Research Article

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Perceived and one's own motion in response priming

<https://doi.org/10.1515/psych-2020-0106>

Received January 20, 2020; accepted June 25, 2020

Abstract: In response priming, motor pre-activations from a prime to the response to a target can be measured, as a function of whether they require the same (compatible) or different (incompatible) responses. With moving primes and static arrow targets, the results depend on the stimulus onset asynchrony between prime and target: with short SOAs, there were faster responses to compatible than incompatible targets, with longer SOAs, the pattern reverses. However, this reversal was not found with more biological motions. The current study comprised 3 experiments in order to replicate several findings from previous research and add evidence regarding the interplay of one's own and perceived motions. Subjects performed a response priming task with moving prime stimuli while in motion themselves. With this paradigm, we tested the general influence of motion on responding and compatibility effects in response priming with moving prime stimuli. Furthermore, we assessed specific interactions of features of the perceived stimuli (e.g., moving vs. static; direction of the prime or target) and the own motion (e.g., walking vs. standing; direction of being rotated). We used two different own motions (walking on a treadmill, Exp. 1 & 3; rotating in a human gyroscope, Exp. 2) and two different visual stimulus types (rows-of-dots, Exp. 1 & 2; point light displays, Exp. 3). Compatibility effects were, in general, neither increased nor decreased during motion. Their size depended on the stimulus type, the velocity of one's own motion, and several interactions of perceived and own motion. We discuss our findings with respect to perception-action interactions and previous findings on response priming with moving prime stimuli.

Keywords: response priming; motion perception; compatibility effects; own motion; point-light walker; biological movement; walking; rotation

Introduction

Our world is anything but static. Indeed, much of the most valuable information we need to process is constantly moving. Motion frequently signals an event worthy of our attention. Accordingly, our perceptual systems have been selected and tuned to respond to motion. However, it is not just our external environment that is moving, but we are also constantly moving through the world. How humans respond and act appropriately to stimuli in the world, and, in turn, how perception and action interact, are some of the most interesting and essential questions in psychology (e.g., James, 1890; Hommel, Müsseler, Aschersleben,

Article note: This article is part of Special Issue Experimental Cognitive Psychology

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& Prinz, 2001; see also van der Wel, Sebanz, & Knoblich, 2013). As already captured in the claim that ‘perception is for action’ (Milner & Goodale, 1985; see also, e.g., Chemero, 2006; Gibson, 1979; Warren, 2006), motion seems to be a key aspect when acting in the world, and that in two directions.

On the one hand, actions or motion influence perception. For example, we use our own motion to structure the environment spatially (e.g., by adjusting our body midline as a reference point) and we are able to interact with objects, animals, and other people by use of our effectors, eyes, or verbally – for each we use motions. Further, planned actions or motion prime the perception of specific features of visual objects. Schütz-Bosbach and Prinz (2007) have subsumed the modulation of action perception by the production of an own’s action under the term “perceptual resonance”. They assume that action production primes perception and, in turn, selectively increases the sensitivity to action-related events and similar actions of others. Support for such a “motor/visual priming” is seen in studies in which (the preparation of) an own action influences feature or object detection.

For example, action-relevant features of objects are preferentially processed when people plan to grasp (compared to point to) a (graspable) object (e.g., Bekkering & Neggers, 2002; Wykowska, Schubö, & Hommel, 2009). For instance, Wykowska et al. investigated manual grasping or pointing movements and their impact on feature detection in a visual search task. At the beginning of each trial, subjects were instructed (via movement cues) to prepare for a grasping or pointing movement. Thereafter, they had to decide in a visual search display whether the target was present or not. The search display consisted of 28 grey circles, arranged on three imagery larger circles. Targets were defined either by luminance (i.e., one of the small circles was lighter grey than the other circles) or by size (i.e., one of the small circles was smaller than the other circles). After the detection response, participants were required to execute the prepared grasping or pointing movement on a specially designed device. For grasping, size is task-relevant, whereas for pointing, luminance is of larger importance. Results showed faster target detections when the target was defined by the corresponding relevant dimension of the action, i.e., there were shorter reaction times for luminance targets when subjects prepared for a pointing compared to a grasping movement and vice versa shorter reaction times for size targets when subjects prepared for a grasping compared to a pointing movement. Such experiments are seen as evidence of a preference of the visual system for features most relevant to a (planned) action. It is assumed that task-relevant perceptual features are weighted even more heavily when another action also requires consideration of the corresponding dimension (Wykowska et al., 2009).

Another line of research supporting the influence of motion on perceptual processing comes from studies in which subjects move or are moved before or during a visual task. For example, van Elk and Blanke (2014) rotated their subjects with a velocity of 45 °/sec on a platform together with the whole setup (i.e., whole-body passive movement) either clockwise or counterclockwise. During acceleration as well as during deceleration, they saw an avatar also rotated either clockwise or counterclockwise. Their task was to decide for each avatar which of its hands had a different color than its body. During acceleration, subjects responded faster if own motion and the avatars rotation corresponded (i.e., both clockwise or both counterclockwise) compared to non-corresponding constellations (for congruency effects the other way round – i.e., influence of rotated visual stimuli on the perception of the direction of passive self-motion – see Lopez, Falconer, & Mast, 2013).

On the other hand, attention is rapidly allocated to perceived motion or action (e.g., Atkinson, Simpson, & Cole, 2018), which is a necessity in a fast-changing environment. Indeed, the special role of locomotion and moving objects has garnered much interest in perception and attention research (e.g., Bosbach, Prinz, & Kerzel, 2004, 2005; Egeth & Yantis, 1997; O’Craven, Rosen, Kwong, Treisman, & Savoy, 1997; Treue & Maunsell, 1996). In particular, a close connection is assumed to exist between action observation and production (e.g., Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005; Cross, Kraemer, de C. Hamilton, Kelley, & Grafton, 2009; Decety & Grèzes, 1999; Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Grèzes, Fonlupt, Bertenthal, Delon-Martin, Segebarth, & Decety, 2001; Kilner, Paulignan, & Blakemore, 2003; Saygin, Wilson, Hagler, Bates, & Sereno, 2004). For example, observing action or motion activates the same motor programs involved in performing that same action or motion (Jeannerod, 1994; Prinz, 1997). In sum, motions quickly activate orientation behavior or other actions, and motion in general

seems to have the capacity to trigger responses rapidly and involuntarily (e.g., Machado, Wyatt, Devine, & Knight, 2007).

The response priming paradigm (for a review see, e.g., Schmidt, Haberkamp, & Schmidt, 2011) is very well suited to investigating the interaction of perceived and one's own motions, including how perceived motions trigger own actions. Essentially, response priming investigates the effects of (motor) pre-activation from a prime event (i.e., a first stimulus) on the processing of and the (motor) response to a target event (i.e., a second stimulus which has to be categorized). Typical stimuli that have been used in response priming¹ are shape (e.g., arrows, circles, squares, etc.) and color stimuli (e.g., Eimer & Schlaghecken, 2002). For example, primes and targets are squares vs. circles and the subjects' task was to quickly and accurately respond to the shape of the target (e.g., left button press for squares and right button press for circles). Responses to the target are often faster when the preceding prime stimulus and the target are associated with the same response (i.e., primes and targets are congruent, consistent, or compatible; e.g., both are circles) compared to targets that are associated with another response (i.e., primes and targets are incongruent, inconsistent, or incompatible; e.g., the prime is a square, the target is a circle). Compatibility effects were computed as the difference between incompatible and compatible trials; in turn, the typical pattern is a positive compatibility effect (PCE). Under specific experimental conditions – often with masked primes and in longer SOAs –, the effect is reversed with faster responses in incompatible than compatible trials, i.e., there is a negative compatibility effect (NCE) (e.g., Eimer, 1999; Eimer & Schlaghecken, 1998, 2002, 2003; Jaśkowski, Białuńska, Tomanek, & Verleger, 2008; Klapp & Hinkley, 2002).

PCEs can be easily explained in terms of motor pre-activations by the prime which leads to a response advantage when a compatible target has to be classified (see especially the theory of direct parameter specification, Neumann, 1990, and extensions of it, e.g., the action-trigger theory, e.g., Kiesel, Kunde, & Hoffmann, 2007; Kunde, Kiesel, & Hoffmann, 2003, or the rapid-chase theory, Schmidt, Niehaus, & Nagel, 2006). NCEs and the turn from PCEs with shorter SOAs to NCEs with longer SOAs can be explained by several theories (for a review see, e.g., Kiesel et al., 2007). Some authors have argued that NCEs result either from object updating from prime to mask because often the mask consists of parts of the primes (e.g., Lleras & Enns, 2004), or reflect mask-induced activations that inhibit ongoing action (e.g., Jaśkowski, Białuńska, Tomanek, & Verleger, 2008). However, NCEs were also found without common features of mask and prime (e.g., Klapp, 2005; Schlaghecken & Eimer, 2006; Schlaghecken, Klapp, & Maylor, 2009), and even without any mask or intervening object, for example in the case of moving primes (e.g., Bermeitinger, 2013, see below). Thus, Schlaghecken, Eimer, and colleagues (e.g., Schlaghecken & Eimer, 2002) argued that NCEs reflect an inhibition mechanism in low-level motor control as an automatic consequence inherent to the prime (and released if the sensory evidence for activation is lacking) after initial response activation by the prime. Klauer and Dittrich (2010) described a further supplementary mechanism contributing to PCEs vs. NCEs which is thought as acting at a more central categorization level. In their evaluation window account, the authors assume that – according to the Weber-Fechner law – new evidence for one of two responses has more impact if the initial level of evidence is low. Depending on whether the prime is included in the evaluation window for the target or not, PCEs or NCEs will result, respectively. However, there are other mechanisms that might contribute to the PCE-NCE pattern of results, such as attentional mechanisms.

