Speed, more than depth, determines the strength of induced motion

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Motion of an inducer in a given direction can cause illusory motion in the opposite direction in a neighboring target object, a phenomenon called induced motion. Induced motion may be due to inducer–target interactions that are local in visual space. Accordingly, increasing the depth between inducer and target should weaken induced motion. Alternatively, separation in depth may not determine whether one object can affect the motion of another. Either viewpoint is supported by separate studies. We show that this contradiction is due to a methodological artifact related to target velocity. Our results support the suggestion that induced motion is not affected by depth separation. Participants rated the effect of an inducer on a target dot presented at different disparities. When target velocity varied with depth, induced motion decreased with depth separation. When target velocity was constant across depth, induced motion was also constant across depth. Thus, target velocity, more than depth, influence motion induction.

Keywords: induced motion, depth perception, velocity perception

Citation: Léveillé, J., & Yazdanbakhsh, A. (2010). Speed, more than depth, determines the strength of induced motion. *Journal of Vision, 10*(6):10, 1–9, http://www.journalofvision.org/content/10/6/10, doi:10.1167/10.6.10.

Introduction

Induced motion refers to the observation that an illusory velocity component in a visual stimulus emerges in a direction opposite to that of the real motion of another stimulus (Duncker, 1938). One widely used induced motion display consists of a vertically oscillating target dot surrounded by a horizontally oscillating inducer rectangle (Wallach, Bacon, & Schulman, 1978). In such a display, the dot appears to move on a diagonal axis on the frontoparallel plane (tilt), as if it contained a horizontal motion component opposite the motion of the rectangle. The same kind of induced motion has also been shown to occur using various other types of displays, using for example pairs or greater number of dots as inducer instead of a rectangle (e.g., Camenzuli & Fisher, 1984).

Besides the planar shape of display elements, other geometrical features such as depth have also been investigated as factors affecting motion induction. A number of studies have addressed the effect of separation in depth of the target and inducer (Di Vita & Rock, 1997; Gogel & MacCracken, 1979; Gogel & Tietz, 1976). The methodology employed in these studies is to present inducer and target elements at different distances from the observer and measure the perceived tilt on the frontoparallel plane of the target motion path. Based on the suggestion that target and inducer are represented in an object-centered reference frame (Lappin & Craft, 2000; Wade & Swanston, 1987), increasing their relative distance should suffice to reduce the magnitude of induced motion. The same hypothesis can be formulated based on the adjacency principle, which simply states that any kind of interaction between neighboring stimuli should decrease with separation, whether on the frontoparallel plane or in depth (Gogel, 1974). Gogel and MacCracken (1979) tested target–inducer configurations at five relative depths and varied absolute distance from the observer as well as attentional instructions. A general finding was that induced motion was inversely proportional to perceived target–inducer separation in depth. A careful look at the data and statistics suggests that induced motion decreased strongly when the target was presented behind the inducers, as the target distance from the observer was increased. In contrast, induced motion decreased only slightly, if at all, when the target was presented in front of the inducers. Thus, the results may actually better be described as a reduction in induced motion as the target moves farther away than the inducers. Although this asymmetry was noted by Gogel and MacCracken (1979, p. 350), they did not provide a satisfactory explanation. In comparison, Di Vita and Rock (1997) reported that the perceived tilt did not depend on whether the target and inducer were in the same depth plane or not (cf. results of the single-frame conditions in Experiment 1 and Experiment 3). They also reported a failure to obtain depth-dependent modulation of induced

doi: 10.1167/10.6.10 Received February 25, 2010; published June 8, 2010 ISSN 1534-7362 © ARVO

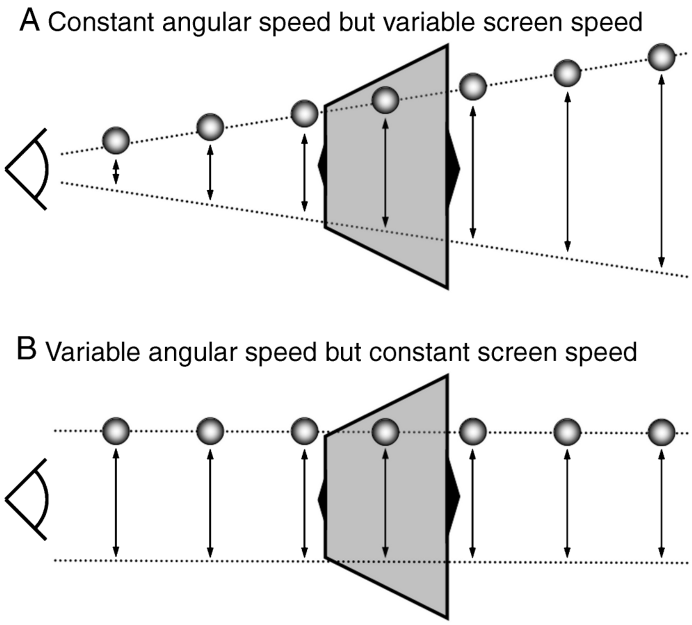

Figure 1. Visual angle and extent of motion on the screen. (A) When the target dot is seen to cover a constant visual angle, the extent of motion on the screen is proportional to depth. (B) This is not the case if the extent of motion on the screen is kept constant across depth. Keeping the temporal period of target oscillation constant, target dot speed increases with depth in (A) but not in (B).

