience shows that after really extensive practice, sharply reduced search times can be achieved, but the effects of motion parameters persist.

### 3 Experiment 2

The second experiment differed from the first in one respect only: the target element, instead of moving faster than the distractor elements, moved more slowly. So the interpretative instructions given to participants in the story condition, instead of suggesting a dangerous predator stalking a sheep, suggested a frail, lost lamb trying to find and keep up with its mother.

#### 3.1 Method

Except for the differences described below, the method was the same as in experiment 1.

3.1.1 *Participants.* Ten further volunteers were drawn from the same population as used in experiment 1, and were divided into two groups as before.

3.1.2 *Stimuli and experimental design.* The stimuli and the stimulus parameters were the same as those listed in table 1, except that the speed advantage of the target was now negative. Its values were  $-1$  and  $-3$ . Note that the target 'lamb' could still have a positive relentlessness or minimum distance moved. The instructions to the participants in the neutral condition were exactly as in experiment 1; in the story condition, they described a lamb trying to find its mother rather than a wolf trying to catch an ailing sheep. We therefore refer to this experiment as using the 'lamb/sheep' condition.

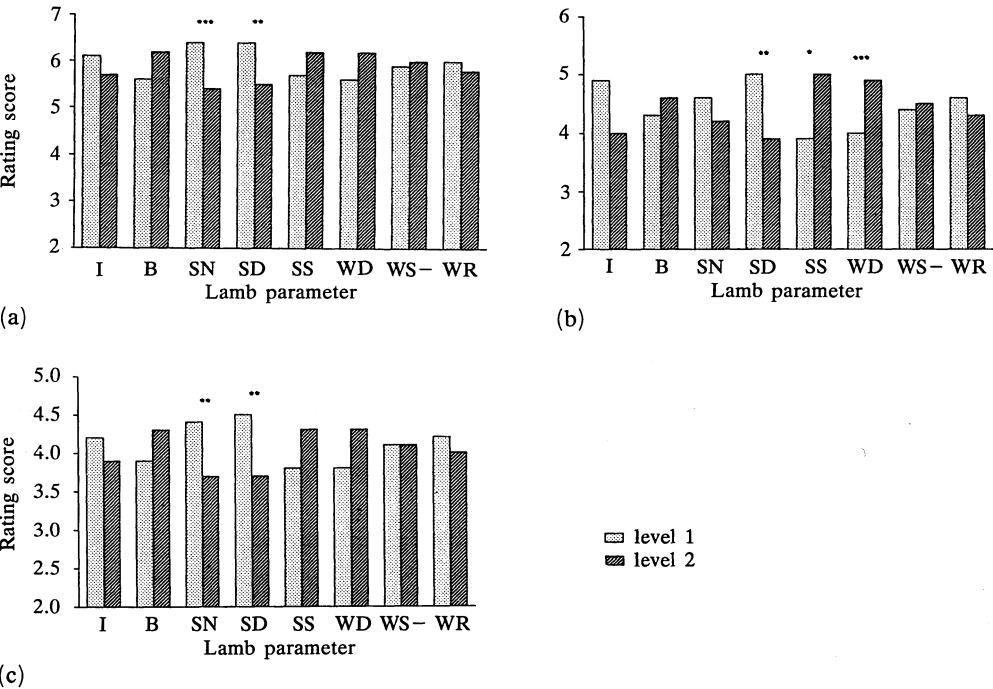
#### 3.2 Results and discussion

The percentage of conditions where the target was not spotted within three attempts was greater than in experiment 1, amounting to 12.7% of all parameter combinations. Again, however, this number is small enough not to have a substantial effect on the main effects of parameters.



Figure 3 shows the main effects on all three rating measures, and *F*-values for significant main effects are given in table 2. Mean ratings of purposefulness were 0.8 units lower on the nine-point scale than in experiment 1, ratings of interaction 0.5 units higher, and ratings of animateness about the same (the difference was less than 0.2 units). The effects of motion parameters were similar to those found in experiment 1, though more of the effects were significant; there were also more significant first-order interactions. Not surprisingly, the effects of distractor speed were in the opposite direction from those found in experiment 1; in experiment 1 slower distractors led to higher ratings of target purposefulness and animateness, whereas in experiment 2 faster distractors did so. Target relentlessness had no significant main effects in this experiment, but it remained an important variable, since it was involved in several significant first-order interactions. The effects of instructions were again nonsignificant, and they were smaller than in experiment 1. Trial block had no significant effect on any variable.

