Research Article

# Motion Perception Investigated Inside and Outside of the Laboratory

## Comparable Performances for the Representational Momentum and Representational Gravity Phenomena

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**Abstract:** Representational Momentum and Representational Gravity describe systematic perceptual biases, occurring for the localization of the final location of a moving stimulus. While Representational Momentum describes the systematic overestimation along the motion trajectory (forward shift), Representational Gravity refers to a systematic localization bias in line with gravitational force (downward shift). Those phenomena are typically investigated in a laboratory setting, and while previous research has shown that online studies perform well for different task, motion perception outside of the laboratory was not focused to date. Therefore, one experiment was conducted in two different settings: in a typical, highly controlled laboratory setting and in an online setting of the participants' choosing. In both experiments, the two most common trial types, implied motion stimuli and continuously moving stimuli, were used, and the influence of classical velocity manipulations (by varying stimulus timing and distance) was assessed. The data pattern across both experiments was very similar, indicating a robustness of both phenomena and indicating that motion perception can very well be studied outside the classical laboratory setting, opening a feasible possibility to diversify access to motion perception experiments everywhere.

**Keywords:** Representational Momentum, Representational Gravity, vision, motion perception, online, offline

In nearly every waking moment of our life, the perceptual system is confronted with ever-changing stimulations. The perception of a stimulus that changes its location over time has been investigated for a long time (e.g., Fröhlich, 1923) and is still of utmost interest (for recent reviews and discussion, see e.g., Burr & Thompson, 2011; Park & Tadin, 2018; Pei & Bensmaia, 2014). Research on human (motion) perception is typically conducted in a highly controlled laboratory setting. To understand the intricate ways in which the senses perceive and process the information they receive, it is important to exactly control the experimental situation to allow for a direct match of experimental manipulation and observed data pattern, as a high data quality is the necessary basis for the development and testing of theoretical ideas. Yet, while this allows researchers to work on and develop an understanding of the perceptual system with high precision, this comes with some costs. That is, access to these laboratories is restricted: not only for researches, as laboratory capacities are limited (this problem was made even more prominent due to the recent COVID-19 pandemic), but also for participants, as laboratories are typically only located in specific, populated areas such as cities. As much research can be conducted with a nowadays standard PC or laptop, research in the last two decades has more and more focused on the possibilities to conduct studies online (Birnbaum, 2004). While many different experimental paradigms have been successfully tested in online/web-based studies (Germine et al., 2012; Semmelmann & Weigelt, 2017), the perception of moving stimuli was not tested before to the best of my knowledge. This is especially interesting as characteristics and intraindividual differences of the observer (e.g., age, psychopathological differences) have been reported in the Representational Momentum literature (for discussions, see Hubbard, 2010, 2014), and a diverse field of participants might be more easily assessed with online studies. Therefore, in the present study, a typical motion perception experiment is conducted twice to investigate any potential influence of experimental setting.

The Representational Momentum (e.g., Freyd & Finke, 1984) and the Representational Gravity phenomena (e.g., Hubbard & Bharucha, 1988) are well-known biases for the localization of dynamic objects. When asked to localize the perceived offset of a dynamic stimulus, participants

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typically overestimate the final location, the offset, in motion direction (*Representational Momentum phenomenon*; for a discussion about the possible underlying mechanisms, see Hubbard, 2010; for a recent new framework, see Merz et al., 2022). Since its first discovery (Freyd & Finke, 1984), an abundance of research investigated the different moderating influences (for extensive reviews, see Hubbard, 2005, 2018). That is, the Representational Momentum phenomenon has been found with a continuously moving stimulus (continuous motion stimulus; e.g., Hubbard & Bharucha, 1988; Hubbard, 1990; Merz et al., 2022) or with a stationary stimulus that is sequentially presented in different locations that imply motion in a consistent direction (implied motion stimulus; e.g., Freyd & Finke, 1984, 1985; Merz et al., 2022). Additionally, the effect has been observed beyond the visual sensory modality, indicating a strong generalizability (e.g., tactile: Merz, Deller et al., 2019; Merz, Meyerhoff et al., 2019; e.g., auditory: Schmiedchen et al., 2013). One of the main influences of the Representational Momentum phenomenon is the effect of speed, and most studies demonstrated an increase of the shift with increasing speed (e.g., Hubbard & Bharucha, 1988; but see Munger & Owens, 2004; Müsseler et al., 2003; for an extensive discussion, see Hubbard, 2005, 2014).

While the Representational Momentum phenomenon describes the systematic forward shift in motion direction of moving targets, the Representational Gravity phenomenon describes a systematic downward shift in the direction of gravity for (moving) stimuli (for a recent review, see Hubbard, 2020). This downward shift is typically not influenced by the speed of the moving stimulus (e.g., Hubbard, 1990; Hubbard & Bharucha, 1988), but De Sá Teixeira et al. (2013) reported an indication of a slight decrease of the downward shift with increasing speed. Yet, as it is true for the Representational Momentum literature, no nonlaboratory studies exist in the Representational Gravity literature, therefore leaving any potential influence of experimental setting unclear up to now.

## The Present Study

In the present study, two experiments were conducted. The first experiment was conducted offline in a laboratory, as it is typical in the literature. In contrast, the second experiment was conducted online in a less controlled setting of the participants' choosing, and participants were able to complete the experiment from their own computer at their time of choice. Possible, random disturbances such as background noise/music could not be accounted for and prevented. In both experiments, participants estimated the final location of the two most common stimuli types in the Representational Momentum literature, an implied motion stimulus and a continuously moving stimulus. For the continuous motion stimulus, the stimulus shifted horizontally with each frame refresh of the computer screen, indicating a continuous horizontal motion, while for the implied motion stimulus, the stimulus was presented at five distinct stimulus locations, indicating a horizontal motion (for a visualization of both trial types, see Figure 1; for an overview about the trial types used in the Representational Momentum literature, see Hubbard, 2005, 2018). Additionally, the stimulus speed was systematically manipulated. For the continuous motion sequence, the size of the shift with each screen refresh was systematically manipulated, with larger shifts indicating a faster stimulus speed. For the implied motion sequence, the distance between adjacent stimulus presentations and the timing of the sequence (stimulus duration and interstimulus interval [ISI]) was systematically manipulated. That is, increasing stimulus distance (under otherwise identical timing conditions) or speeding up the timing of the sequence (under otherwise identical distance conditions) increased stimulus speed.

Concerning the typical data pattern, increasing stimulus speed normally increases the forward shift, an effect often replicated in the Representational Momentum literature (for a discussion, see Hubbard, 2005, 2018). Therefore, this data pattern was expected in the laboratory setting (Experiment 1), especially as the central features of the tasks (e.g., distance, ISI) are comparable to those of already published studies (e.g., Freyd & Finke, 1984, 1985; Hubbard, 1990). Yet, if the data pattern of Experiment 1 can be replicated in a less controlled setting (Experiment 2) was the main focus of the present study. That is, for Experiment 1, conducted in a controlled laboratory setting, an increase of the forward shift with increasing stimulus speed is expected, observed for both stimuli types. As for Experiment 2, conducted online, a similar pattern of an increasing forward shift with increasing velocity was expected.