motion as part of additional pilot experiments (Di Vita & Rock, 1997, p. 1347). Rather, depth was found to play a role only when static stimulus elements were added that made the target look as if it belonged to a physical entity separate from the inducer, in which case induced motion was lost. The discrepancy between the two previous studies is enough of an incentive to reinvestigate, in a controlled experiment, the hypothesis that motion induction is inversely dependent on the distance between target and inducer.

Besides the type of inducer used, the studies of Di Vita and Rock (1997) and Gogel and MacCracken (1979) differ in the way the length of the target dot's path was set in the various conditions. In the first study, the visual angle of the path covered was constant across depth, as in Figure 1A. Thus, in such a condition the target dot's perceived extent of motion on the computer screen increases as the dot and screen move further in depth. In the second study, however, the extent of motion on the computer screen appears to have been constant across depth, as displayed in Figure 1B.

Although the extent of the target's path may vary across depth, the time for the dot to complete one cycle is fixed. Thus, in the constant angle condition, the dot's speed in the world (i.e., its *distal* speed) is proportional to its depth in visual space. In contrast, in the constant screen speed condition, the dot's distal speed is constant across depth. Thus, the effect observed by Gogel and MacCracken (1979) but not by Di Vita and Rock (1997) may be due to the target dot's distal speed rather than its depth relative to the inducer.

Why would target speed be inversely proportional to the magnitude of induced motion? One theoretical framework that predicts an inverse relation between target speed and induced motion magnitude is that of vector subtraction (Léveillé, Grossberg, & Versace, 2009; Perrone & Krauzlis, 2008), which is closely related to vector decomposition (Johansson, 1950). In the current context, vector subtraction predicts that the rectangle forms a reference frame whose motion is subtracted from that of the target dot. Without loss of generality, Figure 2 illustrates a particular case where inducer frame and target are both located in the same depth plane.

Figure 2A illustrates the stimulus at a particular phase, as the target dot moves upward and the inducer frame moves in the right direction. In Figure 2B, the dot moves slowly, such that its velocity (dashed lines) has a small component in the upward direction. Following subtraction of the motion signals of the inducer frame (middle column), the resulting motion vectors have a strong component in the upper left direction.

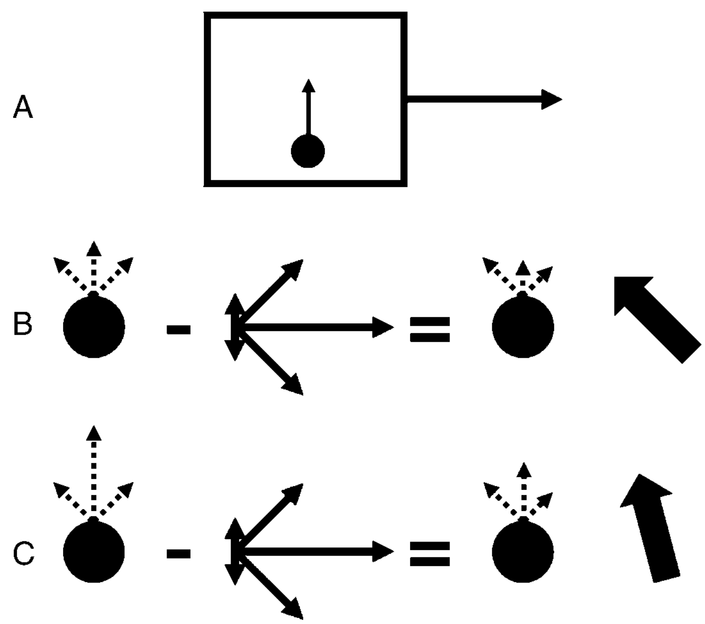

Figure 2. Speed of the target dot and magnitude of vector subtraction. (A) Fictional stimulus configuration where the dot moves upward as the frame moves rightward. (B) If the dot moves at a slow pace (left), subtraction of the frame's motion signals (middle) results in an overall strong motion direction toward the upper left corner (right). (C) If the dot moves at a fast pace, upward velocity is especially strong, such that after subtraction, the upward direction of motion is still strong, resulting in an overall motion direction close to the vertical. Note that in (B) and (C) dashed lines stand for the various velocity components of the target dot. Full arrows in the middle represent velocity components of the rectangle.