For investigating the motor pre-activations from perceived directional (i.e., left vs. right) motions, Bermeitinger (2013) introduced a variant of response priming in which moving rows of dots were used as primes for static arrow targets. With this variant, Bermeitinger indeed found compatibility effects (i.e., responses to incompatible targets minus responses to compatible targets). Interestingly, the sign of the compatibility effect crucially depended on the stimulus onset asynchrony (SOA) between prime and target. Essentially, with shorter SOAs (100 to 150 ms), PCEs emerged. With longer SOAs (above 250 ms), NCEs emerged. This pattern appeared whether the SOA was varied between or within subjects, independently

¹ Please note that in classical and typical studies on response priming the same stimuli are used for primes and targets, i.e., in these studies, perceptual priming and response priming are intermingled. However, for the current work, we use perceptually different stimuli for primes and targets. Thus, explanations in terms of perceptual priming are not applicable and, in turn, this differentiation is not of central importance to our work.

of prime duration (Bermeitinger, 2013; Hackländer, Eckert, & Bermeitinger, 2015), and even in free-choice tasks (Bermeitinger & Hackländer, 2018).

In further experiments utilizing a single moving dot (instead of rows of dots) as a prime, the same relative pattern occurred (PCEs with shorter SOAs and NCEs with longer SOAs), but with a delay: PCEs occurred up to SOAs of 360 ms (Bermeitinger & Wentura, 2016). In contrast, with static primes as well as with several biological moving primes (i.e., point-light walkers, eye movements), long-lasting and strong PCEs (but no NCEs) were found. These long-lasting PCEs even appeared in a variant with very long SOAs of 1,320 ms (Eckert & Bermeitinger, 2016).

In a recent study (Bermeitinger, Eckert, Baess, & Rey-Mermet, *in prep.*), we were able to demonstrate that some theories are better able to explain (or predict) the results with moving primes, whereas other mechanisms seem to not play a significant role in NCEs or the PCE-NCE pattern with moving primes. Especially, a self-inhibition mechanism in low-level motor control (e.g., Schlaghecken & Eimer, 2006), in combination with the evaluation window account by Klauer and Ditttrich (2010), seem good candidates for explaining the pattern of results. According to Schlaghecken and Eimer, rapidly and involuntarily triggered response activations – in our case caused by perceived motion – might have been inhibited very quickly if they are classified as unfounded, resulting in NCEs. This classification needs some time, thus, for short SOAs, PCEs occurred. With regard to the evaluation window account, it seems that in longer SOA conditions using moving primes, the onset of the target is especially unpredictable. In short SOAs, moving primes seem to trigger the opening of the evaluation window – resulting in PCEs. In contrast, in longer SOAs, moving primes are not used as signals for opening the evaluation window – resulting in NCEs. With static primes, however, the partitioning of the stream and the prediction of the target's onset seems to be easier, and the prime can act as a go signal in shorter as well as longer SOAs, resulting in a PCE, especially in the longer SOA condition tested in Bermeitinger (2013).

To investigate the interplay of one's own and perceived motion, we had subjects perform a response priming task with moving primes while in motion themselves. We used different kinds of moving stimuli and different kinds of own motion, as well as non-moving stimuli and no motion conditions in which subjects had to stand still. As previously discussed, one's own action or motion strongly influences visual perception. There might be a general amplification of visual processing while in motion. Given that one's own motion activates relevant perceptual features even more (e.g., Wykowska *et al.*, 2009), one might expect larger compatibility effects (at least with moving primes) when subjects simultaneously act or move. In contrast, one could expect generally interfering influences caused by the motion, resulting in larger overall response times (and more errors) while in motion and, in turn, reduced compatibility effects (see e.g., Al-Yahya, Dawes, Smith, Dennis, Howells, & Cockburn, 2011, for a review on general interference of walking on cognitive tasks).

On the other hand, one might expect specific interactions of own and perceived motion in the sense of congruency effects (e.g., van Elk & Blanke, 2016); this might be traced back to the understanding of a common coding of perception and action (see above, e.g., Hommel *et al.*, 2001). Broadly speaking, a distinction can be made between the following types of congruencies: 1) congruency of own motion (yes/no) and perceived motion (yes/no), i.e., in congruent cases there is any own and perceive motion or no own and perceive motion, incongruent cases are those in which there is any perceived motion, but no own motion or any own motion but no perceived motion, 2) congruency of the direction of own motion and perceived motion, 3) congruency of the type of own motion and perceived motion. We realized these possibilities of congruency across our three experiments. As a consequence, (Exp. 1) there might be larger compatibility effects with static primes when subjects had to stand still compared to a condition in which they are in motion themselves and, vice versa, (all experiments) larger compatibility effects with moving primes when subjects are in motion themselves compared to standing still. Additionally (Exp. 2), there may be compatibility effects between the direction of the own motion and the target's direction, either a) independent of the perceived motion, or b) that are further enhanced by compatible perceived motions of the primes (i.e., additive effects of one's own and the perceived motion on the response to the target). Finally (Exp. 3), there might be larger compatibility effects when the own motion is more similar to the perceived motion. According to the idea of perceptual resonance (Schütz-Bosbach & Prinz, 2007), an intentional action

or active motion/action production is needed. However, according to the idea of perceptual resonance that corresponding features of any unit (perceptual, own motion, intentional, bottom-up or top-down) can increase the weight of a specific feature of a given object in perceptual processing, even passive motion (i.e., being moved) could increase processing of perceived visual motion (e.g., van Elk & Blanke, 2016).

Experiment 1

Experiment 1 was conducted in order to investigate the interaction (and overall influence) of own motion (walking vs. standing still) on the compatibility effects with moving vs. static primes. We used the same visual material as in Bermeitinger (2013) – i.e., rows of dots as primes (essentially, either moving leftwards vs. rightwards or statically presented left vs. right) and static arrow targets – and compared a short SOA (147 ms) with a longer SOA (360 ms). Participants worked through the task while either standing still or walking on a treadmill. Given the results of Bermeitinger and colleagues (e.g., Bermeitinger, 2013; Bermeitinger & Hackländer, 2018), substantial compatibility effects were expected, especially with moving primes. In detail and as a replication of previous results, we expected the following. With moving primes, we expected PCEs in the short SOA condition and reduced or even reversed effects in the long SOA condition. With static primes, we expected no or weak positive effects in the short and larger PCEs in the long SOA condition. Beyond replication, we added the question of whether subjects walk or stand still in order to investigate the influence of one's own motion on general responding in response priming and the specific interaction of perceived material and own action – the overall pattern could be influenced by walking vs. standing still. That is, it might be that a general amplification of visual processing while in motion lead to more pronounced (especially positive) compatibility effects while walking (irrespective whether the primes were moving or static primes).

In contrast, motion could lead to a general interference resulting in reduced compatibility effects while walking. A third option might be that there were specific interactions of one's own and perceived motion. Then, we expected larger compatibility effects with static primes while standing still (compared to walking) and larger compatibility effects with moving primes while walking (compared to standing still).

Method

Subjects. 31 students (25 women, 6 men; *MEDage* = 21, ranging from 18 to 39 years) participated at the University of Hildesheim in exchange for partial course credit. Subjects were randomly assigned to the standing condition ($n = 16$) or the walking condition ($n = 15$). Informed consent was obtained from all individual subjects included in the study.

Bermeitinger and colleagues (Bermeitinger, 2013; Bermeitinger & Hackländer, 2018) reported PCEs with a mean effect size of approximately $d = 0.8$ (ranging from 0.59 to 1.06) for moving primes with an SOA of about 147 ms and NCEs with a mean effect size of approximately $d = 0.7$ (ranging from 0.28 to 1.05) with an SOA of about 360 ms. Given the reported effect sizes, it can be stated that the PCE/NCE in our conditions with moving primes can be detected with probability $1 - \beta = .95$ ($\alpha = .05$) if one uses a sample size of at least $N = 19/28$, respectively. Bermeitinger (2013) found a substantial compatibility effect with static primes with an SOA of 300 ms as well ($d = 0.62$). Thus, the PCE in our experiment with static primes with an SOA of about 360 ms should be detected with $1 - \beta = .95$ ($\alpha = .05$) if one uses a sample of at least $N = 30$ (Faul, Erdfelder, Lang, & Buchner, 2007).

Design. The experiment used a 2 (Own motion: standing, walking) $\times 2$ (SOA: 147, 360 ms) $\times 2$ (Prime: static, moving) $\times 3$ (Compatibility: compatible, incompatible, neutral) design. The first factor (Own motion) was varied between subjects. The second factor (SOA) was varied block-wise within subjects; order was counter-balanced across subjects. The other factors (Prime and Compatibility) were varied trial-by-trial within subjects. The prime stimulus in each trial was either a moving row-of dots or a static row-of-dots presented at the left or right side of the screen (in compatible or incompatible conditions). Besides that, in each

trial, the prime and target stimuli either indicated the same direction (compatible) or different directions (incompatible). In one-third of all trials, the prime stimulus did not indicate any direction (neutral; for moving primes the dots moved either inward or outward; for static primes the static row-of-dots was presented in the middle of the screen or split between the left and right of the screen).

Material. Essentially, we used the same material as in Bermeitinger (2013) for the targets as well as for the moving and static primes. All stimuli and visual instructions were presented in black on a white background. Two arrows were used as target stimuli, one pointing to the left and one to the right, the arrows were approximately 3.5 cm in length and 1.0 cm in height. Targets were presented at the center of the screen. For both prime types, we used rows of 11 dots. Each dot was approximately 0.4 cm in diameter. The whole row measured approximately 14.5 cm in length; the distance from one dot to the next dot was approximately 1.0 cm.

For the moving primes, the prime event started with the presentation of the row in the center of the screen. To instantiate the movement, the dots were shifted from their original position in steps of 0.17 cm leftwards or rightwards. After six steps, a dot had reached the original position of its neighboring dot, and the movement started again from the screen's center (original row position). For each prime event, 11 frames were presented, that is, there were 10 movement steps of the dots. For the compatible and incompatible conditions, the dots (i.e., the whole row) were moved rightwards or leftwards. For the neutral conditions, the dots were either moved outwards (i.e., the 5.5 left dots of the row moved leftwards, the 5.5 right dots of the row moved rightwards, meaning that the central dot was split into two semicircles that drifted apart; 1/6 of the trials with moving primes) or inwards (i.e., the 5.5 left dots of the row moved rightwards, the 5.5 right dots of the row moved leftwards, meaning that the central dot was split into two semicircles that progressively superimpose; 1/6 of the trials with moving primes).