## Experiment 1 (Laboratory)

In Experiment 1, Representational Momentum and Representational Gravity were assessed in a controlled, laboratory environment. Participants were seated in a small, experimental cabin, with little distraction, only equipped with a PC and screen to conduct the experiment, and a chin rest was used to keep the spatial distance between the monitor and the participants' head constant. This is a typical experimental setup, in line with the typical conventions in the literature (see Hubbard, 2005).

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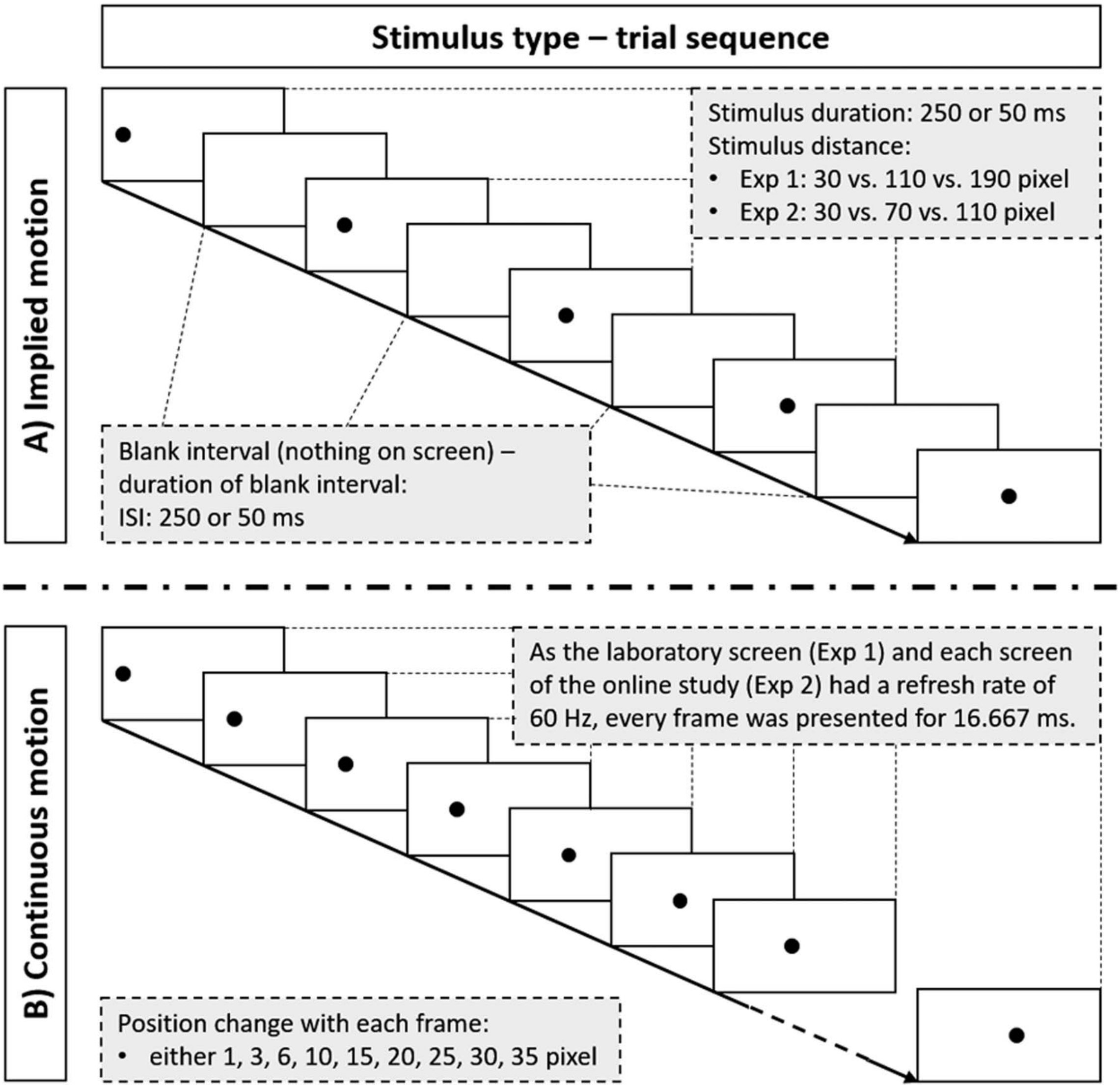

**Figure 1.** Graphical depiction of the motion stimulus for the (A) implied motion trials and (B) continuous motion trials. (A) For the implied motion stimulus, the stimulus was presented at five different locations on the screen, with short blank screens without the stimulus presented between successive presentations. All possible stimulus durations (50 and 250 ms), interstimulus intervals (ISI: 50 and 250 ms), and stimulus distances (Experiment 1: 30, 110 and 190 pixel; Experiment 2: 30, 70, and 110 pixel) were completely crossed. (B) For the continuous motion trial, the stimulus was always shown on the screen and changed its location by different magnitude (1 3, 6, 10, 15, 20, 25, 30, or 35 pixel) with each refresh of the computer screen. For more information, see the main text.

## Methods

### Participants

Visual shift scores on their own typically elicit medium to large effect sizes (*dz* around 0.6); therefore, at least 26 participants were aimed for to find the Representational Momentum phenomenon at the minimum ($\alpha < .05$; $1 - \beta > .90$; power analyses were run with G-Power 3.1.9.2, option "means: difference from constant"; Faul et al., 2009). To account for possible dropouts, $N = 30$ was chosen. Three participants were excluded from data analysis due to technical error and a high dropout of trials, indicating a lack of engagement in the task (for more information, see the Data Preparation section). The final sample (22 female, 5 male, 5 left-handed, mean age: 20.83 years – range between 18 and 26 years) consisted of 27 students from the University of Trier in exchange for partial course credit. Participants reported normal or corrected to normal vision and no color vision deficiencies.

### Design

For the implied motion sequence, the participants were tested in a two-factorial design with the within-participants

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factors of *stimulus timing* (stimulus duration and ISI: slow [both 250 ms] vs. middle [duration of 250 ms and ISI of 50 ms or duration of 50 ms and ISI of 250 ms] vs. fast [both 50 ms]) and *stimulus distance* (long [190 pixels] vs. medium [110 pixels] vs. short [30 pixels]). The nine combinations resulted in nine different overall speed conditions: 1.98 °/s (slow–short), 7.26 °/s (middle–short), 12.54 °/s (fast–short), 3.30 °/s (slow–medium), 12.10 °/s (middle–medium), 20.90 °/s (fast–medium), 9.90 °/s (slow–long), 36.31 °/s (middle–long), and 62.71 °/s (fast–long). For the continuous motion sequence, the participants were tested in a one factorial design with the within-participants factor of *stimulus speed* (horizontal change of location in pixels per frame refresh: 1 vs. 3 vs. 6 vs. 10 vs. 15 vs. 20 vs. 25 vs. 30 vs. 35 pixels). In visual angle, these speeds correspond to 1.98, 5.94, 11.88, 19.80, 29.70, 39.61, 49.51, 59.41, and 69.31 °/s, respectively. Participants were asked for both motion types to estimate the final location of the visual target stimulus, and shift scores (difference between actual and estimated final locations) were used as the dependent variable.

## Apparatus and Stimuli

The visual stimuli were presented on a 22″ screen (47.3 × 29.8 cm; 1680 × 1050 pixels; frame rate: 60 Hz) controlled by a standard PC. A chin rest was positioned at approximately 45 cm in front of the screen (so screen size corresponded to 55.45°). The visual target stimulus was a 20 × 20 pixels (corresponding to about 43 arc-min) white square (RGB value: 255,255,255) on a black background (RGB value: 0,0,0). The experiment was programmed with E-Prime 2.0, and JASP (Version 0.16; JASP Team, 2020) was used for frequentist and Bayesian data analyses (for an introduction about interpreting Bayesian ANOVA, see Van den Bergh et al., 2020).