In Figure 2C, the dot is assumed to move fast, such that it has a large component in the upward direction. After subtraction, that component is still strong, such that the perceived direction is closer to the vertical. Accordingly, induced motion should be weaker when the target dot moves faster, irrespective of the relative depth of the target and inducer.

Motivated by the above analysis, and in order to understand the influence of the 3-dimensional geometry of visual space on motion induction, we performed psychophysical experiments to tease apart the roles of speed and depth. In particular, the discrepancy between earlier results may have originated in the way target path extent, and thus speed, was handled in each study. In the experiments reported here, we compared the perceived orientation of the target path presented at different distances relative to the inducer when the motion path's extent was either proportional to depth or constant across depth. Since perceived target dot speed increases with its depth only in the former condition, induced motion (as measured by the orientation of the target dot path on the frontoparallel plane) should be inversely related to target dot depth in the former but not the latter.

Methods

Participants

A total of 9 observers (8 men and 1 woman) participated in this study. Of these, seven were naive as to the purpose of the experiment, and the remaining two were the experimenters.

Apparatus

The display were presented on an M9179LL/A 30″ LCD monitor (640 × 650 mm) with a resolution of 1600 × 2560 pixels, viewed through a haploscope from a distance of 90 cm and in a dark room environment.

In all experimental conditions, the inducer consisted of a horizontally oscillating rectangle, and the target was a vertically oscillating dot. Both stimulus elements oscillated in phase such that the dot reached its highest and lowest positions when the rectangle was at its leftmost and rightmost positions, respectively.

The inducing rectangle was presented at the depth of the monitor (90 cm). The horizontal position on the monitor of the target dot was shifted relative to the center of the rectangle so as to make it appear at seven different depths (Figure 4A). Let l_i and r_i be the displacements between the dot's center and the rectangle's center in the displays presented to the left and right eyes, respectively. Define $x_i = l_i - r_i$, the total horizontal displacement between the dot and the frame. The seven amounts (in millimeters) of horizontal displacement tested were: 23.5, 13, 5.5, 0, −4.5, −7.5 and −10.5, where "+" and "−" indicate that we obtain uncrossed and crossed disparities, respectively. Such displacements led to a clear impression of depth in the visual display.

The inducing rectangle had a width and height of 10 cm and 9 cm, respectively (6.34° by 5.71° of visual angle). The dot's radius was 3 mm (19 arc min). The time for one cycle (i.e., one sweep up followed by one sweep down of the target dot) was fixed at approximately 2.34 s. The vertical extent of the path covered by the target dot varied across conditions (see below).

Subjects indicated their perceived orientation using a virtual rotatable rod displayed on a CRT screen located on their right-hand side, whose orientation with respect to the vertical could be adjusted using a mouse. The perceived path orientation was then measured as the angle, in degrees, relative to the horizontal line. The experimental setup is schematically illustrated in Figure 3B.

For each trial, subjects were allowed to freely view the stimulus and adjust the measurement rod until they felt satisfied that the rod reflected accurately the angle of the target dot path.

Procedure

Before starting the experiment, subjects were allowed as much time as needed to calibrate the haploscope on static displays that differed from the experimental displays only in that no motion was imparted to either the target dot or inducing frame. Subjects sometimes reported having difficulty fusing the stimulus when the target dot was presented nearest to the observer, a difficulty that may be traced back to Panum's fusional limit (Hershenson, 2000). The experimental trials started once the subject felt satisfied binocularly fusing the dot and frame at each of the seven disparity configurations tested and could perceive the corresponding depths. To ensure that subjects actually perceived depth, they were asked to report the egocentric distance to the inducer and the relative distance of the target to the inducer in static versions of the displays. The mean distance to the inducer, computed across subjects, was 86.1 cm. Figure 4A shows the absolute distances to the target (d_i) computed by adding the mean target–inducer relative distances to the absolute inducer distance. These distances are displayed as a function of the target dot's position relative to the frame. For example, relative target plane position 1 (with respect to frame) is in front of the relative target plane position 2. The numbers in the range [−3 3] have no linear relation with disparity or depth. As the figure clearly shows, subjects truly perceived distances in each disparity configurations.

In order to understand the experimental conditions, it is necessary to distinguish between the extent of the target dot's motion path on the monitor (i.e., its screen path, denoted π) and its resulting perceived extent (P).