For the compatible or incompatible static primes, the row-of-dots was presented at the left or right side of the screen. The center of the left or right row was approximately 4 cm left or right from the center of the screen, respectively. For the neutral static condition, the dots were presented either centered (1/6 of all static trials) or split with 5.5 dots at the left side and 5.5 dots at the right side of the screen (1/6 of all static trials). In these cases, the outermost point was presented at the same location as the outermost point of the compatible/incompatible primes, and the inner (half) points were presented at the corresponding center of the compatible/incompatible primes (i.e., 4 cm left or right from the screen's center).

Procedure. Subjects were individually tested either on a treadmill while walking with a velocity of 2.5 km/h or in another test room while standing still. The computer, screen (17" CRT monitor, screen resolution 640 x 480 pixels, refresh rate 75 Hz), and keyboard was in front of the subjects at a standing desk. In both conditions subjects had a short adaptation phase of approximately 1 minute in which they could familiarize with walking on the treadmill or standing in an upright position. While standing, they should distribute weight evenly between both legs. The viewing distance was about 65 cm. The experiment was run using E-Prime software (version 2) with standard PCs. Instructions were given verbally by the experimenter or on the screen. The experiment consisted of 2 SOA blocks each consisting of 4 sub-blocks, each containing 72 trials. Half of the trials in each sub-block used the static and moving primes, respectively. Each half was comprised of one-third compatible, incompatible, and neutral trials. Within each sub-block, trial order was determined randomly by the computer. After each sub-block, the subjects were given the chance to take a short rest. At the beginning of each SOA block, subjects worked through a practice phase with 24 trials.

Subjects were required to make responses with their left or right index finger, depending on the side the target arrow pointed to (response keys were the 1 and the 3 key on the numeric pad, which had arrow stickers pasted on them). Subjects were instructed to respond as quickly and as accurately as possible.

The sequence of each trial was as follows (see **Figure 1**): first a fixation stimulus (+) appeared at the center of the screen for 1,000 ms. It was followed by the row-of-dots. For the moving primes, this first row was presented for one refresh cycle (i.e., approximately 13 ms) at the center of the screen. Then, the next row was presented for the next refresh cycle and so on. For the static primes, the row was presented the whole time at the same location (i.e., left, right, centered or split). Prime presentation duration was 147 ms (i.e., 11

dot presentations * refresh cycle). For the 147 ms SOA condition, the prime event was followed immediately by the target, which remained on the screen until a response was given. For the 360 ms SOA conditions, the prime event was followed by a blank screen that remained for 213 ms; this was immediately followed by the target, which again remained on the screen until a response was given. The intertrial interval was 400 ms.

Figure 1. Trial order in Experiment 1 and Experiment 2. The grey arrow in the prime display is only to indicate the prime's motion in the figure; it was not shown to subjects.

Results

For the analysis of reaction times, only correct responses were used (mean error rate was 2.32% of all trials). Outlying RTs that were 1.5 interquartile ranges above the third quartile with respect to the individual distribution (Tukey, 1977) for each SOA were discarded, as well as RTs above 1,500 and below 200 ms. These constituted 3.94% of all trials. **Table 1** shows mean response times and errors in all conditions; **Figure 2** shows mean compatibility effects. A mixed analysis of variance (ANOVA) on mean RTs was performed with the factors Own motion (standing, walking; between subjects), SOA (147, 360 ms; within subjects), Prime

Table 1. Mean response times (in ms; *SD* in parenthesis) and mean error rates (in %; *SD* in parenthesis) of the compatible, the incompatible, and the neutral conditions (regarding prime-target compatibility) for each own motion (standing, walking) x SOA (147, 360 ms) x prime (static, moving primes) condition of Experiment 1.

	moving primes						static primes					
	response times (in ms)			error rates (in %)			response times (in ms)			error rates (in %)		
	compatible	incompatible	neutral	compatible	incompatible	neutral	compatible	incompatible	neutral	compatible	incompatible	neutral
Standing												
147 ms SOA	324 (15.98)	331 (16.75)	324 (16.18)	1.17 (1.52)	3.78 (3.97)	1.69 (2.97)	334 (16.92)	336 (19.33)	331 (15.78)	2.08 (2.01)	2.21 (2.34)	1.69 (1.90)
360 ms SOA	314 (18.92)	313 (23.05)	313 (17.11)	2.99 (3.40)	4.30 (4.78)	1.95 (2.89)	312 (18.33)	320 (17.14)	315 (17.39)	2.21 (2.08)	3.13 (3.23)	1.82 (2.83)
Walking												
147 ms SOA	346 (27.46)	354 (24.56)	346 (21.40)	2.22 (2.78)	1.81 (1.91)	2.50 (2.25)	353 (25.75)	357 (28.83)	354 (23.80)	2.22 (3.38)	1.81 (2.21)	2.08 (2.08)
360 ms SOA	333 (27.48)	329 (23.87)	330 (28.95)	2.08 (1.93)	3.61 (2.67)	0.97 (1.55)	327 (27.00)	331 (22.03)	329 (23.88)	2.78 (3.47)	2.50 (3.07)	1.94 (2.55)

Figure 2. Prime-Target compatibility effects (in ms): Differences in RTs between compatible and incompatible trials for trials using moving row-of-dots primes (= moving primes) and static row-of-dots primes (= static primes), separately depicted for the two different SOA conditions (147 ms, 360 ms) and the walking and standing condition in Experiment 1 (error bars represent the standard error of the mean; * $p < .05$).

(static, moving; within subjects) and Compatibility (compatible, incompatible, neutral; within subjects). If necessary (i.e., if the Mauchly's test of sphericity was significant), the F -, p -, and η_p^2 -values were corrected in all following ANOVAs according to the Greenhouse-Geisser method. In the first step, post-hoc analyses of the higher-level ANOVA were based on calculated contrasts, especially for compatibility effects. In the next step, we used post-hoc t -tests for compatibility effects (i.e., only the difference of incompatible and compatible trials while ignoring neutral trials) in order to present the results in a more compact and concise manner which also seemed more common and comparable to previous results.

Response times. The main effect Own motion was significant, $F(1, 29) = 6.82, p = .014, \eta_p^2 = .190$; there were faster responses in the standing compared to the walking condition. The factor SOA showed a significant main effect as well, $F(1, 29) = 116.12, p < .001, \eta_p^2 = .800$, indicating faster responses in the longer compared to the shorter SOA. The main effect Primes was also significant, $F(1, 29) = 30.06, p < .001, \eta_p^2 = .509$, with overall slightly faster responses with moving compared to static primes. Additionally, prime-target Compatibility had a significant influence on RTs, $F(2, 58) = 8.24, p = .001, \eta_p^2 = .221$, with overall faster responses in neutral than incompatible trials, $F(1, 29) = 16.82, p < .001, \eta_p^2 = .367$, and equally fast responses in compatible and neutral trials, $F(1, 29) < 1, p = .528$ (as shown by repeated contrasts), indicating a general positive compatibility effect with a contribution by restriction (from incompatible primes, i.e., slower reactions to incompatible than neutral trials).

The main effects were qualified by significant interactions of SOA and Prime, $F(1, 29) = 40.74, p < .001, \eta_p^2 = .584$, of Prime and Own motion, $F(1, 29) = 5.44, p = .027, \eta_p^2 = .158$, and of SOA, Prime, and Compatibility, $F(2, 58) = 5.95, p = .004, \eta_p^2 = .170$. The interaction of SOA and Compatibility just missed the criterion for being significant, $F(2, 29) = 3.08, p = .053, \eta_p^2 = .096$. All other main or interaction effects were clearly not significant, $ps > .07$; especially the interaction of all four factors was not significant, $p = .854$.

To further clarify these interactions, we subsequently conducted ANOVAs with the factors SOA and Compatibility, separately for the two Prime conditions (as there were no interesting interactions including the factor Own motion besides the Prime x Own motion interaction which indicated a slightly larger difference in RTs between walking and standing after moving than after static primes, we collapsed across the Own motion conditions).

Static primes. Both main effects were significant; main effect SOA: $F(1, 30) = 126.68, p < .001, \eta_p^2 = .809$; main effect Compatibility: $F(2, 60) = 5.70, p = .005, \eta_p^2 = .160$. The interaction of both factors was not significant, $F(2, 60) = 1.08, p = .347, \eta_p^2 = .035$. Post-hoc t -tests (two-tailed) revealed a nonsignificant PCE ($M = 3$ ms, $SE = 2.34$) in the short SOA, $t(30) = 1.32, p = .196, d = 0.237$, and a significant PCE ($M = 6$ ms, $SE = 2.01$) in the long SOA, $t(30) = 2.77, p = .010, d = 0.498$, which did not differ significantly from each other (see nonsignificant interaction).

Moving primes. The main effect SOA and the interaction effect were significant; main effect SOA: $F(1, 30) = 77.82, p < .001, \eta_p^2 = .708$; interaction: $F(2, 60) = 6.56, p = .003, \eta_p^2 = .179$. The main effect Compatibility was not significant, $F(2, 60) = 2.80, p = .090, \eta_p^2 = .085$. Post-hoc t -tests (two-tailed) revealed a significant PCE ($M = 8$ ms, $SE = 2.50$) in the short SOA, $t(30) = 3.05, p = .005, d = 0.548$, and a nonsignificant NCE ($M = -3$ ms, $SE = 2.71$) in the long SOA, $t(30) = 1.05, p = .301, d = 0.189$, which differed significantly from each other, $t(30) = 3.25, p = .003, d = 0.584$.