## Procedure

For the implied motion trials, five successive presentations of the target stimulus (inducing stimuli), which implied either a consistent motion in the left-to-right or right-to-left direction, were presented. The horizontal distance between the successive presentations (30, 110, or 190 pixels) and the timing (stimulus duration of either 250 or 50 ms and ISI of either 250 ms or 50) were constant within one trial but varied across trials. The final location of the visual target stimulus, that is, the fifth location of the target, which had to be estimated, was restricted to an 80 × 60 pixels window centered on the center of the screen. Subsequently, the location of the first presentation of the target stimulus was 120, 440, or 760 pixels (depending on the 30, 110, or 190 stimulus distance condition, respectively) to the left (left-to-right motion direction) or right (right-to-left motion direction) of the final location. The *y*-axis value of the target stimulus was constant throughout the whole trial, resulting in a consistent, horizontal movement of the target stimulus.

For the continuous motion trials, the final location of the stimulus was selected as for the implied motion trials. The first presentation of the target stimulus was 450 pixels to the left (left-to-right motion direction) or right (right-to-left motion direction) of the final location (except 20 pixels and 35 pixels condition, for which the first location was 460 and 455 pixels, respectively, to the left or right) to keep the traveled distance for each condition approximately identical. With each screen refresh, the target stimulus was shifted 1, 3, 6, 10, 15, 20, 25, 30, or 35 pixels toward the final location. The stimulus was presented for 450, 150, 75, 45, 30, 23, 18, 15, or 13 screen frames, respectively, and given the 60 Hz refresh rate, this corresponded to 7,500, 2,500, 1,250, 750, 500, 383, 300, 250, or 217 ms.

For both implied motion and continuous motion trial types, a 600-ms blank interval was presented before target onset, and after the target disappeared, a 500-ms blank interval was presented before the mouse cursor, displayed as a crosshair, appeared at the center of the screen. The participant had to move the crosshair to the perceived final location of the visual target stimulus and indicate this location by pressing the left mouse button. Participants had no time constraints for giving their response, and the next trial started after a response was detected.

Both trial types were presented with identical instruction except for the description of the trial types. All instructions before the practice trials, as well as between the different experimental blocks, were provided via the experimental software. First, participants completed the implied motion trials, before then completing the continuous motion trials. Participants worked through 12 practice trials for both trial types (randomly selected from all possible trials), before then working through 192 implied motion trials or 144 continuous trials (16 repetitions per design cell). Note that the middle stimulus timing condition of the implied motion trials consisted of two distinct trial types, that is, a stimulus duration of 250 ms combined with an ISI of 50 ms, and vice versa. Both trial types were repeated 16 times, resulting in the 192 trials overall. The participants were given a chance for a break every 40 trials.

## Data Preparation

For one participant, responses to about half of the continuous motion trials were not collected due to a technical failure. Furthermore, for each participant, those trials in which the mouse cursor was not moved by the participant,

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that is, those trials in which the initial location and the final location of the mouse cursor were identical, were removed. It might have been the rare case that the estimation without any cursor movement was a conscious decision as the final location was actually perceived at the location at which the cursor appeared (the center of the screen in Experiment 1).[1] But it is much more likely that it was an accidental, erroneous mouse click or that it indicated a lack of engagement in the experiment. Participants needed to respond to get to the new trial, so just clicking the mouse without any movement was the fastest way to finish the task. Due to these criteria, 3.1% of trials were excluded from data analysis.[2] Additionally, I analyzed the number of trials still included per participant. Three participants, the participant with the technical error, but also two further participants (likely indicating a lack of engagement in the task), were above the 1.5 interquartile range below the first quartile (Tukey, 1977). Therefore, these three participants were excluded from data analysis.[3]

To investigate the Representational Momentum phenomenon, shift scores indicate the difference between the actual and estimated final locations of the visual target stimulus along the horizontal $x$-axis (as the stimulus always moved horizontally). A positive value indicates an overestimation in motion direction, whereas a negative value indicates an estimation against the direction of motion. Shift scores in the direction of motion are also known as M-displacement in the literature (e.g., Hubbard & Bharucha, 1988). To investigate the Representational Gravity phenomenon, shift scores indicate the difference between the actual and estimated final locations of the visual target stimulus along the vertical $y$-axis. A negative value indicates a downward shift (Representational Gravity), whereas a positive value would indicate an upward shift. Shifts in the orthogonal direction of motion direction are also known as O-displacement in the literature (e.g., Hubbard & Bharucha, 1988). In our design, M-displacement scores coincide with displacement along the horizontal axis (subsequently Representational Momentum), whereas O-displacement scores coincide with displacement along the vertical axis (subsequently Representational Gravity). The relevant information (actual final stimulus location, estimated location by the participants) was collected in pixel but then transferred into visual angle scores in arcminutes (arcmin) for analysis.

## Results

### Representational Momentum

#### *Implied Motion*

Estimates of Representational Momentum were compared to zero, and a significant forward shift was observed, $t(26) = 7.84$, $p < .001$, $d = 1.51$, $BF_{10} = 533{,}197$, indicating the expected Representational Momentum phenomenon (for a visualization of the results, see Figure 2; for mean shift scores, see Table 1). A 3 (stimulus timing: slow vs. middle vs. fast) × 3 (stimulus distance: short vs. medium vs. long) repeated-measures ANOVA was conducted, and horizontal shift scores were used as a dependent variable. For violations of sphericity, Greenhouse–Geisser corrections were used. The results indicated a main effect of stimulus timing, $F(1.14, 29.68) = 36.81$, $p < .001$, $\eta_p^2 = .586$, and polynomial contrast coding revealed a linear increase of the forward shift with faster stimulus timing (slow: 18.68 arcmin; middle: 30.47 arcmin; fast: 53.38 arcmin), $t(52) = -8.437$, $p < .001$. Additionally, the main effect of stimulus distance was significant, $F(1.26, 32.74) = 7.16$, $p = .008$, $\eta_p^2 = .216$, and Helmert contrast coding revealed a significant difference between the long distance (40.24 arcmin) and the mean of the medium and short distance (31.14 arcmin), $t(52) = 3.782$, $p < .001$, but no difference between the medium (31.36 arcmin) and short (30.93 arcmin) distances, $t(52) = 0.15$, $p = .879$. Additionally, the interaction between the two factors was significant, $F(2.29, 59.46) = 6.29$, $p = .002$, $\eta_p^2 = .195$. A closer inspection of the data in Figure 2 indicated an ordinal interaction, that is, the effect of stimulus timing increased with increasing stimulus distance. A significant difference between the fast and slow conditions was observed for the long, $t(26) = 5.85$, $p < .001$, $d = 1.13$, $BF_{10} = 5{,}405$, and the short distance condition, $t(26) = 6.79$, $p < .001$, $d = 1.31$, $BF_{10} = 49{,}651$, yet the difference was significantly larger in the long compared to the short distance condition, $t(26) = 3.00$, $p = .006$, $d = 0.58$, $BF_{10} = 7.36$. The same Bayesian ANOVA revealed similar results, with the best model being the model including both main effects and the interaction ($BF_M = 6.14$).