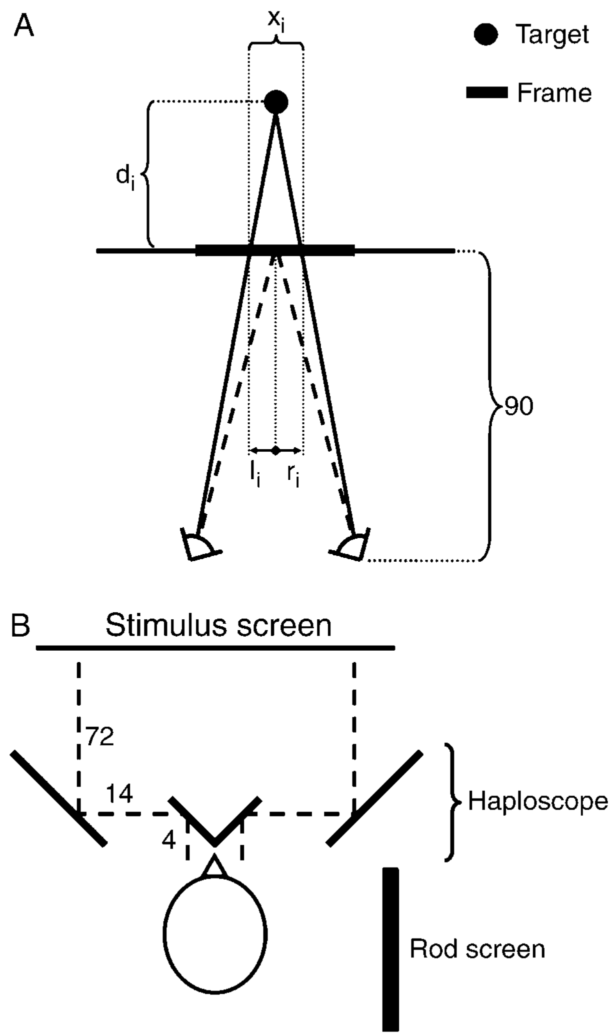

Figure 3. Experimental setup. All quantities are in units of centimeters. (A) Subjects viewed the stimulus screen through a haploscope and indicated the perceived orientation of the target path on the monitor on the right ("rod screen"). (B) Assuming fixation on the monitor (dashed lines), relative stereoscopic depth of a target dot (d_i) can be estimated from the total amount of displacement (x_i = l_i − r_i) between the horizontal location of the center of the dot and that of the rectangular frame.

In the constant path condition, the target path length (π_c^0) covered approximately 2 cm (1.27°) on the display screen, irrespective of the depth configuration. In the proportional path condition, the target path length on the monitor (π_p^i) increased with the theoretical distance of the dot, yielding approximately 2.2, 2.5, 2.8, 3.2, 3.7, 4.2, and 4.6 cm (i.e., 1.40, 1.59 1.78, 2.03, 2.35, 2.67, 2.92°) for the seven depth settings, respectively. The target path extents in our conditions were estimated by taking into account perceived target depth and applying Emmert's law to the physical path extents π_c^0 and π_p^i:

$$P_T^i = \frac{(90 + d_i)}{90}\pi_T^i, \qquad (1)$$

where T = c or p for the constant and proportional conditions, respectively.

We performed two independent experiments that differed only in where the subjects were asked to fixate. In the experiment depicted in Figure 5A, observers were asked to fixate the frame, which thus appeared to be at a constant depth. In this case, the target dot was perceived as changing depth across trials. The corresponding perceptual extents

