WHEN WHERE THINGS ARE DEPENDS ON WHAT YOU'RE DOING: STIMULUS CONTROL REVERSES IMPLIED FRICITON EFFECTS IN SPATIAL PERCEPTION

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Abstract

The perceived vanishing point of a moving stimulus is displaced beyond the actual vanishing point. Displacement decreases as the stimulus appears to move under implied friction (i.e., by itself, over a surface, or between two surfaces). The present experiment examined what would happen if stimulus movements were controlled by the participant, not the computer. As participants controlled the stimulus in conditions of increasing implied friction, the displacement actually increased. This reversal is consistent with economy-of-action effects in which variables such as perceived distance increase as the energy-requirements implied by the stimulus (e.g., a steeper hill) increase. What is unique about these findings is that the implied effort was virtual—the computer-generated stimulus only appeared to be under increased friction, and the behaviors required to control the stimulus (i.e., button presses) were exactly the same in all conditions. These finding indicate spatial perception entails intentional, planning properties and is, therefore, more than a mapping process regarding where things are.

When observers are asked to indicate the vanishing point of a moving stimulus, they indicate perceived vanishing points that are displaced beyond the actual vanishing point, in the direction of stimulus motion (Hubbard, 1995, 2005). These forward displacements (FD) have been found to vary systematically as a function of dynamic stimulus properties. For example, the faster the stimulus moves, the larger the FD. Also, downward moving stimuli give rise to larger FD than upward moving stimuli. Finally, stimuli that move under implied friction (i.e., the stimulus appears to move across a surface) give rise to less FD, and the FD decreases as the degree of implied friction increases (i.e., the stimulus appears to move between two surfaces). These findings have been referred to as representational velocity, representational gravity, and representational friction, respectively, and are often accounted for in terms of *representational momentum*, the idea being that the brain evolved to represent dynamic as well as static stimulus properties. Thus, at the moment the stimulus vanishes, the representation of its dynamics continues for some time, in a manner consistent with the momentum properties of those dynamics. And when participants are then asked to indicate the vanishing point, they use a representation that has since, 'moved on', as it were, beyond the vanishing point, due to representational momentum.

While the psychophysics of dynamic stimulus properties seems clear, and the interpretation, straightforward, some researchers are challenging the notion that FD constitutes a post-stimulus distortion of perceptual space. Instead, they propose FD might constitute an index of perceptual anticipation. Jordan and Knoblich (2004) for example, conducted an FD experiment in which the participants, not the computer, controlled the movements of the stimulus. Specifically, participants were instructed to make a dot stimulus move back and forth across a computer monitor via right- and left-arrow key presses. If the dot was moving to the right, right-presses accelerated the dot to the right, while left-key presses decelerated the dot. If the dot was moving to the left, the opposite relationship obtained. At an unexpected moment during the deceleration phase, the dot vanished. Participants then used a mouse-driven cross-hair to indicate the perceived vanishing point.

An analog of this task is driving a car. Pressing a button to decelerate the dot is like putting on the brakes, and doing so to accelerate, like pressing the gas pedal. Anticipation plays a role here, because as one presses the brakes to decelerate a car, one does so with the anticipation of a certain degree of deceleration per unit force applied to the brake. This is obvious to anyone who learned to drive using manual brakes and then attempted to use power brakes. When one applies the force required for manual brakes to power brakes, one presses in anticipation of a slower rate of deceleration and is surprised to feel the car come to a rather abrupt halt. The point of the Jordan and Knoblich (2004) paradigm was to determine whether these types of anticipations would manifest themselves in perceived vanishing points.

To manipulate anticipation, key presses were programmed to have either high or low impact, the former constituting the driving equivalent of good brakes, and the latter, bad breaks. In addition, participants did the task either alone, or as a member of pair. In the alone condition, they controlled both keys. In the pair condition, each member controlled one key. The driving analog would be driving alone and having control of both the brakes and the gas, versus driving as a team, with one member controlling the brakes, and the other, the gas. This influences the anticipation surrounding each button press because for those in the alone condition, the right hand knows what the left hand is doing, for both hands belong to the same brain. In the pair condition, the two hands belong to different brains. Hence, uncertainty regarding what the other will do at any given moment leads to the need for more anticipation, just as sharing control over a car with another requires one to begin braking earlier than if one is alone, so as to have enough time to compensate should the other prove uncooperative.

The results were consistent with the notion of anticipatory perception. FD was larger in the low-impact (i.e., bad brakes) versus the high-impact (i.e., good brakes) condition. It was also larger in the pair versus alone condition. These finding are difficult to account for in terms of post-stimulus representational momentum because all the stimulus displays were basically the same. The only thing that varied was the anticipations participants had to generate with each button press in order to successfully control the stimulus' movements back and forth across the monitor.