#### *Continuous Motion*

Estimates of Representational Momentum were compared to zero, and as with the implied motion stimuli, a significant

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[1] The final location was restricted to an 80 × 60 pixel window centered on the center of the screen. Therefore, 4800 possible final locations existed, but participants only responded to 336 experimental trials, resulting in a 7% chance for each participant that one such trial occurred during their experiment.

[2] The exclusion of these trials did not significantly change the results of the main 3 × 3 repeated-measures ANOVA for implied motion trials and the main one-factorial repeated-measures ANOVA of continuous motion trials reported in the Results section.

[3] The exclusion of these three participants did not significantly change the results of the main 3 × 3 repeated-measures ANOVA for implied motion trials and the main one-factorial repeated-measures ANOVA of continuous motion trials reported in the Results section.

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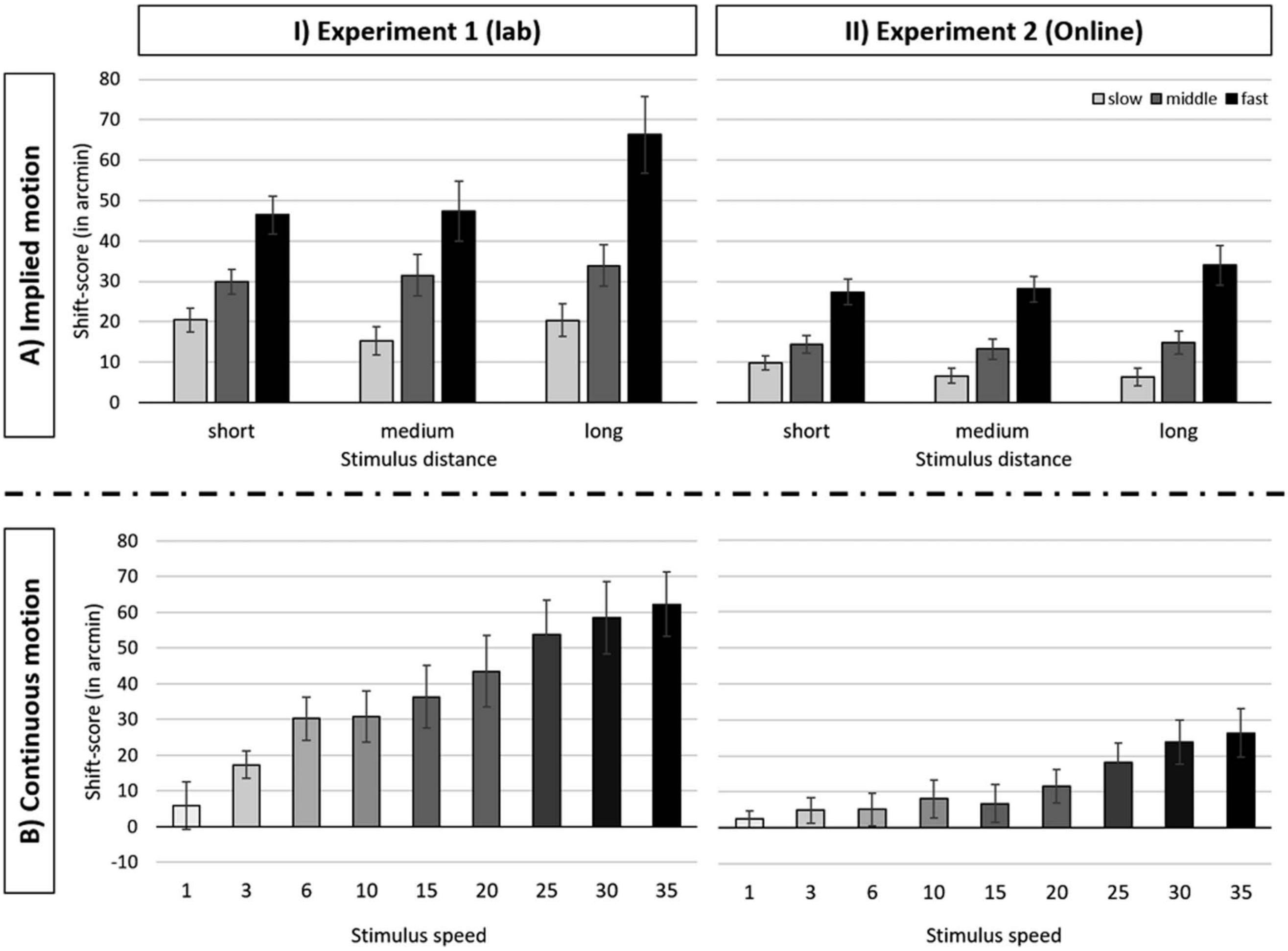

**Figure 2.** Graphical depiction of the motion stimulus for the (A) implied motion trials and (B) continuous motion trials. (A) For the implied motion stimulus, the stimulus was presented at five different locations on the screen, with short blank screens without the stimulus presented between successive presentations. All possible stimulus durations (50 and 250 ms), interstimulus intervals (ISI: 50 and 250 ms), and stimulus distances (Experiment 1: 30, 110 and 190 pixel; Experiment 2: 30, 70, and 110 pixel) were completely crossed. (B) For the continuous motion trial, the stimulus was always shown on the screen and changed its location by different magnitude (1 3, 6, 10, 15, 20, 25, 30, or 35 pixel) with each refresh of the computer screen. For more information, see the main text.

forward shift was observed, $t(26) = 5.61$, $p < .001$, $d = 1.08$, $BF_{10} = 3{,}059$, indicating the typical Representational Momentum phenomenon. A one-factorial repeated-measure ANOVA with the factor stimulus speed (1 vs. 3 vs. 6 vs. 10 vs. 15 vs. 20 vs. 25 vs. 30 vs. 35 pixels per frame) was conducted (for mean shift scores, see Table 2). The main effect of stimulus speed was significant, $F(2.04, 52.92) = 14.65$, $p < .001$, $\eta_p^2 = .360$, and polynomial contrast coding revealed a significant linear trend, $t(208) = 10.68$, $p < .001$. As indicated in Figure 2, the forward shift increases with increasing stimulus speed, as expected and found in many studies using visual stimuli (e.g., Hubbard, 2005, 2018). The same Bayesian ANOVA indicates the model with the main effect condition fitted much better the data than the model without the main effect ($BF_{01} = 8.93\text{e}^{13}$).