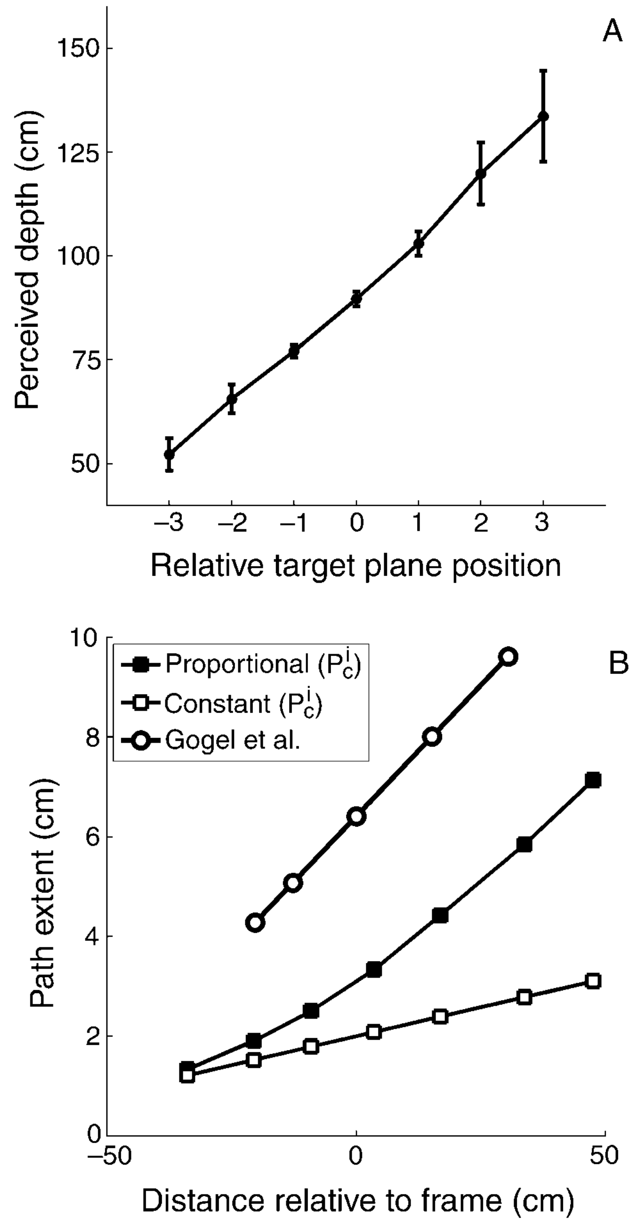

Figure 4. Depth and extent of target path. (A) Perceived depth of the target dot at each of the seven disparity configurations, estimated while fixating on the rectangular frame. Error bars represent the standard error. (B) Increments in target dot distance from the observer result in comparable increments of target path length in the original Gogel and MacCracken's study and the proportional path condition. In comparison, the constant path condition yields only small length changes due to Emmert's law.

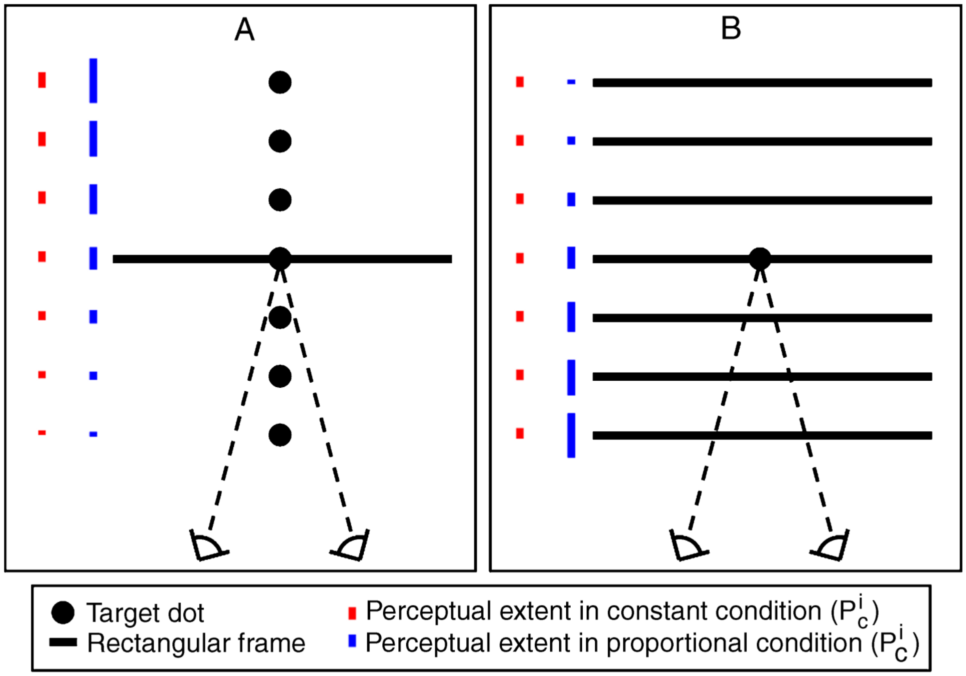

Figure 5. Two fixation conditions viewed from above. In the experiment shown in (A), observers were asked to fixate the rectangular frame, as the relative depth of the target dot was varied across the seven depths tested. The corresponding perceptual extents for the target dot's path are indicated on the left, in red and in blue, for the constant and proportional extents, respectively. In (B), observers were asked to fixate the target dot, as the relative depth of the frame was varied. In both cases, dot path extent increased steeply in the proportional condition as the dot was moved farther in depth relative to the frame. However, due to Emmert's law, path length in the constant condition increased weakly in (A) whereas it was constant in (B). Furthermore, only in (A) was dot path extent proportional to its absolute distance from the observer.

for both path conditions (P_p^i and P_c^i, where $\forall_i\ \pi^i = \pi^0$) are thus given by direct application of Equation 1, the result of which are displayed in Figure 4B. The shallow non-zero slope obtained in the constant path condition (empty squares) results from application of Equation 1 to the constant screen path π_c^0 while increasing perceived depth through disparity.

Figure 4B also compares these values with theoretically derived ones from Gogel and MacCracken (1979). In that study, the target path covered a constant angle of 6° and was judged by the observers to be approximately 40, 48, 61, 76, and 91 cm away (considering only the trials when the inducer was perceived to be 61 cm away). As shown in Figure 4B, the perceived extents that result when scaling the 6° angle by these distance estimates increase with depth at about the same rate as in the current proportional condition. However, perceived extent is mostly constant in the constant condition. Furthermore, the range of angles spanned across stimulus conditions is similar (5.33° and 5.80° for Gogel & MacCracken, 1979 and the current study, respectively).