Compared with the wolf condition, the lamb condition posed the subjects with a much more difficult problem. The lower purposefulness ratings are consistent with the general trend, found within each experiment, for slower movements to give less impression of intentionality. Slower movements are also more difficult to detect, and it could be that the lower ratings of intentionality are partly a consequence of this. The higher ratings of interaction probably reflect the fact that a target with a negative speed advantage can spend some time ‘tracking’ its goal at close range, making their interaction evident; this did not happen with the targets with a positive speed advantage in experiment 1, which, once within range of their goals, moved in rapidly to a ‘kill’.



**Figure 3.** Experiment 2: main effects of all factors on ratings of (a) purposefulness, (b) interaction, and (c) animateness under the ‘lamb’ condition. Parameters are coded as in figure 2; WS-, target speed advantage negative; for parameter levels, see table 1.

As in experiment 1, ratings of animateness showed quite a complex pattern of causation, but it could be summarised by saying that animateness is a product of purposefulness and interaction. In the next two experiments, therefore, we examined the effects of removing those two factors.

#### 4 Experiment 3

In experiments 1 and 2 there really was an interaction between the target element and its goal, and under some conditions that could become very evident, especially if the target was not spotted until it came close to its goal. In experiment 3 we tested the effect of removing that 'true' interaction. In one condition, the distractor that served as the goal of the target element was made invisible. Its position was still known to the computer program, and it still moved in exactly the same way, so the movement of the target was also unchanged.

##### 4.1 Method

Except for the differences described below, the method was the same as in experiments 1 and 2.

**4.1.1 Participants.** Sixteen further volunteers were recruited from the same population as in experiments 1 and 2, and were divided into four groups. Half participated in experiment 3a and half in experiment 3b; half of each of these groups experienced a story condition, and half a neutral condition.

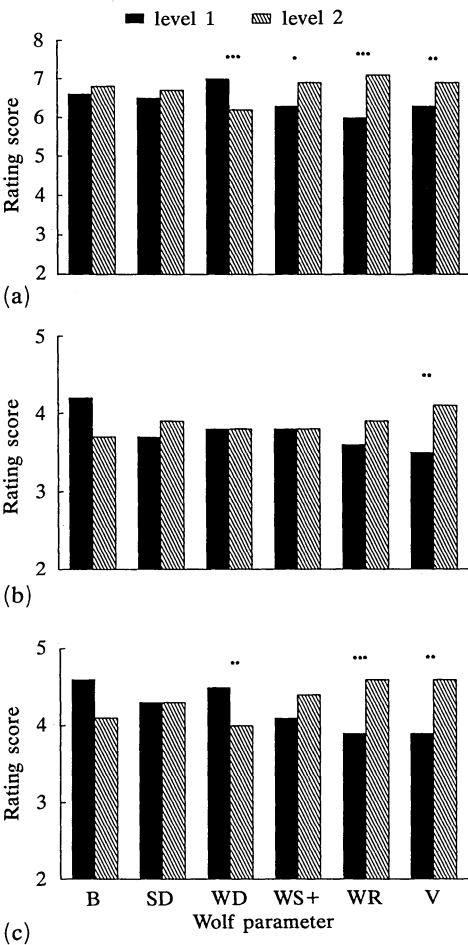
**4.1.2 Stimuli and experimental design.** The stimuli were the same as in experiments 1 and 2. The stimulus parameters that were varied are included in table 1. Most of the variables used in experiments 1 and 2 were used again, but the number of distractor elements was held constant at ten, and their speed at a maximum displacement of 5 pixels cycle<sup>-1</sup>. In experiment 3a the speed advantage of the target was positive, so the experiment involved the wolf/sheep task as used in experiment 1, and the instructions to the subjects under the story condition were the same as in experiment 1. In experiment 3b the speed advantage of the target was negative, so the experiment involved the lamb condition used in experiment 2, and the corresponding instructions were used. The novel feature of experiment 3 was that in both parts of the experiment, as an additional within-subject parameter, the goal which the wolf or lamb tracked was visible to the participant on some trials and invisible in others. However, invisible goal elements moved in exactly the same way as visible ones (the program in fact drew them on the screen, but in the same colour as the background), so the nature of the movement of the target was not changed at all; what was removed was the possibility that the target could interact with a visible goal. An extra, visible, distractor was added on 'invisible' trials so that the number of visible distractors was the same in both conditions. Because we had fewer experimental conditions than in the experiments 1 and 2, the entire design was repeated three times for each participant instead of twice.