Estimates of Representational Gravity were compared to zero, and a significant downward displacement was demonstrated for both trial types, implied motion (6.05 arcmin), $t(26) = 4.38$, $p < .001$, $d = 0.84$, $BF_{10} = 161.2$, and continuous motion (5.04 arcmin), $t(26) = 3.18$, $p = .004$, $d = 0.61$, $BF_{10} = 10.58$, indicating the existence of the Representational Gravity phenomenon. A 3 (stimulus timing: slow vs. middle vs. fast) × 3 (stimulus distance: short vs. medium vs. long) ANOVA was conducted for the implied motion stimuli, and a one-factorial ANOVA with the factor stimulus speed (1 vs. 3 vs. 6 vs. 10 vs. 15 vs. 20 vs. 25 vs. 30 vs. 35 pixels per frame) was conducted for the continuous motion stimuli to investigate the existence of the Representational Gravity phenomenon. Yet, none of the main effects and interaction for implied motion stimuli, $F\text{s} < .95$, $p > .361$, and for continuous motion stimuli, $F(4.71, 122.42) = 1.82$, $p = .117$, were significant, indicating no influence of stimulus speed on the downward displacement. In line with this, the same Bayesian

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**Table 1.** Implied motion trials: mean shift scores (*SD*s in brackets) as a function of stimulus distance (short vs. medium vs. long) and stimulus timing (slow vs. middle vs. fast) for Representational Momentum and Representational Gravity scores in Experiment 1 and Experiment 2

| | Short | | | Medium | | | Long | | |
|---|---|---|---|---|---|---|---|---|---|
| | Slow | Middle | Fast | Slow | Middle | Fast | Slow | Middle | Fast |
| Representational Momentum (horizontal shift scores)* | | | | | | | | | |
| Experiment 1 (laboratory) | 20.41 (15.75) | 25.97 (15.64) | 46.42 (24.56) | 15.22 (18.09) | 31.49 (26.88) | 47.36 (38.78) | 20.40 (21.13) | 33.94 (26.21) | 66.37 (49.26) |
| Experiment 2 (online) | 9.84 (9.31) | 14.43 (12.12) | 27.39 (17.93) | 6.61 (10.58) | 13.22 (14.16) | 28.07 (17.40) | 6.26 (12.22) | 14.89 (15.72) | 33.96 (27.33) |
| Representational Gravity (vertical shift scores)** | | | | | | | | | |
| Experiment 1 (laboratory) | 5.82 (7.03) | 7.82 (6.02) | 6.11 (9.64) | 4.94 (5.99) | 6.33 (7.56) | 6.20 (13.54) | 5.84 (7.60) | 6.58 (8.57) | 4.82 (12.46) |
| Experiment 2 (online) | 2.55 (3.70) | 2.92 (3.62) | 2.11 (4.69) | 1.82 (5.29) | 2.42 (4.21) | 2.12 (7.53) | 2.29 (5.30) | 1.27 (4.27) | 1.76 (6.92) |

*Note.* *Positive values indicate a forward shift, and negative values indicate a backward shift. **Positive values indicate a downward displacement, and negative values indicate an upward displacement.

ANOVAs resulted in comparable results, with the null model being the best fitting model (implied motion: $BF_M = 18.21$; continuous motion: $BF_M = 3.33$), indicating no influence of any main effect or interaction.

## Discussion

In Experiment 1, the influence of stimulus speed on the localization of the final location of a dynamic stimulus was investigated in a standard laboratory setting. In line with a large number of existing reports in the literature, an increase of the perceptual forward shift with increasing speed was found (e.g., Hubbard & Bharucha, 1988; Hubbard, 2005, 2018). That is, for the implied motion sequence, using faster stimulus timings and increasing stimulus distance, which therefore increased stimulus speed, lead to an increase of the forward shift. Similarly, for the continuous motion trials, increasing stimulus speed (by increasing the location change with each monitor refresh) leads to an increase of the forward shift. These results are in line with a large amount of findings in the literature and fit the a priori expectations for Experiment 1. Additionally, a Representational Gravity effect was observed, which was not influenced by stimulus speed, in line with the existing findings in the literature (e.g., Hubbard, 1990; Hubbard & Bharucha, 1988).

# Experiment 2 (Online)

In Experiment 2, Experiment 1 was replicated in a less controlled, online setting by using the experimental software PsychoPY 3 and its in-build online option PsychoJS (Peirce et al., 2019). Participants could complete the study whenever and wherever they would want to and were only restricted to use a laptop/computer to conduct the experiment (no smartphone). With this transfer, some notable adjustments had to be incorporated into the experiment. First, with PsychoJS, which is a JavaScript-based programming of the experiment to allow the presentation of stimuli with an internet browser, the location of the mouse cursor cannot be manipulated. Therefore, presenting the mouse cursor at

**Table 2.** Continuous motion trials: mean shift scores (*SD*s in brackets) as a function of stimulus speed (1 vs. 3 vs. 6 vs. 10 vs. 15 vs. 20 vs. 25 vs. 30 vs. 35 pixels per frame) for Representational Momentum and Representational Gravity scores in Experiment 1 and Experiment 2

| | 1 | 3 | 6 | 10 | 15 | 20 | 25 | 30 | 35 |
|---|---|---|---|---|---|---|---|---|---|
| Representational Momentum (horizontal shift scores)* | | | | | | | | | |
| Experiment 1 (laboratory) | 5.94 (34.43) | 17.34 (19.68) | 30.25 (31.55) | 30.89 (37.07) | 36.30 (45.79) | 43.49 (51.89) | 53.73 (49.91) | 58.48 (52.68) | 62.22 (46.80) |
| Experiment 2 (online) | 2.39 (13.45) | 4.85 (20.01) | 5.10 (25.46) | 8.04 (29.33) | 6.72 (29.30) | 11.56 (26.10) | 18.10 (30.47) | 23.87 (34.17) | 26.35 (37.75) |
| Representational Gravity (vertical shift scores)** | | | | | | | | | |
| Experiment 1 (laboratory) | 6.64 (8.57) | 6.84 (7.57) | 3.65 (6.33) | 3.70 (9.01) | 4.72 (10.17) | 6.52 (12.00) | 5.57 (10.63) | 2.42 (11.10) | 5.30 (12.55) |
| Experiment 2 (online) | 3.28 (5.01) | 1.43 (5.17) | 2.91 (7.21) | 2.48 (6.85) | 1.96 (6.07) | 1.61 (6.67) | 1.19 (7.35) | 1.59 (7.93) | 2.22 (8.63) |

*Note.* *Positive values indicate a forward shift, and negative values indicate a backward shift. **Positive values indicate a downward displacement, and negative values indicate an upward displacement.

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the center of the screen after the stimulus was presented was not possible, but which is typical in the classical Representational Momentum experiments. This was at least partially accounted for by asking participants to initiate each trial by clicking on a small square, centrally presented, therefore making sure that at least for each trial, the mouse cursor was positioned approximately at the center of the screen at the beginning of the trial. Yet, this change made Experiment 2 a self-paced experiment (i.e., the new trial did not start after a response for the previous trial was detected, but after an extra click on a centrally presented square). Note that the visibility of the mouse can be manipulated; therefore, the mouse was not visible during the stimulus presentation, identical to Experiment 1.

Second, I added two procedures to assess participants' actual screen size and viewing distance to infer actual visual angles of the participants (following Li et al., 2020).[4] To make meaningful comparisons between the two experiments, two different approaches can be taken. The first approach is to program the experiment in visual angle, that is, stimulus presentation is dependent on the participants' screen size/viewing distance. Yet, this opens the possibility that the stimuli could not be completely presented on the actual screen used by the participants given their actual viewing distance. In fact, as the analysis of visual angles in Experiment 2 shows, for none of the participants, the experimental setup as presented in Experiment 1 could have been presented in terms of visual angle (for a detailed description and analysis of the screen scale, viewing distance, and visual angle data of Experiment 2, see ESM 1). The second approach, which was used for Experiment 2, was to make sure that the all stimuli can be presented on the actual laptop/computer screen. Then, actual stimulus speed in visual angle can be calculated, and subsequently comparable speeds can be matched across experiments. For the continuous motion display, shift scores continuously increase with increasing stimulus speed; therefore, this matching procedure allows for a meaningful comparison of the size of the effects across experiments.[5] This approach was taken for Experiment 2.

