A perceptual repulsion from gravitational expectations of acceleration

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Abstract

It is often observed that we are biased to report and perceive what is more likely to be there. However, an opposite, repulsive effect has recently been reported in the visual domain, such that objects are more likely to be reported as decelerating when moving downwards. We wished to examine the nature of this effect to better understand the nuanced influences of expectation on perceptual decisions. Across three experiments, we replicate this effect, demonstrate that the bias has contributions from retinal space as well as contextual cues concerning object position, and present evidence that it has a perceptual locus. That perception can be repelled from our expectations opens a host of questions concerning the complex interactions between learning and perception.

Keywords: Motion Perception; Predictive Processing

Introduction

In visual perception, percepts are most commonly attracted toward prior expectations, such that expected stimuli are faster and more accurately reported (Pinto, van Gaal, de Lange, Lamme, & Seth, 2015), are more likely to be reported in ambiguous environments (Vandenbroucke, Fahrenfort, Meuwese, Scholte, & Lamme, 2016), and are better represented in the visual cortex (Teufel, Dakin, & Fletcher, 2018; Yon, Gilbert, de Lange, & Press, 2018). Assuming expectations are valid and calibrated to the current state of the environment, such attraction renders perception overall more veridical (Kok, Mostert, & de Lange, 2017; Press, Kok, & Yon, 2020).

However, Phan, Jörges, Harris, and Kingdom (2024) have reported a striking effect in the opposite direction, whereby people report downward moving objects as less accelerating than upward moving objects. This is a *repulsion away* from the expectation that gravity causes objects to accelerate downwards.

Here we asked two questions about this repulsion effect. First, is it driven by observation of the surrounding scene (sky vs ground), or alternatively by position (e.g. according to the retina)? Second, does it affect the perception of the location of objects in real time, or alternatively reflect decisional or postdictive processes (Dennett & Kinsbourne, 1992)?

Methods and Results

Exp 1: Replication of Phan et al. (2024)

Exp 1 presented participants (N=100) with upward- and downward-moving basketballs that accelerate, decelerate, or travel at a constant velocity. They were required to report whether the ball was accelerating or decelerating using key presses. Participants were recruited through the Prolific platform.

Following Phan et al.'s procedure, two screen durations (1000ms and 1500ms) and 11 equally spaced acceleration values within each screen duration were used. An approximately normal distribution of acceleration values were presented such that the majority of trials had objects moving around a constant velocity. For each participant, we fit psychometric curves to predict the participant responses from acceleration value, separately for upward and downward trials. From the psychometric curves, we extracted the point of subjective constant velocity (PSCV). Replicating Phan et al. (2024), we find that downward-moving trials have a more positive PSCV than upward-moving balls ($t(89) = -7.35$, $p < .001$; Figure 1 E1: Vertical). This demonstrates that people report downward moving balls as less accelerating than upward moving balls – a repulsion from the expectation that gravity causes objects to accelerate downwards.

Exp 2: Eye-centred vs world-centred frames of reference

Exp 1 shows a repulsive effect of the expectation of gravity on acceleration perception. However, there is more than one cue for the direction of gravity available to the participants. First the direction of motion on the retina (eye-centred frame of reference), and second the direction of motion within the contextual scene (world-centred frame of reference). While both of these influences may be mediated by similar statistical learning mechanisms, it is more likely the case for the latter. As such, a contextually-mediated repulsion would be especially interesting in light of the large number of learnt attraction effects in the literature. Exp 2 was designed to separate these influences.

To this end, we presented participants (N=68) with the same basketball context as Exp 1 but rotated through 90 degrees such that true gravity acts vertically and contextual gravity acts horizontally. Trials were shown both horizontally and vertically at a range of acceleration values and participants were asked to report whether they thought the ball was accelerating or decelerating. This study used a stopping rule based on the horizontal comparison ($BF > 3$ or $BF < \frac{1}{3}$).

In the vertical plane, we find that downward-moving trials have a more positive PSCV than upward-moving trials ($t(65) = -6.81$, $p < .001$, $BF > 3 \times 10^6$; Figure 1 E2: Vertical). In the horizontal plane, we also find that contextually downward-moving trials have a more positive PSCV than contextually upward-moving trials ($t(66) = -2.78$, $p < .01$, $BF = 4.58$; Figure 1 E2: Horizontal). Together, this suggests that the repulsion effect is generated both according to retinal and contextual space.