In the experiment of Figure 5B, observers were asked to fixate the target dot, which thus appeared to be at a constant depth, despite small variations that may have resulted from small changes in vergence across trials. Nevertheless, in this case it is the frame that was perceived as changing depth across trials. Here, unlike in Figure 5A, path extent was the same across all depths in the constant condition since the dot's depth was constant and thus no scaling occurs from Emmert's law:

$$P_T^i = \pi_T^i. \tag{2}$$

Thus, only the first experiment can be considered a proper replication of the experiment of Gogel and MacCracken (1979) since it is the only one in which path extent was proportional to the absolute distance of the target. Both experiments still directly test the influences of target speed and target–inducer distance on induced motion.

Based on the above considerations, the following hypotheses can be stated for the frame fixation experiment. If induced motion depends neither on depth nor speed, perceived target direction should be the same across all trials (H0). If induced motion depends on relative depth, but not on speed, perceived target direction in both the constant and proportional path conditions should vary equally with relative depth (H1). If induced motion depends on speed, but not relative depth, perceived target direction should vary strongly in the proportional path condition but only weakly in the constant path condition, where distal speed also varies but only slightly

(H2). Finally, if induced motion is sensitive to both speed and relative depth, perceived target direction should vary in both path extent conditions, and more intensely in the proportional path condition (H3). Since physical path extents were always longer for the proportional condition than the constant condition ($\forall_i\ \pi_p^i > \pi_c^0$), both H2 and H3 further predict that induced motion should be generally weaker in the former condition than in the latter. Note that it may not be possible to distinguish H2 from H3 on the basis of experimental data alone since they both predict a strong variation in induced motion in the proportional condition and a weak variation in the constant condition.

This problem is eliminated in the target fixation experiment, for which similar H0, H1, and H3 hypotheses can be formulated in exactly the same way as for the frame fixation experiment. For H2, as in the frame fixation experiment, perceived target direction should vary strongly in the proportional path condition. However, the constant path condition here should yield absolutely no changes at all in perceived orientation since target depth is constant (and thus Emmert's law does not induce any change in path extent).

An added benefit of requiring fixation on the inducing plane is to allow us to discard the possibility of a bias on perceived target direction due to corollary signals from fixation eye movements. For trials with long path extents, larger shifts in eye fixation could, in principle, yield stronger corollary signals and thereby give an additional cue as to the verticality of target path. Thus, a reduction in induced motion, as target path increases, in the proportional path condition could be equally attributable to either speed or to the presence of corollary signals. The possibility of this confound was eliminated by requiring observers to fixate the frame in the second experiment.

Treating the fixation conditions separately, each experiment was conducted as a 2 (target path extent type) × 7 (disparity configuration) repeated-measures design, where each block consisted of one trial at each disparity configuration. Block order was randomized across subjects, and all blocks were administered either on the same or different days. All subjects were able to complete the task within approximately 15 min, not counting calibration time for the haploscope.

Results

Mean orientation ratings (in degrees from the horizontal) for each condition are shown in Figure 6. Results for