To ensure the complete presentation of all stimulus types, the distances traveled for the implied motion trials had to be adjusted. In the long distance condition of Experiment 1 (190 pixels), the stimulus traveled 760 pixels per trial on either left or right side of the screen, as the final location was fixed to be approximately at the center of the screen. Therefore, this needed a horizontal screen size of at least 1,600 pixels to be completely presented. Yet, as the data of the prestudy indicated, only for five (of the 32) participants, the long distance condition could have been presented (see the Electronic Supplementary Material, ESM 1). Therefore, the traveled distances were adjusted, and the middle distance of Experiment 1 (110 pixels) was taken as the long distance in Experiment 2. Yet, to keep the experimental design comparable between Experiment 1 and Experiment 2, a middle distance of 70 pixels was used in Experiment 2.

## Methods

### Participants

The same sample size as in Experiment 1 was calculated. In contrast to Experiment 1, the sample size was slightly increased to account for a likely higher number of dropouts and is suggested for online experiments in general (e.g., Reimers & Stewart, 2015). Therefore, a sample size of $N = 36$ (in Experiment 1: $N = 30$) was chosen. Four participants were excluded from data analysis due to a high dropout of trials, indicating a lack of engagement in the task (for more information, see the Data Preparation section). One further participant was excluded since the screen only used a 30-Hz refresh rate. Since timing/programming was dependent on 60 Hz (which is typical for most computer screens and which was registered from all participants in the online prestudy), this participant was also excluded. The final sample (27 female, 0 diverse, 4 male; 6 left-handed; mean age: 22.03 years – range between 18 and 35 years) consisted of 31 new students from the University of Trier in exchange for partial course credit. All participants except for two reported normal or corrected to normal vision, and none reported color vision deficiencies.

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[4] I thank an anonymous reviewer for pointing me to this procedure.

[5] For the implied motion display, this matching procedure could not be used to compare the shift scores across experiments. In contrast to the continuous motion display in which shift scores systematically increases with increasing speed, this is not the case for the implied motion stimulus. For continuous motion displays, the smallest shift score was evidenced for the slowest condition, the second smallest shift score was evidenced for the second slowest condition, and so on. For implied motion stimuli, shift scores increase with increasing stimulus distance and stimulus timing (which is a way to manipulate speed within an implied motion sequence), yet the two factors also interact, indicating that overall speed is not the only central influence on perceived location in implied motion displays. For example, the fourth slowest speed condition (fast–short combination with an overall speed of 9.90 °/s) resulted in the third fastest shift score (46.41 arcmin) or the second slowest speed condition (middle–short combination with an overall speed of 3.30°/s) resulted in the fourth smallest shift score (25.97 arcmin).

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### Design, Apparatus and Stimuli, Procedure, and Data Preparation

The design, apparatus and stimuli, procedure, and data preparation were identical to Experiment 1 with the following exceptions.

The participants were asked to use a computer or laptop of their choosing, and no tablet, touchscreen, or smartphone was allowed. If an operating system for a mobile device was detected, the experiment was not started. The experiment was programmed with PsychoPy and its build-in online translation PsychoJS (Peirce et al., 2019), and data collection was done via pavlovia.org. The final experimental setups were different for the participants – in the following, the number of participants is given in brackets. Participants used the touchpad of a laptop as mouse (18) or an external computer mouse (13) following self-report. As operation system, the Apple Mac OS (6) and Microsoft windows (25), and as browser, Google Chrome (20), Safari (3), and Mozilla Firefox (8) were detected. All screens used a 60-Hz refresh rate, yet resolutions differ strongly between participants: 1920 × 1080 (5), 1680 × 1050 (2), 1600 × 900 (2), 1536 × 864 (5), 1450 × 816 (1), 1440 × 900 (4), 1368 × 912 (1), 1366 × 768 (2), 1280 × 720 (8), and 1024 × 1366 (1). The shape and size of the target were adjusted to account for the likely smaller resolutions and likely smaller screens as used in Experiment 1, and a 15 × 15 pixels white circle was used. Additionally, a 15 × 15 pixels white square was used to start the trial. Naturally, no chin rest was used, and no further instructions about seating position or so were given.

Before the assessment of perceived location, the screen size and viewing distance procedures were conducted (for exact details on these two procedures, see Li et al., 2020). For the screen size procedure, participants were asked to match the size of a virtually presented credit card with the size of an actual credit card (or cards with identical size – for example, their student card that is identical in size as a typical credit card). For the viewing distance procedure, participants were asked to focus on a fixation cross with their left eye (right eye closed) and then to press the space bar when a moving circle was not visible anymore. Participants estimated the location at which the stimulus was not perceived anymore five times, and the average was calculated. Since viewing distance might have systematically changed during the course of the experiments (about 30 min), the viewing distance procedure was conducted three times: at the beginning of the experiments following the screen size procedure, after the implied motion trials, and at the end of the experiment after the continuous motion trials. The analysis of both procedures is reported in ESM 1, in which also no effect of measurement point was observed. Therefore, averaged viewing distance across the three measurement points was used to transform all information from pixels into visual angle.

The trial procedure for location estimation trials was slightly adapted. Each trial started with the presentation of the square at the center of the screen. The mouse cursor in the form of the standard computer pointer was presented, and the participants were asked to click on the square to start the trial. The rest of the trial was identical to Experiment 1 (600 ms blank, presentation of either implied motion or continuous motion stimulus, 500 blank, target localization with the help of the computer mouse), except that participants had to respond within 3,000 ms; otherwise, the trial was terminated and a new trial began. Note that the mouse was only presented when an action was required (either clicking on the square to start a trial or when responding to the final location of the target stimulus), comparable to Experiment 1. For the implied motion trials, the stimulus distances between stimulus presentations of 30, 70, and 110 pixels were used. For the continuous motion trials, only 9 (each speed was presented once) instead of 12 practice trials were presented. The chance for a break every 40 trials was deleted, as the experiment was now self-paced.

The data preparation criteria were identical to Experiment 1; additionally, if participant did not respond within 3,000 ms, no response was detected, and therefore, this trial was necessarily excluded from data analysis (0.82% of trials). Additionally, if the initial and indicated locations of the participants were identical, these trials were also excluded (5.02% of trials). As in Experiment 1, I analyzed if the exclusion of trials occurred for some participants more often, indicating a general lack of engagement in the task. Four participants were therefore excluded. In ESM 1, any potential influence of time of conductance and the actual response setup (touchpad or computer mouse) are reported.