##### 4.2 Results and discussion

In experiment 3a the target remained undetected after three attempts in only 2% of all parameter combinations. This figure rose to 13% in experiment 3b (15.4% for the invisible goal and 10.9% for the visible goal). Figure 4 shows the main effects of all variables on the ratings of purposefulness, interaction, and animateness in experiment 3a; figure 5 shows the corresponding data for experiment 3b. *F*-values for significant main effects are included in table 2. The general pattern of main effects on all variables replicated those of experiments 1 and 2, and only the effects of the new, visibility, parameter are discussed here. It can be summarised very simply: both under wolf and under lamb conditions, all three ratings were reduced if the goal

element of the target was invisible. The main effects were not large, but all were significant, and were of the same order of magnitude as the effects of the other stimulus parameters. There were no significant first-order interactions involving the visibility factor.

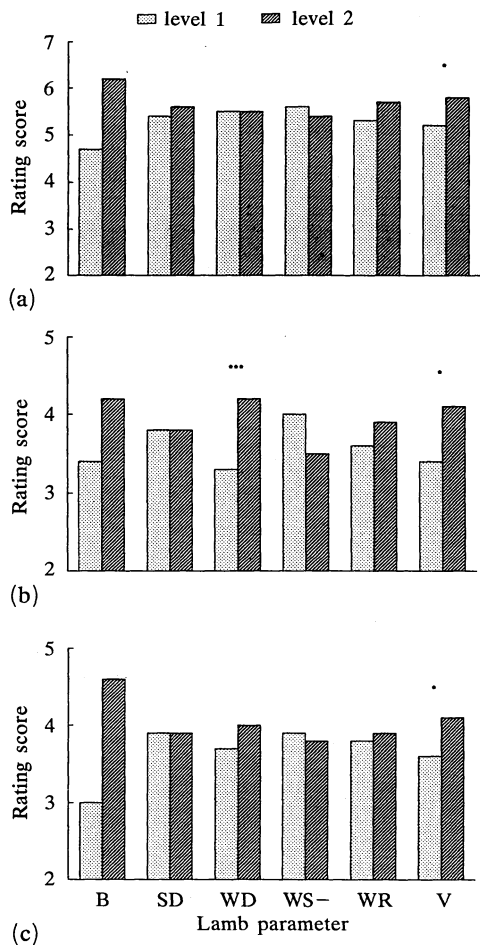
This experiment demonstrates that the presence of a visible goal is not essential for the appearance of purposeful, animate motions, though it certainly enhances the effect. It also serves as a useful demonstration of the basic effects obtained in experiments 1 and 2 are robust, since they were reproduced in this experiment under slightly different conditions.



**Figure 4.** Experiment 3a: main effects of all factors, including the visibility of the goal, on ratings of (a) purposefulness, (b) interaction, and (c) animateness under the ‘wolf’ condition. Parameters and levels of parameters are coded as in figure 2; V, visibility; for parameter levels, see table 1.

5 Experiment 4

In experiments 1 and 2 there was at least a simulation of intentional movement, in the sense that the target was constantly moving towards its goal, and did in the end approach it. In experiment 4 we tested the effect of removing that ‘true’ intentionality.



**Figure 5.** Experiment 3b: main effects of all factors, including the visibility of the goal, on ratings of (a) purposefulness, (b) interaction, and (c) animateness under the ‘lamb’ condition. Parameters are coded as in figure 2; WS–, target speed advantage negative; V, visibility; for parameter levels, see table 1 and figure 3.

In one condition, the target moved in the same way as in experiment 1. But in a second condition, the target actually moved in exactly the same way as the distractors; it was differentiated from them instead by a slight difference of brightness.