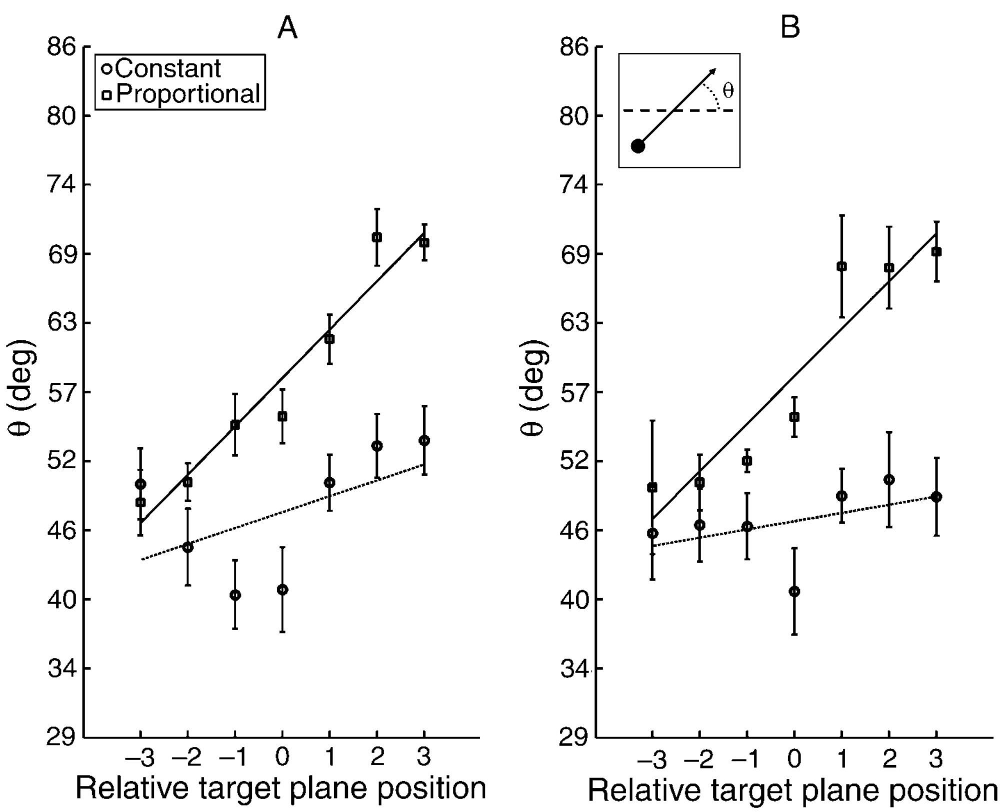

Figure 6. Orientation ratings for the experiments with (A) frame fixation and (B) target fixation. In both cases, affecting the relative disparity in the constant extent condition (circles) leaves the target path orientation essentially constant. In the proportional extent condition, however, target path orientation approaches the vertical as the dot is displaced further in depth relative to the inducer.

the frame fixation and target fixation conditions are shown in Figures 6A and 6B, respectively. Error bars represent confidence intervals ($\pm\sigma/\sqrt{n}$, where n is the number of subjects). Data were fit with a linear polynomial also displayed in the figure.

In both fixation conditions, induced motion decreased as the target moved increasingly farther with respect to the inducer but only when the dot's path was proportional to the relative location. Two-way ANOVAs confirm this pattern of results, with significant interactions for both the frame fixation and target fixation conditions ($F(1, 6) = 2.81$, $p = 0.0154$, $MSE = 0.019$; and $F(1, 6) = 3.92$, $p = 0.0017$, $MSE = 0.021$, respectively). We can therefore reject all hypotheses except for H2, indicating that speed, but not depth, influenced the strength of induced motion.

Tukey post-hoc comparisons between disparity levels were computed independently for each fixation and path extent condition at 5% confidence threshold. In the constant extent condition, no significant difference was observed except for one paired comparison in the frame fixation condition. In the proportional extent condition, significant differences were obtained between several levels, as reported in Tables 1 and 2, where X_1 and X_2 correspond to the two different disparity levels used in a given paired comparison.

As shown in both tables, no comparison involving adjacent disparity levels yielded a significant difference, indicating that our sampling of depth—or of target speed—was higher than needed to capture the spatial resolution of induced motion. Significant differences were found between disparity pairs separated by two or more levels. When interpreting this data, it is helpful to remember that the differences in path extents between adjacent levels were rather small. Thus, induced motion may not have varied much in strength between adjacent levels, leading to step-like increments in the data and to apparent non-linearity in Figure 6.

Finally, as noted above, some subjects reported having difficulty fusing the stimulus when the target was displayed at its nearest depth relative to the frame. To assess whether this difficulty could have affected our results, statistical analyses were performed excluding this data point. For the target fixation experiment, the same interaction as before was observed ($F(1, 5) = 2.97$, $p = 0.0154$, $MSE = 0.024$), indicating that hypothesis H2 cannot be rejected. However, for the frame fixation experiment, the interaction became non-significant ($F(1, 5) = 1.44$, $p = 0.2183$, $MSE = 0.017$), but main effects for path extent and relative depth were obtained ($F = 82.12$, $p < 0.001$ and $F = 14.85$, $p < 0.001$, respectively). In this case, both hypotheses H2 and H3 cannot be rejected. The main effect of path extent could be accounted for by considering that the physical length of the constant path condition was shorter than any path length in the proportional condition (2 cm $= \pi_c^0 <$ 2.2 cm $\leq \pi_p^i$). The speed of the dot was thus generally lower in the constant extent trials than in the proportional extent trials.

As explained above, the frame fixation experiment cannot distinguish between H2 and H3. We take the fact that both experiments concur on hypothesis H2 as supporting evidence for the suggestion that speed, but not depth, influenced induced motion judgments.

		X_1					
		−3	−2	−1	0	1	2
X_2	−2	1.7					
	−1	6.4	4.8				
	0	7.1	5.4	0.7			
	1	13.5*	11.9*	7.1	6.4		
	2	22.0*	20.3*	15.5*	14.8*	8.4	
	3	21.5*	19.9*	15.1*	14.4*	8.0	0.4

Table 1. Mean difference estimates in perceived target direction (in degrees) between target relative positions X_2 and X_1 in the inducer frame fixation experiment with proportional path extents. Statistically significant differences are indicated by asterisks.