## Results

### Representational Momentum

*Implied Motion*

As in Experiment 1, estimates of Representational Momentum were compared to zero, and a significant forward shift was found (17.18 arcmin), $t(30) = 7.49$, $p < .001$, $d = 1.34$, $BF_{10} = 567{,}530$, indicating the expected Representational Momentum phenomenon (for a visualization of the results, see Figure 2; for mean shift scores, see Table 1). Once again, a 3 (stimulus timing: slow vs. middle vs. fast) × 3 (stimulus distance: short vs. medium vs. long) repeated-measures ANOVA was conducted, shift scores were used as a dependent variable, and for violations of

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sphericity, Greenhouse–Geisser corrections were used. As in Experiment 1, the results indicated a main effect of stimulus timing, $F(1.17, 35.18) = 44.87$, $p < .001$, $\eta_p^2 = .599$, and polynomial contrast coding revealed a linear increase of the forward shift with faster stimulus timing (fast: 29.81 arcmin; middle: 14.18 arcmin; slow: 7.57 arcmin), $t(60) = -9.23$, $p < .001$. Yet, although the visual inspection of Figure 2 would indicate a similar data pattern between both experiments, the main effect of stimulus distance did not reach significance, $F(1.37, 41.10) = 2.47$, $p = .114$, but the interaction between the two factors did, $F(2.07, 62.07) = 4.28$, $p = .017$, $\eta_p^2 = .125$. As for Experiment 1, a closer inspection of the data in Figure 2 indicated an ordinal interaction, that is, the effect of stimulus timing increased with increasing stimulus distance. A significant difference between the fast and slow conditions was observed for the long distance condition, $t(30) = 5.77$, $p < .001$, $d = 1.04$, $BF_{10} = 7{,}106$, and the short distance condition, $t(30) = 6.86$, $p < .001$, $d = 1.23$, $BF_{10} = 118{,}559$, yet the difference was significantly larger in the long compared to the short distance condition, $t(30) = 2.67$, $p = .012$, $d = 0.48$, $BF_{10} = 3.80$. This nicely matches the results of Experiment 1. The same Bayesian ANOVA revealed the likelihood of the data for the model with the main effect of stimulus timing to be highest, $BF_M = 18.21$.

#### Continuous Motion

Estimates of Representational Momentum were compared to zero, and as with the implied motion stimuli, a significant forward shift was observed (11.89 arcmin), $t(30) = 2.95$, $p = .006$, $d = 0.53$, indicating the typical Representational Momentum phenomenon. As in Experiment 1, a one-factorial repeated-measure ANOVA with the factor stimulus speed (1 vs. 3 vs. 6 vs. 10 vs. 15 vs. 20 vs. 25 vs. 30 vs. 35 pixels per frame) was conducted (for mean shift scores, see Table 2). As in Experiment 1, the main effect of stimulus speed was significant, $F(2.33, 69.78) = 7.31$, $p = .001$, $\eta_p^2 = .196$, and polynomial contrast coding revealed a significant linear trend, $t(240) = 7.24$, $p < .001$. These results were supported by the same Bayesian ANOVA which revealed the model including the main effect to be the best fitting model, $BF_M = 1.06 {*} e^6$. Once again, as indicated in Figure 2, the forward shift increases with increasing stimulus speed, as observed in the laboratory setting.

### Representational Gravity

Estimates of Representational Gravity were compared to zero, and for both stimulus motions, a descriptive downward displacement was observed indicating Representational Gravity. This downward displacement reached significance for implied motion stimuli (2.14 arcmin), $t(30) = 3.00$, $p = .005$, $d = 0.54$, $BF_{10} = 7.47$, and continuous motion stimuli (2.07 arcmin), $t(30) = 2.17$, $p = .038$, $d = 0.39$, $BF_{10} = 1.47$. As for Experiment 1, a 3 (stimulus timing: slow vs. middle vs. fast) × 3 (stimulus distance: short vs. medium vs. long) ANOVA was conducted for the implied motion stimuli, and a one-factorial ANOVA with the factor stimulus speed (1 vs. 3 vs. 6 vs. 10 vs. 15 vs. 20 vs. 25 vs. 30 vs. 35 pixels per frame) was conducted for the continuous motion stimuli to investigate the influence of stimulus speed on the Representational Gravity phenomenon. Once again, none of the main effects and interaction for both implied motion stimuli, $F\text{s} < 1.84$, $p < .168$, and continuous motion stimuli, $F(5.47, 162.54) = 0.74$, $p = .608$, were significant, indicating no influence of stimulus speed on the downward displacement as in Experiment 1. In line with this, the respective Bayesian ANOVA indicated the best model to be the null model for both implied motion ($BF_M = 27.52$) and continuous motion ($BF_M = 67.99$).

### Between-Experiment Comparison

The design of Experiment 2 makes a direct comparison between Experiment 1 and Experiment 2 possible. The idea for this comparison is to identify for each participant in Experiment 2 the conditions that match the actual speeds used in Experiment 1. This procedure makes a comparison for the continuous motion display straightforward as, for this motion stimulus, the data in the present study (Figure 2) and other published data indicate a continuous increase with increasing stimulus speed (e.g., Hubbard, 1990). Therefore, in a first step, the presented speeds in Experiment 1 were transformed into the speed in °/s for the nine different conditions in Experiment 1. For the continuous motion trials, this resulted in speeds of 1.98° (1 pixels), 5.94 °/s (3 pixels), 11.88 °/s (6 pixels), 19.80 °/s (10 pixels), 29.70 °/s (15 pixels), 39.61 °/s (20 pixels), 49.51 °/s (25 pixels), 59.31 °/s (30 pixels), and 69.31 °/s (35 pixels). In a next step, for each participant in Experiment 2 individually, the actual stimulus speeds in °/s for each of the nine conditions were calculated. Following this, nine new variables were created based on actual stimulus speed in Experiment 1 (in °/s). That is, for each participant in Experiment 2, the condition in which the speed was closest to the speed in Experiment 1 was selected and added. For example, to match the 29.70 °/s (15 pixels) speed condition for continuous motion trials in Experiment 1, the speed, which was closest to this speed, was chosen for each participant individually. That is, for one participant, this might have been the 25 pixels condition, while for another, this might have been the 10°/s condition because of their specific combination of screen size and viewing distance. The newly created conditions were then analyzed to see if this matching resulted on average in comparable speeds between Experiments 1 and 2. Therefore, one sample t-test was conducted, with the difference between the to-be-matched speed (in °/s; from Experiment 1) and the

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matched conditions speeds (in °/s; from Experiment 2) as a dependent variable (see Table 3). If these differences were not different from 0 (the criterion was $p > .05$, but also that the likelihood of null hypothesis is more than three times higher than the alternative hypothesis, that is, $BF_{01}$ is bigger than 3), this indicates that the matching procedure was successful, and matched across all participants in Experiment 2, and a comparable speed was presented as for Experiment 1. As indicated in Table 3, for implied motion trial, this procedure was successful for four speed conditions (5.94 °/s, 11.88 °/s, 19.80 °/s, and 29.70 °/s). For these successful conditions, the participants' shift scores for the individual matching speeds were used for the between-experiment comparison.

To compare Representational Momentum across both experiments, a 2 (Experiment: Experiment 1 vs. Experiment 2) × 4 (speed: 5.94 °/s vs. 11.88 °/s vs. 19.80 °/s vs. 29.70 °/s) ANOVA was conducted, and the shift scores in arcmin were used as a dependent variable. A main effect of speed was observed, $F(2.00, 112.18) = 8.38$, $p < .001$, $\eta_p^2 = .130$, in line with the observed data in the experiments individually, with increasing shift scores along with increasing stimulus speed. Interestingly, a main effect of the experiment was observed, $F(1, 56) = 6.946$, $p = .011$, $\eta_p^2 = .110$, with weaker forward shifts observed for Experiment 2 (8.28 arcmin) than for Experiment 1 (28.02 arcmin). No interaction was observed, $F(2.00, 112.18) = 1.16$, $p = .318$, and this result was supported by the Bayesian ANOVA which indicated the model with both main effects to be the best fitting model ($BF_M = 10.0$). To analyze Representational Gravity scores, the same 2 (Experiment: Experiment 1 vs. Experiment 2) × 4 (speed: 5.94 °/s vs. 11.88 °/s vs. 19.80 °/s vs. 29.70 °/s) ANOVA was conducted with downward displacement scores as a dependent variable. None of the main effects were significant, $F < 2.74$, $p > .103$, but a significant interaction was indicated, $F(3, 186) = 4.66$, $p = .004$, $\eta_p^2 = .077$. Yet, this was not supported by the same Bayesian ANOVA, which indicated that the model including both main effects and the interaction ($BF_M = 3.09$) was just barely different from the model with only the main effect of experiment ($BF_M = 1.27$) or even the null model (without any effect, $BF_M = 1.21$).