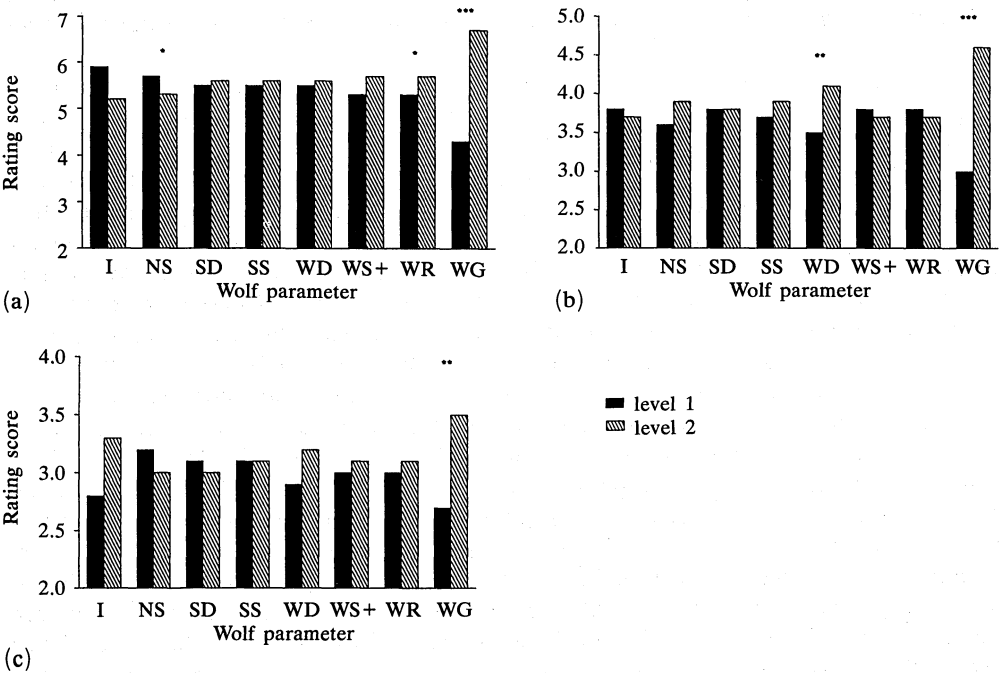
5.1 Method

Except for the differences described below, the method was the same as in experiments 1 and 2.

5.1.1 *Participants.* Ten school students volunteered to participate. They were all aged 17 years, and thus about 2 years younger than the participants in experiments 1 to 3, and they had noticeably less idea of what to expect in a perceptual experiment. They were, however, similar to the previous participants in intelligence and social background.

5.1.2 *Apparatus.* For this experiment two microcomputers were used, the one that was used in experiments 1–3, and a second, identical machine.

5.1.3 *Stimuli and experimental design.* The stimuli were the same as in experiments 1 and 2. The stimulus parameters are listed in table 1. The speed advantage of the target was either positive or zero, so the experiment involved the wolf/sheep task as used in experiment 1. However as an additional within-subject parameter, only some trials involved a wolf. On the remaining trials, no wolf was used, and one of the sheep was designated as target. The sheep moved in exactly the same way as the distractor elements, but it was displayed in the light grey colour of the computer monitor instead of its white colour. The instructions to the subjects under both the story and the neutral condition were slightly modified to direct the participants to look for any difference between the target and distractor elements, not just a difference of movement.



**Figure 6.** Experiment 4: main effects of all factors, including the nature of the differentiation of the target, on ratings of (a) purposefulness, (b) interaction, and (c) animateness under the 'wolf' condition. Parameters are coded as in figure 2; WG, wolf goal-orientation; for levels of parameters, see table 1.

## 5.2 Results and discussion

The proportion of parameter combinations in which the target was not spotted after three attempts was 5% in this experiment. Figure 6 shows the main effects of all variables on ratings of purposefulness, interaction, and animateness. *F*-values for significant main effects are included in table 2. The general pattern of the results conforms to that previously obtained under the wolf condition (experiments 1 and 3a). However, the type of movement programmed had a drastic effect on ratings of purposefulness. Only if the target was actually tracking one of the distractors did participants rate its movement as purposeful, and the difference between the two conditions was highly significant (see table 2). There were smaller but still striking effects on the ratings of interaction and animateness. Analysis of search times showed that differentiation of the target by movement made it slightly harder to spot than differentiation by brightness, but the difference between conditions was not very great, implying that the brightness difference chosen was appropriate in difficulty. The basic results of experiment 1 were again replicated, confirming the robustness of the phenomenon.

## 6 General discussion

### 6.1 The perception of intention

This series of experiments has demonstrated that a convincing illusion of animate, purposeful movement can be produced with relatively simple stimuli. All the experiments show that the perception of intentionality was directly dependent on the variation of movement parameters, such as directedness and speed of target motion and the degree of goal orientation. The impression of intention depends crucially on the movement being directed towards a goal (experiment 4); it is relatively little affected by whether or not that goal can be seen (experiment 3). It is not dependent on observers being told to look for intentional movement, since instructions in experiment 4 were simply to look for an element that was somehow different from the others.

The wolf/sheep condition produced the highest ratings of purposefulness, and the target was much easier to spot under these conditions than in the lamb/sheep condition (Dittrich and Lea, in press). In the lamb condition, on the other hand, ratings of interaction were higher than in the wolf condition (though still not as high as ratings of purposefulness). In our discussion of experiment 2, we suggested that this was because the lamb, with its negative speed advantage, did in fact interact for longer with its goal before colliding with it. This suggestion is supported by the fact that the difference in animateness ratings between experiments 1 and 2 was not found between experiments 3a and 3b, while the difference of purposefulness was replicated.