Error rates. The same analysis on error rates revealed a not significant main effect SOA which just missed the criterion for being significant, $F(1, 29) = 4.08, p = .053, \eta_p^2 = .123$, indicating a tendency towards more errors in the longer compared to the shorter SOA. Further, there was a significant main effect Compatibility, $F(2, 58) = 6.86, p = .002, \eta_p^2 = .191$, with more errors in incompatible than neutral trials, $F(1, 29) = 14.45, p = .001, \eta_p^2 = .333$, but equally error prone responses in neutral and compatible trials, $F(1, 29) = 1.80, p = .190, \eta_p^2 = .058$ (as shown by repeated contrasts). The interaction of Prime and Compatibility just missed the criterion for being significant, $F(2, 58) = 3.03, p = .056, \eta_p^2 = .094$; all other effects $p > .09$.

Discussion

In general, the pattern replicates previous findings for moving as well as for static primes: With moving primes, we found PCEs in the short SOA and reduced (even reversed, but not significant, see also, e.g., Bermeitinger & Hackländer, 2018) compatibility effects in the long SOA. With static primes, we found only a significant PCE (especially in the longer SOA). The results were largely independent of participants' own motion (walking vs. standing). We found no evidence that one's own motion additionally activates relevant features leading to larger compatibility effects, and we found no congruency effects between one's own motion/standing and perceived moving/static stimuli. However, there were generally slower responses when walking than standing, possibly indicating an interfering influence of walking on task performance.

Experiment 2

In Experiment 1 we failed to find any evidence that one's own motion influenced the size of compatibility effects in any of the possible expected ways. One potential reason for this lack of a finding is that the self-generated motion and the moving primes were too dissimilar for any (additive or congruency) effects to have occurred. There are at least two possibilities to make own and perceived motion more similar. First, one could use a different own motion (this was done in Experiment 2). Second, one could use a different perceived motion (this was done in Experiment 3). Using different own and perceived motions that better resembled each other allows for a stronger test of the notion that own motion influences/increases priming effects following similar perceived motions.

In Experiment 2, we used the same moving primes as in Experiment 1 (but no static primes). In contrast to Experiment 1, we now used a different own motion that shares more properties with the perceived motion in order to make them more similar. For this, we used an own motion, which was in the same axis as the perceived motion (i.e., horizontal). To realize the horizontal motion, we used a human gyroscope in which participants were rotated around their vertical axis, either clockwise (i.e., rightwards) or counterclockwise (i.e., leftwards) during the processing of the response priming task. Additionally, there was a condition in which participants were not rotated (i.e., they stood still). We had to change further experimental details to adapt the experiment to become compatible with the gyroscope. Specifically, we used a 3D virtual reality display. Given previous research showing that the use of other displays can alter compatibility effects (e.g., Bermeitinger, Kalbfleisch, Schäfer, Lim, Goymann, Reuter, & Janssen, 2020, with flat screens instead of CRT screens), it was not clear to us that we should expect a pattern of results similar to our past studies which typically used different displays and viewing conditions.

Aside from the general uncertainty with respect to viewing conditions, we otherwise expected similar results to those in Experiment 1 and our previous experiments (e.g., Bermeitinger, 2013) with moving primes when people stood still in the gyroscope. Namely, a PCE with a shorter SOA and at least a reduced effect with a longer SOA. Beyond replication: For conditions in which participants were rotated we expected an interaction of rotation direction and target direction with most probably faster responses if rotation direction and target direction are compatible (i.e., both rightwards or leftwards) compared to the incompatible condition (i.e., own rotation leftwards/rightwards, target direction rightwards/leftwards).

Method

Subjects. Forty students from the University of Hildesheim finished the experiment². They participated in exchange for partial course credit. If they had vision problems of more than ± 1 diopters, they had to wear contact lenses due to the use of a 3D virtual reality display. Five subjects had to be excluded as they reported viewing problems and saw the material only blurredly. In the remaining sample, there were 28 female and

² Additional 6 subjects began the experiment, but decided not to finish it or were unable to complete the procedure due to being nauseated or becoming dizzy.

7 male subjects ($MEDage = 21$, ranging from 18 to 33 years). They were randomly assigned to the SOA 147 ms condition ($n = 17$) or the SOA 360 ms condition ($n = 18$).

Design. The experiment used a 2 (SOA: 147, 360 ms) $\times$ 3 (Own motion: clockwise = rightwards rotation, counter-clockwise = leftwards rotation, without rotation) $\times$ 3 (Prime direction: rightwards, leftwards, neutral) $\times$ 2 (Target direction: leftwards, rightwards) design. The first factor (SOA) was now varied between subjects in order to reduce possible carry-over effects and to reduce the overall length of the experiment for one subject. The second factor (Own motion) was varied block-wise within subjects; all subjects started without rotation, the order of the clockwise/counterclockwise rotation was counter-balanced across subjects. The other factors (Prime direction and Target direction) were varied trial-by-trial within subjects. Note, in this experiment, there were two compatibilities, i.e., one regarding Prime direction and Target direction and the other regarding Own motion and Target direction. In 2/3 of all trials, the prime and target stimuli either indicated the same direction (compatible) or different directions (incompatible). In one-third of all trials, the prime stimulus did not indicate any direction (neutral).

Material, Equipment, and Procedure. Essentially, we used the same material for primes (however, only moving primes) and targets as in Experiment 1. The material was adapted for use in the gyroscope and with a 3D virtual reality display. We used a Lenovo notebook and an Oculus Rift Development Kit 2 with a refresh rate of 75 Hz for presenting the priming task. For using the material with the 3D virtual reality display, the material had to be doubled, such that each stimulus was presented twice (once to each eye). In E-Prime, the material has to be rotated 90° (resulting in the normal horizontal presentation in the 3D virtual reality display). The pictures were presented 20% left and right from the midpoint. For participants, the visual impression was of only one, unitary, stimulus (sometimes, a short adaptation phase was necessary for this, see below). In order to adapt the material to the requirements of the gyroscope and the 3D virtual reality display, we additionally used verbal instead of written instructions. The instructions were given by the experimenter at the beginning of the experiment.

Subjects were tested individually. After arriving in the lab, subjects were familiarized with the order and equipment. Subjects then provided written informed consent. They were instructed to move their head and upper body as little as possible during the experiment to avoid dizziness. Subjects were then fixated in an upright position in a 3D Space Curl (i.e., the human gyroscope). The gyroscope was adjusted in such a way that only rotations around the vertical axis were possible, allowing horizontal motions. All other possible rotations (e.g., via the horizontal axis, etc.) were ruled out by tying up two of the three rings of the gyroscope. Participants were rotated manually by the experimenter with a velocity of approximately 42 °/s. The experimenter controlled the velocity by use of a Wii remote control (model RVL-036) which was tied up at the gyroscope above the subject's head and which was connected wirelessly to an independent notebook running the OSCulator software (indicating the velocity graphically). In front of the participants, there was a platform with the notebook controlling the experiment and recording the responses.

To get accustomed to the gyroscope, participants were rotated several times in both directions (clockwise and counterclockwise) without the 3D virtual reality display and without any further task. Then, participants were requested to put the 3D virtual reality display on (without any visual input). Again, they were rotated several times in both directions without any further task. Finally, subjects wore the Oculus Rift as well as a noise protection headset to reduce disturbing sounds. The experimental setup can be seen in **Figure 3**. After switching the 3D virtual reality display on, two arrows (one for each eye) were presented and participants were requested to bring the two arrows visually on top of each other by accommodation. They eventually should see only one arrow.

After verbal instructions, the priming task started with a short practice phase (with 16 trials). Then, subjects worked through five experimental blocks. During the experiment, they either stood still or were rotated clockwise (i.e., to their right) or counterclockwise (i.e., to their left) around their vertical axis, depending on the own motion condition. The first block was without any rotation (i.e., standing still). This was done for several reasons. Especially, the first block was used as a baseline condition, and second, the eyes should adapt to the viewing conditions with the 3D virtual reality display. In blocks two to five, subjects

were rotated either clockwise or counterclockwise. The order of rotation across blocks was either clockwise – counterclockwise – clockwise – counterclockwise or counterclockwise – clockwise – counterclockwise – clockwise. Order was counterbalanced across participants. Each block contained 72 trials (24 compatible, 24 incompatible, 12 neutral inwards, 12 neutral outwards; half with a right-pointing arrow, half with a left-pointing arrow). Participants could take a rest after every 36 trials (i.e., between each block and in-between each block).

The sequence of each trial was the same as in Experiment 1 with one exception. In the short SOA (147 ms) condition, after the fixation cross and before the prime, a blank screen was presented for 213 ms, resulting in a comparable trial duration for both SOA conditions in order to ensure a comparable rotation time for participants of both SOA conditions.

Figure 3. Experimental setup of Experiment 2 using the Space Curl human gyroscope with a platform for the notebook, an Oculus Rift Development Kit 2 3D virtual reality display, and noise-reducing headset.

Results

For the analysis of RTs, only correct responses were used (mean error rate was 2.22% of all trials). The same outlier criteria were applied as in Experiment 1. These constituted 5.90% of all trials. **Table 2** shows mean RTs and errors in all conditions; for reasons of comparison with the other experiments, **Table 3** shows the mean RTs and error rates for compatible, incompatible, and neutral trials; **Figure 4** shows mean compatibility effects. A mixed ANOVA on mean RTs was performed with the factors SOA (147, 360 ms; between subjects), Compatibility of own motion and target direction (compatible, incompatible, without rotation; within subjects) ($\text{Comp}_{\text{own_motion-target}}$), Compatibility of Prime and Target direction (compatible, incompatible, neutral; within subjects) ($\text{Comp}_{\text{prime-target}}$). If necessary (i.e., if the Mauchly's test of sphericity

was significant), the F -, p -, and η_p^2 - values were corrected in all following ANOVAs according to the Greenhouse-Geisser method.