		X_1					
		−3	−2	−1	0	1	2
X_2	−2	0.4					
	−1	2.2	1.8				
	0	5.8	5.4	3.6			
	1	18.3*	17.9*	16.1*	12.5		
	2	18.2*	17.8*	16.0*	12.4	0.1	
	3	19.5*	19.1*	17.3*	13.7*	1.2	1.3

Table 2. Mean difference estimates in perceived target direction (in degrees) between target relative positions X_2 and X_1 in the target dot fixation experiment with proportional path extents. Statistically significant differences are indicated by asterisks.

Discussion

The experiments reported here aim at providing an understanding of how the geometry of visual space affects induced motion. In particular, the results for the target fixation experiment support the claim that depth per se does not affect motion induction, as shown by the lack of change in perceived path angle in the constant extent condition. Although our current experimental setting does not allow us to distinguish whether it is the retinal or the distal target speed that is inversely related to induced motion, only an explanation based on distal speed can explain all available results (i.e., our results, those of Gogel & MacCracken, 1979 and those of Di Vita & Rock, 1997). In Gogel and MacCracken (1979), retinal speed was truly constant as disparity changed (whereas distal speed varied), such that the variation observed in induced motion cannot be explained by a change in retinal speed. In Di Vita and Rock (1997), retinal speed varied with depth, whereas induced motion did not, such that consideration of retinal speed alone seems insufficient to explain induced motion constancy. We thus favor an interpretation based on distal speed.

Although not statistically important (only one paired comparison reached significance in Figure 6A), it may be argued that the results for the constant path condition in the frame fixation experiment also show a minor tendency for induced motion to decrease with increasing target depth. Such a result would seem at first compatible with part of Gogel and MacCracken's (1979) initial claim that depth adjacency alters motion induction. However, in this condition, although target path was constant on the monitor, perceived path extent—and thus distal target speed—may have slightly increased with depth in accordance with Emmert's law as shown in Figure 4B. The same explanation may also account for the absence of a significant statistical interaction between path extent type and disparity configuration and the presence of a main effect of the latter variable (when neglecting nearest target configurations). The frame fixation experiment is therefore consistent with the views that either distal speed only or distal speed and depth influence induced motion. In any case, the present results make clear that a variation in distal speed influences induced motion much more than a variation in depth. The traditional conception of a vector subtraction mechanism (Figure 2) is that it is based on image velocities. To suggest that the perceived dot speed is influenced by its perceived distance (via Emmert's law) is implying that some sort of "higher level" representation of speed is being used in the vector subtraction process. Vector subtraction may thus involve neural mechanisms occurring at a late stage in the visual cortical hierarchy, where retinal speed and depth could jointly encode distal speed. The model of Perrone and Krauzlis (2008), for example, postulates that vector subtraction may occur no earlier than in MST.

As in Figure 2, vector subtraction taking into account the speed of motion signals of the target dot appears to be sufficient to account for the current pattern of result. Support for this prediction would be provided by showing that the ratio of target-to-inducer speed matters rather than the absolute speed of the target or the inducer, an aspect not captured in the present experiment (but see Post, Chi, Heckmann, & Chaderjian, 1989). Another explanation sometimes invoked is that the motion of the frame causes shifts in the observer's global spatial orientation (Brooks & Sherrick, 1994). According to this view, neither target speed nor depth should affect induced motion, a scenario that was covered by hypothesis H0 and that the results explicitly disconfirm. A related hypothesis is that the motion of the rectangular frame is tracked by observers, thereby generating retinal motion in the opposite direction corresponding to the target dot's motion (Chaudhuri, 1991). This hypothesis is not corroborated by our data since essentially the same results were obtained whether fixating the frame or the target dot.

One way to account for the lack of influence of depth is to postulate that the neural mechanisms underlying vector subtraction do not encompass a metric term for relative depth (i.e., the magnitude of relative depth is not part of the subtraction equation). This conclusion echoes the findings of Di Vita and Rock (1997) who suggested that it is the presence of form features governing "belongingness", rather than depth, which determines the strength of relative interactions such as induced motion. A less extreme alternative is to suggest that motion induction is only coarsely related to depth, a claim whose validation would require testing larger relative depths than the ones used here. However, because the relative disparity range can probably not be extended any further than the range tested here without causing diplopia, such an experiment would require the use of other (e.g., monocular) depth cues.

Conclusion

The present experiment thus shows that motion induction is only coarsely, if at all, dependent on the distance between inducer and target elements. Rather, the strength of induced motion depends on the speed of the target element, or on the relative speed of the target and inducer. We suggest that neural mechanisms underlying induced motion must therefore be tuned to distal speed.

Acknowledgments

This work was partially supported by CELEST, an NSF Science of Learning Center (SBE-0354378). We would like to thank the reviewers for helpful comments about many aspects of the manuscript.

Commercial relationships: none.
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