Given the impact of planning on FD, the purpose of the present experiment was to investigate the extent to which planning interacts with stimulus factors such as implied friction. This question is important because researchers such as Proffitt (2006a,b) report that perception entails the energy demands of behaving in a particular environment, what Proffitt refers to as 'economy-of-action'. For example, while participants are able to accurately judge the pitch of a hill if the dependent variable is behavioral (i.e., they use an unseen hand to set the felt angle between two boards equal to the pitch of a hill), they tend to overestimate pitch if the dependent variable is perceptual (i.e., they set a picture of a hill equal to the perceived pitch of an actual hill). What is more, the magnitude of the overestimation increases as participants become fatigued. In short, these experiments reveal that perception entails planning demands. In light of these 'economy-of-action' effects in perception, the present experiment assessed whether such effects would manifest themselves in FD, despite the fact the demands are virtual (i.e., the required behaviors stay constant across changing demands).

Method

To test the impact of dynamic stimulus variables on planning, participants observed the movements of a square stimulus that moved back and forth across a computer monitor in one of three implied friction contexts: Low (i.e., square by itself), medium (i.e., square appeared to move across the top of a surface), and high (i.e., the square appeared to move between two surfaces). These stimuli were designed, to the pixel, after stimulus descriptions reported in Hubbard (1998). There were 36 participants. Half controlled the movements of the square themselves (via the key-press method of Jordan and Knoblich, 2004), while the other half observed the movements of the square as they were being controlled by another participant. This manipulation resulted in two categories of participants; namely, controllers and observers. Each participant experienced 20 trials of each implied-friction condition (i.e., low, medium, and high) in blocked fashion.

At an unpredictable moment during each trial, the square vanished, and the participant indicated the perceived vanishing point.

Results and Discussion

The difference between the actual and perceived vanishing point was determined for every trial, and trials entailing a difference larger than 70 pixels were excluded. Figure 1 depicts the average FD, in pixels, per condition. A 3 x 2 mixed ANOVA revealed that while neither of the main effects was statistically significant, the interaction was; $F(2, 68) = 3.8$, $p < .05$.

As can be seen in Figure 1, FD decreases with implied friction when one simply observes the movements of the stimulus. This pattern of FD is consistent with implied-friction effects reported in FD experiments in which stimulus movements are controlled solely by the computer (i.e., participants simply observe the movements). In contrast, Figure 1 also reveals that FD increases with increased implied-friction when one controls the stimulus. This reversal of the traditional implied-friction effect is consistent with the notion that perception entails planning content, what Proffitt (2006) refers to 'economy-of-action'. This finding is more remarkable in light of the fact that the impact each button press had on the velocity of the square was the same in all three implied-friction contexts. That is, the behavioral requirements were the same even though the stimulus implied different behavioral requirements.

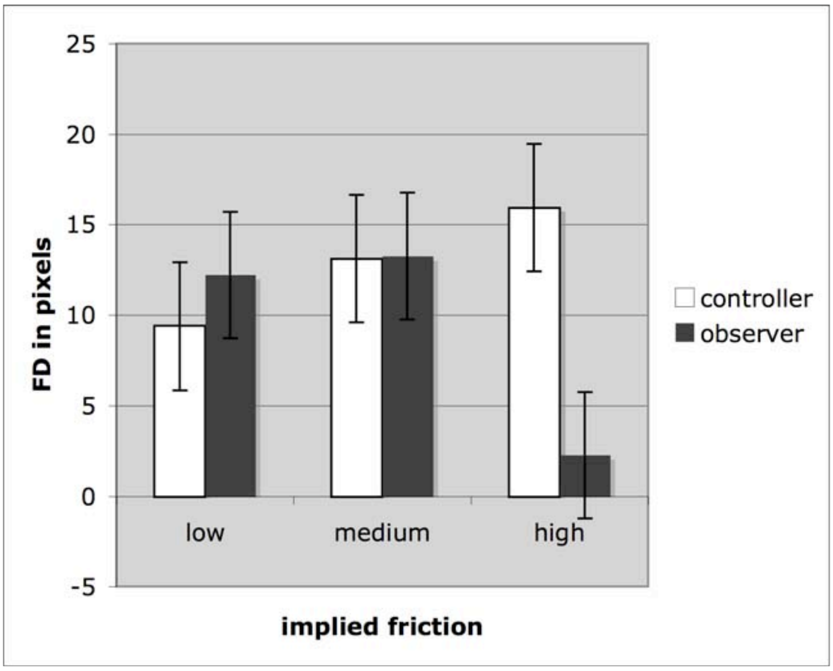

Fig. 1. FD in pixels as a function of role (i.e., controller versus observer) and degree of implied friction (i.e., low, medium, high).

These findings are hard to reconcile with the notion that FD constitutes a post-stimulus distortion of perceptual space brought on by representational momentum. The movement dynamics of the square were basically the same in the observer and controller conditions, as well as in each of the implied-friction conditions. Thus, it appears to be the case that in the observer condition, participants were experiencing the square as an object whose movements were simply succumbing to the laws of physics. In the controller condition however, they seemed to be experiencing the square as an object they were attempting to move through a medium, with increasing implied friction implying more necessary effort which, in turn, due to the notion of 'economy-of-action' lead to larger FD. This implies that perceptual space is not so much a straightforward metric regarding the spatial location of objects and events, but rather a *Lebenswelt* that is continuously constrained and contextualized by the plans one generates while attempting to interact with the world.

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