Exp 3: Perceptual repulsion affects representational momentum

While participants were consistently biased to report downward moving balls as less accelerating than upward-moving balls in Exp. 1 and 2, the bias could have a perceptual or decisional origin. That is, we may be biased to see downward moving balls as less accelerating, or we may be biased to report them as such to potentially correct for, and over-correct for, an opposing perceptual bias. If the bias is perceptual, but

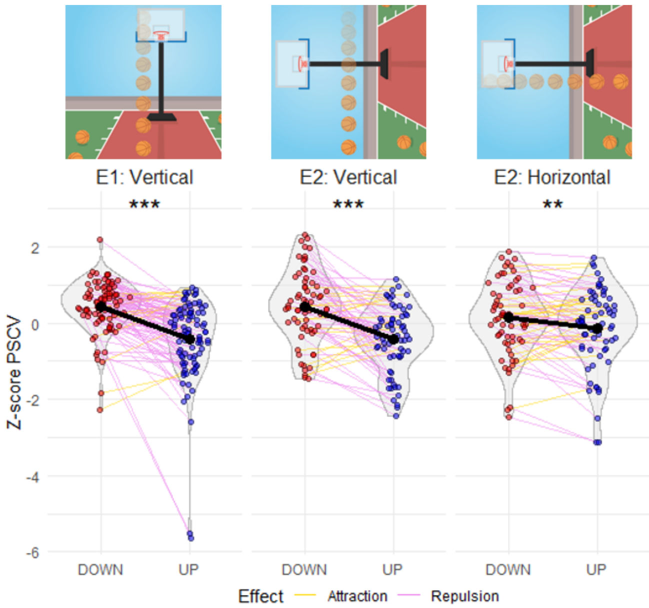

Figure 1: PSCV values from Exp 1 (left) and Exp 2 (middle and right) show that PSCV values for downward-moving stimuli are more positive than for upward-moving stimuli. This reflects a repulsion effect as participants are more likely to respond decelerating when objects are travelling downwards.

not if it is decisional, it may be seen in another task that does not require an explicit judgement about acceleration. In Exp. 3 we employed a perceptual reproduction task to distinguish these explanations.

Participants were presented with a grey background where black balls could travel vertically at a range of accelerations. The ball remained visible on the screen for 1000ms and flashed grey at a pseudorandom point along its motion. Once the ball had left the screen, participants could move their mouse to click the location of the flash. Literature on representational momentum indicates that people are biased to report objects as appearing further along their movement trajectory than they were probed, and this "perceptual overshoot" is stronger for faster-moving objects (Hubbard, 1993). Our reasoning was as follows: the more accelerating an object is perceived to be, the more the overshoot should increase as it moves along its trajectory. If upward moving-objects appear as more accelerating than downward-moving objects, this increase in the perceptual overshoot should be stronger for upward- than for downward-moving objects.

In order to compare the percepts between upward- and downward-moving stimuli, we computed the correlation between the distance the ball has travelled and the reported overshoot ($direction \times \frac{yclick - yflash}{screensize}$) for each participant and direction. Then we used a paired t-test to test whether there was a difference between the correlations for upward and downward trials. In an exploration sample (N=79), we found that the correlation between overshoot and distance was more negative for downward trials compared to upward trials ($t(78) = 2.40$, $p < .05$; Figure 2 Exploration Sample). In a follow up pre-registered replication (N=150), the effect was qualitatively similar (not significant with the preregistered two-tailed test, $t(149) = 1.89$, $p = .060$, but significant against a one-tailed cut-off, $p = .03$; Figure 2 Replication). This implies that downward moving stimuli are perceived as more negatively accelerating than upward moving stimuli, and that this repulsion from gravitational expectation affects the perception of object location in real time.

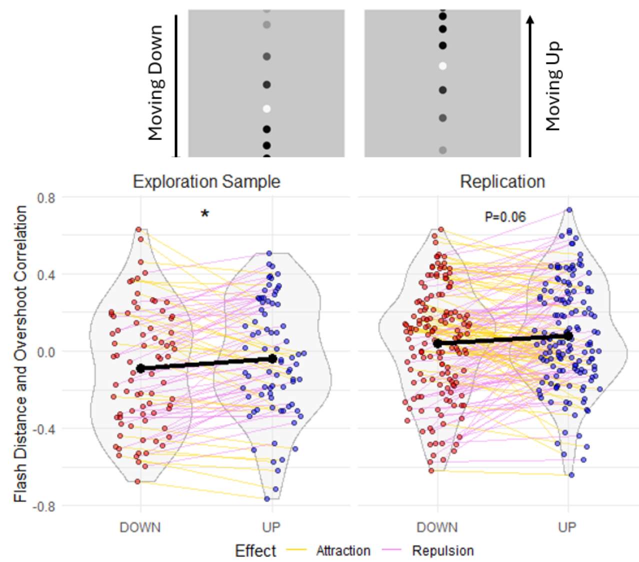

Figure 2: Correlation of overshoot and distance along the trajectory of a flash for upward- and downward-moving stimuli. A more positive correlation indicates a bias to report objects as accelerating.

Conclusion

We successfully replicated Phan et al's effect: a repulsion from perceptual expectations in the visual domain. We show that this effect reflects a combination of retinal and contextual space contribution, with evidence that it has a perceptual locus. Demonstrating that our visual perception can truly be repelled from our expectations. Alongside the host of demonstrations in the literature of attraction effects, models are now needed to explain when and why these distinct influences emerge.

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