## Discussion

The results of the online conducted Experiment 2 are very similar to the results observed in the laboratory setting. That is, with increasing speed, the forward shift increased, and that was observed for both trial types – and, more interestingly, for both experimental contexts. That is, similar manipulations lead to similar changes of the effect, indicating no qualitatively meaningful influence of experiment setting on the Representational Momentum phenomenon. Similarly, the Representational Gravity phenomenon could be observed for both experimental settings. Even more, the direct comparison between both experiments indicated only a main effect of experiment for the Representational Momentum scores. That is, stronger shift scores were observed in Experiment 1 than in Experiment 2. Yet, the pattern of results (increasing stimulus speed leads to increasing forward shift) was comparable in size for both contexts. As for Representational Gravity, the results were unclear, as neither the existence nor an absence of an effect of experimental context could be conclusively supported by the data. Yet, what is clear is that Representational Gravity was evidenced in both experimental contexts.

# General Discussion

In the present study, the possibility to investigate motion perception outside of the highly controlled laboratory setting was focused. As motion perception research was

**Table 3.** Newly created conditions for continuous motion trials in Experiment 2

| Condition | Mean speed (SD) | Mean difference (SD) | $t$ | $p$ | $BF_{01}$ |
|---|---|---|---|---|---|
| 1.98° (1 pixel) | 1.41 (0.32) | −0.57 (0.32) | −9.83 | < .001 | $6.90*e^{-9}$ |
| **5.94 °/s (3 pixels)** | **6.16 (1.31)** | **0.22 (1.31)** | **0.95** | **.352** | **3.46** |
| **11.88 °/s (6 pixels)** | **11.63 (1.54)** | **−0.25 (1.54)** | **−0.90** | **.375** | **3.60** |
| **19.80 °/s (10 pixels)** | **20.14 (1.90)** | **0.34 (1.91)** | **0.99** | **.329** | **3.33** |
| **29.70 °/s (15 pixels)** | **29.51 (2.68)** | **−0.19 (2.68)** | **−0.40** | **.693** | **4.85** |
| 39.61 °/s (20 pixels) | 37.54 (4.72) | −7.00 (7.53 | −2.44 | .021 | 0.42 |
| 49.51 °/s (25 pixels) | 42.51 (7.53) | −6.99 (9.64) | −5.17 | < .001 | $6.59*e^{-4}$ |
| 59.31 °/s (30 pixels) | 44.39 (9.64) | −15.02 (9.64) | −8.68 | < .001 | $9.69*e^{-8}$ |
| 69.31 °/s (35 pixels) | 44.69 (10.18) | −24.62 (10.18) | −13.47 | < .001 | $4.35*e^{-12}$ |

*Note.* *Highlighted in bold the conditions which were analyzed further. For each condition, Mean speed value (in °/s), mean difference from the actual speed in Experiment 1 (in °/s; *SD* in brackets), One sample *t*-test values, *p*-values, and $BF_{01}$ scores are presented.

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typically conducted in an unrealistic optimal setting with little to no disturbances, it is an open question if and to what degree such typically laboratory findings can be observed in less controlled settings. Therefore, two experiments were conducted in two different experimental contexts – either in a standard, highly controlled laboratory setting or in a less controlled setting of the participants' choice. Overall, the observed data patterns were comparable across both experiments, supporting the idea that the Representational Momentum and Representational Gravity phenomena are robust and can be observed in less controlled situations. That is, the forward shift systematically increased with increasing stimulus speed, whereas the downward shift was not influenced by stimulus speed, both data patterns were in line with findings in the respective literature (e.g., Freyd & Finke, 1985; Hubbard, 1990; Hubbard & Bharucha, 1988; for recent discussions, see Hubbard, 2018, 2020).

The present results indicate that similar manipulations result in qualitatively similar changes of the Representational Momentum and Representational Gravity phenomenon, respectively, indicating that these phenomena can be investigated in such online, uncontrolled settings. Even more, the direct comparison indicate only a difference in size for Representational Momentum scores, but not in its change with stimulus speed. This is somewhat surprising, as prior research indicates that uncertainty about the stimulus, which is likely introduced in a less controlled setting, would lead to stronger effects at least for Representational Momentum (e.g., Hayes & Freyd, 2002). Yet, the reverse data pattern was observed.

While the present study only investigated two specific motion-related phenomena, the results should be taken as a positive indication that also other phenomena investigating motion perception, for example, the more closely related Fröhlich/onset repulsion effect (Fröhlich, 1923; Thornton, 2002; for recent reviews and discussions, see Kerzel, 2010; Müsseler & Kerzel, 2018), but also other motion illusions such as the motion after effect (e.g., Anstis et al., 1998) or Thompson effect (e.g., Thompson, 1982) might be tested and demonstrated in less controlled settings. Researchers in other fields of cognitive science such as binding control (Frings et al, 2020; Moeller & Frings, 2020) are expanding their experimental procedure to other populations and non-laboratory setting, investigating the robustness of their respected research (see also Germine et al., 2012; Semmelmann & Weigelt, 2017).

The present study has some important practical and theoretical implications for future research avenues. The ability to run studies online opens up the possibility for researchers to conduct meaningful research under less constraints, navigating around not just current struggles with closed laboratories and campuses due to the COVID-19 pandemic, but general limitations of laboratory capacities. Furthermore, conducting online research is less costly compared to (installing and) maintaining a high-quality laboratory set. Conducting research online, for which participants do not need to be at a specific location but can take part whenever they want and wherever they are, may open up the possibility to investigate currently underrepresented subpopulations such as clinical samples or rural and less mobile samples, as well as allowing for investigating cross-cultural differences. In fact, characteristics of the observer (e.g., such as age, psychopathology) have been identified as a moderator of Representational Momentum (for discussions, see Hubbard, 2010, 2014), and assessing and accessing such subgroups is more feasible with online application of otherwise locally restricted laboratory experiments.

## Electronic Supplementary Material

The electronic supplementary material is available with the online version of the article at https://doi.org/10.1027/1618-3169/a000545

**ESM 1.** Information about the online prestudy (part A); screen size, viewing distance, and visual angle analysis of Experiment 2 (part B); and the influence of response setup and time of participation (part C).

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No conflict of interest exists.

**Publication Ethics**

All procedures performed were in accordance with the ethical standards of the national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Experiment 1: All participants gave written informed consent prior to participation. Experiment 2: All the participants gave active informed consent prior to participation.

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## Authorship

Not applicable/only one author.

## Open Data

All experimental files, raw data, and analyses scripts are openly available at https://osf.io/vwnzr/?view_only=fcd08a9156574312a8aac977b8356aac. None of the experiments reported here were pre-registered.

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