Table 2. Mean response times (in ms; SD in parenthesis) and mean error rates (in %; SD in parenthesis) for each combination of a Target direction (left, right) x Prime direction (left, right, neutral) x Own motion (without rotation, clockwise rotation, counter-clockwise rotation) x SOA (147, 360 ms) condition of Experiment 2.

	left-pointing arrow targets						right-pointing arrow targets					
	response times (in ms)			error rates (in %)			response times (in ms)			error rates (in %)		
	left prime movement	right prime movement	neutral prime movement	left prime movement	right prime movement	neutral prime movement	left prime movement	right prime movement	neutral prime movement	left prime movement	right prime movement	neutral prime movement
Without rotation												
147 ms SOA	349 (23.42)	363 (22.72)	350 (23.61)	2.45 (4.90)	3.43 (5.15)	2.94 (5.05)	352 (18.13)	345 (22.91)	343 (24.85)	2.45 (3.91)	2.94 (4.10)	1.47 (3.27)
360 ms SOA	357 (46.55)	369 (43.32)	363 (45.74)	0.93 (2.69)	3.24 (4.18)	2.78 (6.39)	365 (42.36)	357 (47.75)	352 (48.04)	0.93 (2.69)	2.78 (4.95)	0.00 (0.00)
Clockwise rotation												
147 ms SOA	344 (26.68)	350 (20.08)	348 (21.06)	3.19 (4.78)	3.43 (4.23)	3.19 (4.55)	341 (26.63)	341 (34.23)	336 (29.14)	1.47 (2.53)	2.94 (4.83)	1.96 (2.99)
360 ms SOA	358 (41.78)	357 (37.65)	356 (37.33)	3.70 (4.01)	0.93 (2.28)	1.85 (2.57)	345 (37.57)	345 (35.75)	345 (37.43)	1.39 (2.48)	1.39 (3.20)	0.93 (1.78)
Counter-clockwise rotation												
147 ms SOA	343 (23.87)	349 (22.17)	345 (20.85)	2.94 (3.54)	3.92 (4.77)	0.98 (2.34)	344 (27.66)	340 (35.21)	336 (30.23)	4.17 (4.17)	3.43 (4.48)	0.98 (1.82)
360 ms SOA	352 (38.68)	355 (36.25)	348 (31.57)	1.85 (2.94)	1.62 (3.24)	0.93 (1.78)	337 (26.85)	343 (28.41)	338 (31.26)	2.31 (3.27)	2.08 (3.57)	2.31 (3.84)

Table 3. Mean response times (in ms; SD in parenthesis) and mean error rates (in %; SD in parenthesis) of the compatible, the incompatible, and the neutral conditions (regarding prime-target compatibility) for each Own motion (without rotation, clockwise rotation, counter-clockwise rotation) x SOA (147, 360 ms) condition of Experiment 2.

	response times (in ms)			error rates (in %)		
	compatible	incompatible	neutral	compatible	incompatible	neutral
Without rotation						
147 ms SOA	347 (21.12)	357 (18.33)	347 (21.42)	2.70 (3.88)	2.94 (3.83)	2.21 (3.33)
360 ms SOA	357 (45.82)	367 (41.40)	357 (44.86)	1.85 (2.94)	2.08 (2.58)	1.39 (3.20)
Clockwise rotation						
147 ms SOA	352 (26.88)	352 (23.61)	352 (22.50)	3.06 (4.24)	2.45 (2.58)	2.57 (3.50)
360 ms SOA	341 (30.63)	343 (29.86)	340 (30.11)	2.55 (2.21)	1.16 (1.63)	1.39 (1.60)
Counter-clockwise rotation						
147 ms SOA	352 (21.63)	350 (24.30)	346 (23.10)	3.19 (2.67)	4.04 (3.08)	0.98 (1.82)
360 ms SOA	340 (30.38)	342 (23.11)	337 (26.15)	1.97 (2.42)	1.97 (2.20)	1.62 (2.53)

Figure 4. Prime-Target compatibility effects (in ms): Differences in RTs between compatible and incompatible trials for trials using moving row-of-dots primes (= moving primes), separately depicted for the two different SOA conditions (147 ms, 360 ms) and the standing, clockwise, and counterclockwise rotation condition in Experiment 2 (error bars represent the standard error of the mean; ** $p < .01$).

Response times. There was a significant main effect of $\text{Comp}_{\text{own_motion-target}}$, $F(2, 66) = 8.98$, $p = .003$, $\eta_p^2 = .214$: Responses were faster when subjects' motion direction was compatible to the direction of the target than when subjects were standing still, $F(1, 33) = 9.99$, $p = .003$, $\eta_p^2 = .232$; responses were also faster when subjects' motion direction was incompatible to the direction of the target than when subjects were standing still, $F(1, 33) = 9.21$, $p = .005$, $\eta_p^2 = .218$; and responses were equally fast when subjects' motion direction was compatible and incompatible to the direction of the target, $F(1, 33) = 0.39$, $p = .536$, $\eta_p^2 = .012$, as shown by repeated contrasts. The main effect $\text{Comp}_{\text{prime-target}}$ was significant as well, $F(2, 66) = 5.55$, $p = .015$, $\eta_p^2 = .144$: Responses were equally fast when the prime's direction was compatible to the target's direction and when primes were neutral regarding their motion direction, $F(1, 33) = 0.03$, $p = .875$, $\eta_p^2 = .001$; responses were faster in trials with neutral primes than in trials in which the prime's direction was incompatible to the target's direction, $F(1, 33) = 19.38$, $p < .001$, $\eta_p^2 = .370$; and responses were faster in trials in which the prime's direction was compatible to the target's direction than in trials in which the prime's direction was incompatible to the target's direction, $F(1, 33) = 4.80$, $p = .036$, $\eta_p^2 = .127$, as shown by repeated contrasts. Finally, the interaction of both Compatibility factors was significant, $F(4, 132) = 4.01$, $p = .013$, $\eta_p^2 = .108$. There were no significant effects including the factor SOA, all $ps > .44$ (i.e. overall, there were equally pronounced prime-target compatibility effects in the short and long SOA; however, the PCE was individually significant (two-tailed) only in the short SOA condition, $t(16) = 2.44$, $p = .026$, $d = 0.59$, but not in the long SOA condition, $t(17) = 0.88$, $p = .394$, $d = 0.21$).

The interaction implied – as shown by follow-up ANOVAs with the factor $\text{Comp}_{\text{prime-target}}$, separately for the three $\text{Comp}_{\text{own_motion-target}}$ conditions – that there was only a significant main effect $\text{Comp}_{\text{prime-target}}$ when no motion was executed, $F(2, 68) = 9.95$, $p < .001$, $\eta_p^2 = .226$ (with faster responses in compatible than incompatible trials, $F(1, 34) = 10.89$, $p = .002$, $\eta_p^2 = .243$, faster responses in neutral than incompatible, $F(1, 34) = 19.64$, $p < .001$, $\eta_p^2 = .366$, and equally fast responses in compatible and neutral trials, $p = .662$, as shown by repeated contrasts), but not in both motion conditions, $ps > .42$.

Error rates. The same analysis on error rates revealed no significant main or interaction effects, all $ps > .08$. However, participants made significantly less errors in trials in which rotation and target direction were compatible compared to incompatible trials, as indicated by the corresponding contrast, $F(1, 33) = 6.23$, $p = .018$, $\eta_p^2 = .159$ (all other contrasts: $p > .13$).

Discussion

There were no significant effects including the factor SOA and overall, we found only a significant PCE, although the numerical pattern tends to be, overall, in the direction of previous findings (e.g., Bermeitinger, 2013) with PCEs in the short SOA condition and reduced compatibility effects in the longer SOA condition. There was no difference between compatible and incompatible motion, but the effects in the rotation conditions were overall rather weak. Additionally, when looking at the condition without any rotation (which was thought as a baseline and should be highly comparable to other experiments where subjects sit or stand still, see also Experiment 1), the compatibility effect at the longer SOA seems a bit curious. The effect was not significant by its own, but numerically it was highly similar to the PCE in the short SOA condition and there was clearly no significantly reduced compatibility effect in the longer SOA compared to the short SOA.

Experiment 2 was the first attempt to show compatibility effects with moving primes by use of a 3D virtual reality display. Thus, some of the differences to previous findings (e.g., Bermeitinger, 2013) could be attributed to the specific changes and the equipment. With regard to our question of interactions with own motion: We found no evidence for RT differences in own motion-target compatible vs. incompatible trials and no congruency (in RT) of own and perceived motion, that is, there were no additive effects of both compatibilities. However, results can be interpreted as evidence for a general acceleration when participants were rotated (irrespective of the compatibility of rotation/motion direction and target direction) compared to the condition in which they were not rotated (see main effect $\text{Comp}_{\text{own_motion-target}}$). When looking at the error results, then, in contrast, we found a compatibility effect with own motion: Subjects made fewer errors when the direction of the arrow and the direction of one's own motion were compatible compared to incompatible. Again, this effect was not qualified by SOA. Although the results of Experiment 2 were, in general, rather weak, we can conclude that, first, response priming with moving primes can be adapted to a human gyroscope and a 3D virtual reality display. Second, we found some influence – in errors – of own motion on the processing of the perceived material, i.e., there were less error prone responses to targets that were in the same direction as the own motion. Third, the general pattern in RTs seems only numerically, but not statistically, comparable to that found in previous results (e.g., Bermeitinger, 2013).

Experiment 3

In Experiment 2, we used the same material as in Experiment 1 with an own motion that was in the same dimension as the movement of the prime material. In contrast, in Experiment 3, we wanted to test the effect of making the material more similar to the own motion, i.e., by using a human movement as prime stimuli. Thus, we now used the same own motion as in Experiment 1 (i.e., walking on a treadmill vs. standing) but a different perceived motion. Particularly, in Experiment 3 we used point-light displays showing either a person walking leftwards/rightwards or a less biological, but also directional, motion. We used the same material and general procedure as in Eckert and Bermeitinger (2016) – i.e., biological and less biological point-light displays as primes and static arrow targets – with the following extension: Subjects worked through the task while on a treadmill; they either stood (i.e., 0 km/h) or walked on the treadmill with velocities of 1 km/h or 2 km/h. As in the previous two experiments, subjects' task was to classify the target arrow's direction by pressing the left/right key with their left/right index finger. Thus, we are able to analyze the influence of own standing vs. walking on response pre-activations caused by perceived directional walking (vs. otherwise moving) motions on the execution of left and right responses. SOA was varied between subjects (147 vs. 360 ms). In order to replicate our findings from Eckert and Bermeitinger, we expected large PCEs irrespective of SOA with biological point-light displays as primes and still positive, but less larger, compatibility effects (again irrespective of SOA) with less biological point-light displays. Beyond replication: If there are congruency effects between own and perceived motion, one would expect a larger difference between biological (i.e., walking) and less-biological movements as primes in the walking compared to the standing condition.