In all experiments, but especially under the wolf/sheep condition, the instructions given to the subjects made very little difference to any dependent measure, while virtually all parameters of motion had some straightforward effects either on ratings or on search time (for the latter, see Dittrich and Lea, in press). On the basis of these results, we argue that the perception of intentionality can be a relatively immediate, bottom-up process, probably occurring quite early in the visual processing. However, we also assume that in higher-level processes, such as speaking and reasoning, intentionality judgments are also based on additional, propositional, mental operations. Schlottman and Shanks (1992) present evidence that such a distinction between perception and judgment can be made in the case of causality. While our evidence shows that intentionality can be perceived immediately, we are not saying that it cannot also be judged propositionally.

Ratings of interaction, on the other hand, were the most sensitive to the instructions. The change from the wolf/sheep to the lamb/sheep condition reduced the

impression of intentionality (compare figure 2 with figure 3, and figure 4 with figure 5), but, insofar as it produced any change in impression of interaction, enhanced it (compare figure 2 with figure 3, though there is no difference in this respect between figures 4 and 5). Clearly interaction is under the control of different variables from those controlling intention. In both comparisons, the impression of animateness is intermediate—slightly increased between figures 2 and 3, slightly reduced between figures 4 and 5. From this pattern of differences, we argue that the coding of a movement as animate may depend on two factors. The first is the impression of intentionality, which is derived mainly from the trajectory of the target (absolute spatiotemporal kinematics); the second is the degree of interaction between the target and its goal, which is necessarily a function of relative spatiotemporal kinematics. Both the wolf/sheep and the lamb/sheep condition therefore gave quite an effective illusion of animate motion, but for opposite reasons. This approach to intentionality is similar to the one that has been taken in the study of intentionality perception in infants (Trevvarthen 1979; Kaye 1982; Vedeler 1987).

Bassili (1976) argued that impressions of interaction and intentionality depend on temporal and spatial contingencies, respectively. Our results contradict this generalisation, since both kinds of ratings were related both to spatial and to temporal parameters. For example, even when the goal of the motion of the wolf or the lamb was invisible, so there could be no question of real interaction, ratings of interaction depended on spatial factors like the directness of the movement of the target, while ratings of purposefulness were related to temporal parameters like the speed advantage of the target. Bassili's separation of temporal and spatial parameters seems much too simple to explain the perception of complex patterns of interacting moving figures; besides, all movement is inherently both spatial and temporal.

### 6.2 *Motion and intentionality*

A two-stage process is the more plausible because, as Dittrich and Lea (in press) report, the search times in the present experiments were substantially longer than those usually reported in the literature (eg Treisman and Schmidt 1982; Driver and Baylis 1989). We suggest that this is because our task requires two stages of perceptual processing: first, motion features must be extracted and the critical feature found, and then a matching process is required for the understanding of the movements. Such template matching requires an internally represented model of the stimulus. Intentional information receives its specific nature from the combination of perceptual and memorised information which act as signs for intentionality. It does not result from the direct extraction of intention from the stimulus, nor from a distinct cognitive process such as knowledge of the interpretation of the stimuli. Intentionality is perceived because particular features of the stimuli, when encoded, activate intentional concepts.

This encoding hypothesis of intentionality seems to follow an information-processing approach similar to that of Sayre (1986), but in fact it offers a fundamentally different explanation of intentionality. Sayre claimed that intentionality arises from the identity of a representation *R*, established in the cortex, with a particular objective structure *O*, entering the other end of the perceptual channel. In contrast to this identity approach, we assume that intentionality can be expressed by a variety of different (though not unrelated) motion patterns. Intentionality is primarily determined by its role within a complex cognitive economy, and not by direct perception (*sensu* Gibson) or by additional, linguistically bound interpretations of underdetermined percepts. Thus our approach resembles a network or conceptual-role theory of semantic information (eg Churchland 1979). For an abstract, relational property such as intentionality, there can be no single stimulus representation, no single necessary or

sufficient feature. Rather, intentionality must be treated like the polymorphous categories or concepts, by which we successfully classify natural objects (Rosch 1975; Dittrich 1988, 1990).

Premack and his colleagues have suggested using intentionality as a form of causality, namely 'psychological causality' (Dasser et al 1989). But they try to derive intentionality from the mere order of stimulus movements, and this implicitly involves additional interpretation processes; we have already seen that spatial as well as temporal factors are involved in judgments of intentionality. We assume, on the other hand, that humans can use cues or clues to interpret the visual scene by building semantic representations. Therefore, it seems pointless to look for a precise specification of intentional information, either in the percept or in the knowledge of intentionality. Perception of intention from motion occurs because of the specific conceptual integration of different motion features.

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