Method

Subjects. 49 students from the University of Hildesheim participated in exchange for partial course credit. One subject had to be excluded from analysis due to multiple disturbances in the lab during data recording. The remaining sample consisted of 46 women and 2 men, ranging in age from 18 to 41 years ($MED = 21$ years). They were randomly assigned to the 147 ms SOA condition ($n = 24$) or the 360 ms SOA condition ($n = 24$).

Given the results of Eckert and Bermeitinger (2016), large compatibility effects were expected. They reported PCEs with a mean effect size of approximately $d = 1.2$ for biological movement primes and of approximately $d = 0.5$ for less biological movement primes in the SOAs 147 and 360 ms (Exp. 1 & 2). It can be stated that the PCE in our biological motion condition can be detected with probability $1-\beta = .95$ ($\alpha = .05$) if one uses a sample size of at least $N = 10$. The corresponding PCE with less biological movements can be detected with $1-\beta = .95$ ($\alpha = .05$) if one uses a sample of at least $N = 45$, respectively. If we assume a small effect for differences between the three velocities, these could be detected if we use a sample of at least $N = 43$ (Faul et al., 2007).

Design. The experiment used a 2 (SOA: 147, 360 ms) $\times$ 3 (Velocity: 0, 1, 2 km/h) $\times$ 2 (Biologicalness: biological, less biological movement) $\times$ 3 (Compatibility: compatible, incompatible, neutral) design. The first factor (SOA) was varied between subjects. The second factor (Velocity) was varied block-wise within subjects; order was counter-balanced across subjects. The other factors (Biologicalness and Compatibility) were varied trial-by-trial within subjects. The prime stimulus in each trial was either an upright point-light walker (immediate impression of biological motion) or a split point-light walker (weaker to no impression of biological motion). Besides that, in each trial, the prime and target stimuli either indicated the same direction (compatible) or different directions (incompatible). In one-third of all trials, the prime stimulus did not indicate any direction (neutral).

Material. We used the same material as in Eckert and Bermeitinger (2013, Exp. 1-4). The target stimuli were arrows, pointing either to the left or to the right. They were presented at the center of the screen. The arrows were approximately 4 cm in length and 1.6 cm in height. All stimuli and visual instructions were presented in white on a black background.

Three different types of prime stimuli were used. First, normal (upright) point-light walkers in sagittal view, consisting of 14 light dots arranged as a human being (8 cm in height, 4.5 to 6.5 cm in width). Upright point-light walkers walked rightwards or leftwards; only a gait fragment was presented. Second, split point-light walkers (8.5 cm in height, 2.0 to 5.0 cm in width), consisting of 11 dots and moving rightwards or leftwards. Split point-light walkers were created by horizontally cutting the point-light walkers of slides 7 to 15 in half, and putting the two parts back together, moving the bottom half to the top and vice versa. Third, neutral point-light motions, consisting of 15 dots that moved symmetrically to both sides. For the neutral motions, the normal point-light walker was vertically divided into two parts, from which the front part was mirrored and put next to the original front part (discarding the rear part).

The entire movement sequence of the point patterns in both Biologicalness conditions (biological, less biological movement) was presented stationary (as if on a treadmill; i.e., the light dots on average did not actually move closer to the side of the screen). For normal and split walkers, primes were created in which the walking direction was towards the left or right border of the screen. The left moving primes were simply created by vertically mirroring each slide of the right moving primes. Each prime was presented overall for 120 ms, consisting of 9 succeeding slides (each for approximately 13.33 ms).

Procedure. The procedure was similar to that of Experiment 1. Subjects were tested individually on a treadmill. The computer, screen (17" CRT monitor, screen resolution 640 x 480 pixels, refresh rate 75 Hz), and keyboard was in front of them on a standing desk. Viewing distance was about 65 cm. The experiment was run using E-Prime software (version 1.3) with standard PCs. Instructions were given verbally by the experimenter or on the screen. Subjects were told that the aim of the study was to investigate the influence

of motion and posture on ergonomic aspects of working conditions and workflow. The experiment consisted of 3 velocity blocks each consisting of 4 sub-blocks, each containing 72 trials.

Before the 1 km/h and 2 km/h condition, subjects had 30 seconds to familiarize with walking at the according velocities (without any button presses or other tasks). Velocities were manually adjusted by the experimenter. Half of the trials in each block used the normal walker and the split walker primes, respectively. Each half was comprised of one-third compatible, incompatible, and neutral trials. Within each block, trials were chosen randomly by the computer. After each block, the subjects were given the chance to have a short rest. Before the experimental blocks, subjects worked through a practice block with 12 trials.

In the response priming task, subjects were required to make responses with their left or right index finger, depending on the side the target arrows pointed to (response keys were the 1 and the 3 key on the numeric pad, which had arrow stickers pasted on them). Subjects were instructed to respond as quickly and as accurately as possible.

Each priming trial started with a fixation cross (1,000 ms). After that, 9 displays of light dots were shown (i.e., the prime; 120 ms total duration) in the center of the screen. Subsequently, a blank display appeared for 27 or 240 ms for the 147 and 360 ms SOA condition, respectively. Then, the target (arrow to the left or to the right) appeared in the center of the screen, until a classification response was given by the participant. The blank-screen inter-trial interval lasted 400 ms.

Results

For the analysis of RTs, only correct responses were used (mean error rate was 4.08% of all trials). The same outlier criteria (for each velocity condition) were applied as in Experiment 1. These constituted 4.18% of all trials. **Table 4** shows mean RTs and errors in all conditions; **Figure 5** shows mean compatibility effects. A mixed ANOVA on mean RTs was performed with the factors SOA (147, 360 ms; between subjects), Velocity (0, 1, 2 km/h; within subjects), Biologicalness (biological, less biological movement; within subjects) and Compatibility (compatible, incompatible, neutral; within subjects). If necessary (i.e., if the Mauchly's test of sphericity was significant), the F -, p -, and η_p^2 -values were corrected in all following ANOVAs according to the Greenhouse-Geisser method.

Figure 5. Prime-Target compatibility effects (in ms): Differences in RTs between compatible and incompatible trials for trials using the normal walker (i.e., biological condition) and the split walker (i.e., less biological condition) as primes, separately depicted for the two different SOA conditions (147 ms, 360 ms) and the three velocities (0 km/h, 1 km/h, 2 km/h) in Experiment 3 (error bars represent the standard error of the mean; *** $p < .001$, ** $p < .01$, * $p < .05$).

Table 4. Mean response times (in ms; *SD* in parenthesis) and mean error rates (in %; *SD* in parenthesis) of the compatible, the incompatible, and the neutral conditions (regarding prime-target compatibility) for each Velocity (0 km/h, 1 km/h, 2 km/h) x SOA (147, 360 ms) x Biologicalness (biological movements, less biological movements) condition of Experiment 3.

	biological movement						less biological movement					
	response times (in ms)			error rates (in %)			response times (in ms)			error rates (in %)		
	compatible	incompatible	neutral	compatible	incompatible	neutral	compatible	incompatible	neutral	compatible	incompatible	neutral
Velocity 0 km/h												
147 ms SOA	319 (28.06)	356 (30.47)	334 (23.36)	2.00 (3.55)	10.76 (11.83)	2.78 (2.51)	329 (28.41)	350 (33.05)	335 (24.24)	2.08 (2.82)	6.51 (8.06)	2.86 (3.30)
360 ms SOA	301 (19.74)	339 (35.08)	319 (25.44)	2.43 (3.05)	6.16 (4.36)	1.56 (1.76)	316 (24.55)	333 (28.46)	318 (26.82)	1.39 (1.81)	2.52 (3.74)	1.83 (2.63)
Velocity 1 km/h												
147 ms SOA	317 (28.58)	353 (26.98)	333. (29.66)	2.00 (4.05)	11.81 (8.94)	3.13 (3.01)	328 (31.02)	341 (29.91)	334 (27.66)	2.34 (2.56)	4.51 (3.97)	2.69 (3.22)
360 ms SOA	301 (28.23)	339 (41.30)	320 (32.30)	1.04 (1.37)	8.07 (5.64)	1.91 (2.74)	316 (29.99)	332 (33.61)	321 (29.28)	1.82 (2.07)	2.60 (2.62)	1.91 (2.74)
Velocity 2 km/h												
147 ms SOA	311 (28.49)	349 (31.27)	324 (27.20)	2.86 (5.28)	15.45 (12.77)	4.43 (5.87)	322 (32.67)	332 (28.97)	326 (27.38)	3.47 (2.86)	6.51 (8.67)	3.30 (3.88)
360 ms SOA	296 (21.22)	337 (40.03)	316 (28.40)	2.60 (3.09)	10.16 (7.09)	1.65 (2.60)	314 (29.16)	327 (27.66)	315 (27.96)	1.91 (2.12)	3.30 (3.25)	2.95 (3.36)

Response times. The main effect Velocity was significant, $F(2, 94) = 6.59, p = .002, \eta_p^2 = .123$; there were faster responses in the 2 km/h than the 1 km/h condition, $F(1, 47) = 10.06, p = .003, \eta_p^2 = .176$, but no difference between the 1 km/h and 0 km/h condition, $F < 1, p = .779$ (as shown by repeated contrasts). The factor Biologicalness showed a significant main effect as well, $F(1, 47) = 5.38, p = .025, \eta_p^2 = .103$, indicating slightly faster responses in trials with normal walker primes (i.e., biological) compared to split walker primes (i.e., less biological). Further, prime-target Compatibility had a significant influence on RTs, $F(2, 94) = 120.18, p < .001, \eta_p^2 = .719$, with faster responses in compatible than neutral trials, $F(1, 47) = 68.69, p < .001, \eta_p^2 = .594$, and faster responses in neutral than incompatible trials, $F(1, 47) = 147.57, p < .001, \eta_p^2 = .758$ (as shown by repeated contrasts), indicating a general positive compatibility effect to which facilitation (faster reactions to compatible than neutral trials) as well as restriction (from incompatible primes, i.e., slower reactions to incompatible than neutral trials) contributed.

The main effects were qualified by significant interactions of Biologicalness and SOA, $F(1, 47) = 6.92, p = .012, \eta_p^2 = .128$, of Biologicalness and Compatibility, $F(2, 94) = 26.14, p < .001, \eta_p^2 = .357$, and of Biologicalness, Compatibility, and Velocity, $F(4, 188) = 2.85, p = .025, \eta_p^2 = .057$. All other main or interaction effects were not significant, $ps > .08$.

To further clarify these interactions, we subsequently conducted ANOVAs with the factors Biologicalness and Compatibility, separately for the three velocities (as there were no interesting interactions including the factor SOA, we collapsed across the SOA conditions).

Velocity 0 km/h. Both main effects and the interaction effect were significant; main effect Biologicalness: $F(1, 47) = 4.44, p = .041, \eta_p^2 = .086$; main effect Compatibility: $F(2, 94) = 114.44, p < .001, \eta_p^2 = .709$; interaction: $F(2, 94) = 14.27, p < .001, \eta_p^2 = .233$. Post-hoc *t*-tests (two-tailed) revealed a significant PCE for biological, $t(47) = 10.09, p < .001, d = 1.456$, as well as for less biological movements, $t(47) = 6.18, p < .001, d = 0.892$, with a larger PCE for biological than less biological movements, $t(47) = 4.00, p < .001, d = 0.577$.

Velocity 1 km/h. The main effect Compatibility and the interaction effect were significant; main effect Compatibility: $F(2, 94) = 86.88, p < .001, \eta_p^2 = .649$; interaction: $F(2, 94) = 23.85, p < .001, \eta_p^2 = .337$. (The main effect of Biologicalness was not significant, $p = .166$). Post-hoc t -tests (two-tailed) revealed a significant PCE for biological, $t(47) = 9.71, p < .001, d = 1.402$, as well as for less biological movements, $t(47) = 5.38, p < .001, d = 0.777$, with a larger PCE for biological than less biological movements, $t(47) = 5.47, p < .001, d = 0.790$.

Velocity 2 km/h. The main effect Compatibility and the interaction effect were significant; main effect Compatibility: $F(2, 94) = 80.99, p < .001, \eta_p^2 = .633$; interaction: $F(2, 94) = 25.78, p < .001, \eta_p^2 = .354$. (The main effect of Biologicalness was not significant, $p = .456$). Post-hoc t -tests (two-tailed) revealed a significant PCE for biological, $t(47) = 8.80, p < .001, d = 1.270$, as well as for less biological movements, $t(47) = 4.11, p < .001, d = 0.593$, with a larger PCE for biological than less biological movements, $t(47) = 5.44, p < .001, d = 0.785$.

Further – due to the significant interaction of Biologicalness, Compatibility, and Velocity –, we tested whether the difference in compatibility effects between biological and less biological movements differed between the three velocities. For this, we conducted three paired t -tests (two-tailed) comparing the three velocities with each other. There was a larger difference between the compatibility effects with biological vs. less biological moving primes when walking with a velocity of 2 km/h compared to standing (i.e., 0 km/h), $t(47) = 3.46, p = .001, d = 0.499$. There were no significant differences between 0 km/h and 1 km/h ($p = .236$) or between 1 km/h and 2 km/h ($p = .134$).

Error rates. The same analysis on error rates revealed a significant main effect of Biologicalness, $F(1, 47) = 41.23, p < .001, \eta_p^2 = .467$, indicating more errors in trials with normal walker primes (i.e., biological) compared to split walker primes (i.e., less biological). Further, there was a significant main effect of Compatibility, $F(2, 94) = 54.76, p < .001, \eta_p^2 = .738$, with more errors in incompatible than neutral trials, $F(1, 47) = 57.52, p < .001, \eta_p^2 = .550$, but equally error prone responses in neutral and compatible trials, $F(1, 47) = 2.64, p = .111, \eta_p^2 = .053$ (as shown by repeated contrasts), indicating a general positive compatibility effect even in error rates. The main effect of Velocity was significant as well, $F(2, 94) = 7.60, p = .001, \eta_p^2 = .139$. There were more errors in the 2 km/h than the 1 km/h condition, $F(1, 47) = 13.12, p = .001, \eta_p^2 = .218$, but no difference between the 1 km/h and 0 km/h condition, $F < 1, p = .912$ (as shown by repeated contrasts). Additionally, the main effect of SOA was significant as well, $F(1, 47) = 6.05, p = .018, \eta_p^2 = .114$, indicating less errors in the longer than the shorter SOA.

The main effects were qualified by (almost) significant interactions of Compatibility and SOA, $F(2, 94) = 4.58, p = .030, \eta_p^2 = .089$, of Biologicalness and Velocity, $F(2, 94) = 3.04, p = .053, \eta_p^2 = .061$, of Biologicalness and Compatibility, $F(2, 94) = 22.74, p < .001, \eta_p^2 = .326$, and of Biologicalness, Compatibility, and Velocity, $F(4, 188) = 4.45, p = .005, \eta_p^2 = .087$. All other main or interaction effects were not significant, $ps > .21$.

To further clarify these interactions, we subsequently conducted ANOVAs with the factors biologicalness and compatibility, separately for the three velocities. All main and interaction effects, in each velocity condition, were significant, all $ps < .007$. As with response times, there were significant compatibility effects with less errors in compatible than incompatible trials for both the biological as well as the less biological movements in each velocity condition, all $ps < .03$, with larger compatibility effects for biological compared to less biological movements in each velocity condition, all $ps < .03$.

Discussion

In Experiment 3, we used the same own motion (walking on a treadmill) as in Experiment 1 with velocities of 0, 1 and 2 km/h. In contrast to both previous experiments, we used biological and less biological movements as primes (Eckert & Bermeitinger, 2016). We found strong PCEs with biological and less strong but still significant PCEs with less biological movements, independent of SOA. Overall, this replicates previous findings (Eckert & Bermeitinger, 2016). Further, we found an influence of the own motion: With the fastest own motion, the difference in PCEs between biological and less biological prime movements was largest. That is, although perceived and own motion were not in the same axis (own motion was forwards; perceived motion was leftwards/rightwards), there was an interaction of own and perceived motion, which argues for a general influence of own motion on the pre-activations by perceived motions – at least when both motions are highly similar.

General Discussion

Our overall research interest was to investigate the interplay of perceived and one's own motion. Specifically, we were interested in determining whether and how own motion influences the size of compatibility effects with moving prime stimuli in a response priming task. In addition to generally replicating previous findings, we found that own motion influences the processing of perceived motion, at least when the own and perceived motions are similar. We discuss these findings in more detail below.

Replication and extension of previous findings

In addition to our focus on the interplay between own and perceived motion, the experiments in the current investigation served to replicate and extend previous findings related to response priming. For one, in Experiments 1 (but only partially in Experiment 2) we again replicated the finding that row-of-dots moving primes lead to PCEs at short SOAs and reduced PCEs (or even NCEs) at longer SOAs (e.g., Bermeitinger, 2013; Bermeitinger & Hackländer, 2018; Bermeitinger & Wentura, 2016). We also extended this to show that this pattern occurs whether the individual is standing still or is in motion themselves. Second, in Experiment 1 we overall found a PCE with static row-of-dots primes. The largest (and individually significant) PCE occurred in the longer SOA condition. That is, there is no evidence for a reversal of the compatibility effects within the given range of SOAs, but instead an increase in the longer SOA condition. This perfectly replicates our previous findings with static row-of-dots primes (Bermeitinger, 2013). Third, there were larger PCEs with biological than less biological primes, independent of SOA (Experiment 3) which perfectly replicates our findings with the same material (Bermeitinger & Eckert, 2016). Thus, our results largely substantiate the reliability of previous results with moving primes in response priming.

An important extension of previous research is that we found compatibility effects with row-of-dots moving primes even in a non-standard viewing setting with a 3D virtual reality display. In most of the previous experiments, the primes had been shown to be effective when presented on a CRT monitor in a controlled laboratory setting. In one other study (Bermeitinger *et al.*, 2020), we used, for the first time, flat screens – and tested subjects in some conditions outside the lab. With exactly the same material of horizontal row-of-dots moving primes – which typically leads to the PCE-NCE pattern when using CRT screens –, we were able to show PCEs in short and sometimes even in longer SOA conditions; in several experiments, we could find reduced compatibility effects with longer SOAs; however, we failed to find any (significant) NCE with longer SOAs in six samples. In part, this is compatible with the present result of a significant PCE in the short SOA condition and a numerical PCE in the long SOA condition when viewing through the virtual reality, when not in motion. These findings seem to call for future research investigating the different presentation methods by directly comparing different screens and taking into account the underlying techniques (e.g., for refreshing the display) and their possible influence on perceptual processing.

Interaction with one's own motion

Across three experiments, we found evidence that own motion can influence the size of compatibility effects with moving primes, given certain conditions. Regarding our three possible expectations, we have to state the following.

General amplification of processing by own motion? In relation to expectation 1, across three experiments, we found no evidence for generally larger compatibility effects by own motion compared to “no motion”. That means, in our experiments, own motion did not amplify or facilitate the processing of directional and response-related features (i.e., left vs. right) of primes. Accordingly, pre-activations (left/right response, triggered by the prime) were not generally raised by own motions. That is, in our experiments we could not find further evidence that, in general, response-related features of objects are preferentially processed (e.g., Bekkering & Neggers, 2002; Wykowska *et al.*, 2009). What might explain this discrepancy with other research? One point could be that in our experiments the response-relevant objects are the targets, while the expected influence should especially act at the level of the prime. Another point

could be that the own motion in our experiments was not a direct response to the stimuli, as was the case in previous research (e.g., Buttaccio & Hahn, 2011; Suh & Abrams, 2018; Weidler, Suh, & Abrams, 2018). That is, a pre-condition for an influence of one's own action on the processing and response to stimuli might be that the own motion/action has to be directly in response to or directed towards the stimuli. It does not seem to be a general effect of motion and/or not a general effect of motion on a feature dimension of stimuli (e.g., their direction). In future studies it might be fruitful to use motions which are direct responses to the stimuli (e.g., by use of pointing responses or left/right rotations of the body as response) in order to test the necessity of this aspect for motion having an influence on the processing of stimuli. The other way round, one could, for example, also use moving targets for testing whether the influence of motion acts at the stimulus, but not yet at the dimensional level.

General interference by own motion? Regarding expectation 2, we could not find converging evidence of interfering effects from our motions on task performance. In Experiment 1, there were indeed faster responses while standing compared to walking (with 2.5 km/h). However, this pattern could not be confirmed in Experiment 2, in which we found faster RTs with rotation compared to without rotation, and especially not in Experiment 3, in which participants responded fastest with the fastest walking velocity (i.e., 2 km/h). At the same time, errors were not generally higher in the motion conditions (esp. in Exp. 1 and Exp. 2; in Exp. 3 there were more errors in the fastest walking condition (2 km/h) compared to slower walking (1 km/h) as well as the standing condition (0 km/h), which did not differ). Correspondingly, compatibility effects were not generally reduced in the motion conditions. During walking (Exp. 1 and Exp. 3), the resulting effects were overall equally as large as during standing, however, being rotated in the gyroscope lead to reduced compatibility effects compared to the standing still (Exp. 2). Overall, it does not seem warranted to state that there is a general interfering effect of own motion on response performance in our experiments. It is generally interesting that own motion did not dramatically reduce overall task-related performance, as it has previously been shown that physical movement and posture stability require cognitive resources (Asai, Misu, Doi, Yamada, & Ando, 2014; Melzer, Benjuya, & Kaplanski, 2001; but see Wertheim, 1998). One might speculate whether the motions used in our experiments were too slow (slow walking is a highly automatized motion, especially for young subjects) to result in interference with the cognitive task or the response coordination (key press).

Specific interactions of own motion and perceived material. Expectation 3 was the most complex. It was related to possible congruency effects of one's own and perceived motion. Congruency effects in this sense would have expressed themselves differently across the three experiments. Let us reconsider the following types of congruencies (see Introduction): 1) congruency of own motion (yes/no) and perceived motion (yes/no), 2) congruency of the direction of own motion and perceived motion, 3) congruency of the type of own motion and perceived motion. Across our three experiments, different types of these congruencies have been addressed. The first case was addressed in all three experiments (at least partially in Experiments 2 & 3, fully in Experiment 1): Congruency of own motion and perceived motion would have meant that compatibility effects with motion primes would have been larger when subjects are in motion themselves compared to standing still. Vice versa, there would have been larger compatibility effects with static primes when subjects had to stand still compared to a condition in which they are in motion themselves. Results of all three experiments showed that this was not the case.

The second case – congruency of the direction of own motion and perceived motion – was realized in Experiment 2. That is, there should have been additive effects of rotation direction and direction of the moving prime (effects on priming have been shown to be additive in the past, such as between motion and color, even if both attributes were irrelevant to the current trial; Kristjansson, 2009, note that in this study the motion was related to the prime stimulus, not the subject). We found no additive effects of own motion and perceived motion, and in RTs there were only significant prime-target compatibility effects without any own motion. It is possible that the reason why own motion did not increase the compatibility effects in this experiment is because the motion was not self-generated. It is likely that (sense of) agency or active own motion may be an important factor for such additive effects. Further, there were also no own motion-target compatibility effects – there were only overall faster responses when participants were rotated compared to not. However, in Experiment 2, there were lower error rates in trials in which rotation and target direction

were compatible compared to incompatible trials (there was no interaction with prime-target compatibility). This supports the claim that own motion might act as a prime and thus influence the target's processing and the response to the target. This was the case even with motion that was not self-generated (see above).

Last but not least, congruency of the type of own and perceived motion was manipulated in Experiment 3 with more or less biological visual stimuli. According to the assumption of congruency effects, larger differences in compatibility effects between more biological (= normal point-light walking) moving primes and less-biological moving primes while subjects walked than stood still. Results showed that this was the case, at least when comparing the fastest walking (2 km/h) and the standing condition. We see this as further evidence for a common coding of perceived and own motion.

To sum up, motion – at least in our experiments with a response priming task – does not primarily activate or amplify processing and response systems in an unspecific manner. There is also no general interference by motion. However, a certain motion specifically activates the representation of the specific motion, which facilitates processing of a similar (perceived) motion. For this, it is not necessary that both motions have to be on the same axis or perspective.

Theoretical implications

With moving row-of-dots primes, the typical pattern are PCEs at short SOAs and NCEs at longer SOAs (e.g., Bermeitinger, 2013; Bermeitinger & Hackländer, 2018; Bermeitinger & Kappes, 2018; Bermeitinger & Wentura, 2016; Hackländer, Eckert & Bermeitinger, 2015). We found this pattern at least in Experiment 1. With static primes, the expected pattern were no or small PCEs at short SOAs and PCEs at longer SOAs (Bermeitinger, 2013). Experiment 1 confirmed this pattern. Further, with point light displays we found the expected pattern of long lasting substantial PCEs (Eckert & Bermeitinger, 2016). What we can conclude in general is: Even with motion, the general pattern can be found. As our experiments were not designed to decide between the various kinds of explanations for PCE-NCE patterns or response priming in general, we refrain from explaining our results in the light of such accounts.

Instead, we want to discuss differences between the materials (i.e., static vs. moving; point light displays vs. row-of-dots). First of all, motion might trigger activations longer and more sustained than static primes resulting in generally larger compatibility effects, especially with biological motions. This might be due to a general higher relevance and salience of motion (again: especially biological motions). Directional motion is closely related to spatial attention (e.g., Xu, Suzuki, & Franconeri, 2013). Spatial attention modulates information processing early. In terms of event related potentials (ERPs), the first pronounced positive as well as negative voltage deflections (especially P1 and N1 components) during visual processing are modulated by shifting attention to the location of a stimulus. P1 showed an early onset approximately 80/100 ms after stimulus onset. N1 occurred approximately 100 ms after stimulus onset, it has several subcomponents flowing over frontal, parietal, and occipital scalp areas over time. Across a huge variety of tasks, P1 and N1 amplitudes are enhanced for stimuli at attended locations compared to stimuli at unattended locations while neither component latency nor scalp distribution is affected by attention. P1 and N1 are interpreted as reflecting selective amplification (and suppression) of sensory information between 80 and 200 ms after stimulus onset in order to improve the signal to noise ratio favoring relevant aspects of the visual field. At these early stages, inputs are analyzed preferentially with regard to their location, but not regarding their identity. The origin of the P1 as well as N1 modulation by attention has been located in the extrastriate cortex (for reviews see Hillyard & Anllo-Vento, 1998; Herrmann & Knight, 2001).

On the other hand, selection and analysis of visual input on the basis of nonspatial features (e.g., shape, color) is associated with later brain potentials, especially with the so-called “selection negativity” (SN) with onsets between 140 and 180 ms and a long-lasting duration (up to approximately 500 ms), often with a similar distribution as the N1. The SN is more negative for attended features compared to unattended features, most pronounced over the posterior visual cortex (for a review see, e.g., Hillyard & Anllo-Vento, 1998). van Elk, van Schie, Neggers, and Bekkering (2010) additionally showed that the intention to interact with an object (i.e. to grasp it) resulted in a stronger N1 and SN component compared to a condition without the intention to interact (i.e. only to point to the object).

Taken together, motions are particularly capable to shift spatial attention towards the motion's direction. In case of our row-of-dots primes, the early and fast activation (of orienting and/or responses) then turns into inhibition. This matches the common finding that the sensory strength of perceptual information (and the resulting activation) is closely linked to inhibitory processes (e.g., Allport, Tipper, & Chmiel, 1985). The fast turn from PCEs to NCEs (or at least sharply reduced PCEs) can be seen as reflecting coping strategies in order to deal with inappropriately elicited activations (see, e.g., Machado et al., 2007) or as over-corrections for the influence of preceding events (Klauer et al., 1997).

In contrast, after perceiving biological moving stimuli, the activation is maintained for a long time period, there is no quick inhibition. This is especially noteworthy. In light of the above mentioned relation between activation and inhibition, there should have been a strong counter-regulation after the initially strong activation. Biological motions seem too important for surviving. Perceiving another living being might be seen as the prerequisite for reacting appropriately. Most likely, it provided a survival advantage to quickly, strongly and relatively long-lasting activate orienting and response systems to prepare a response – for hunting, approaching, escaping, etc. Further, biologically moving objects have a special (evolutionary) meaning, either as a predator, a prey, or a conspecific and, for human beings most importantly, as a potential occasion for social interaction (Jokisch & Troje, 2003). In turn, perception of biological motion is often seen as an instance of social perception (e.g., Adolphs, 2001; Allison, Puce, & McCarthy, 2000). Facing the aspect of action preparation, contemporary theories assume that action and perception are coded in the same representational code (e.g., Hommel et al., 2001) and perceived biological motion is ascribed such a high influence because people do not only perceive biological motions, they also *make* biological motions. However, as can be seen from our experiments, the saliency of biological motion is not generally increased when people are in motion themselves.

Conclusion

In three experiments, we combined a response priming task using different moving prime stimuli with an own motion of the subjects. We were able to replicate some of the most important findings regarding the pattern of compatibility effects as found in experiments without an own motion of the subjects. Biologically moving stimuli pre-activate responses fast, strong and long-lasting whereas artificial motions lead to less pronounced, sharply reduced or even reversed compatibility effects. Regarding the influences of own motions, we found neither evidence for a general amplification of performance or compatibility effects by own motion nor for a general interference by own motion. Specific interactions between walking speed and the compatibility effects for biological vs. less biological primes can be interpreted as evidence of an influence of own motion on perceptual processing or response preparation. Further research is needed in order to draw firm conclusions about the interaction of own and perceived motion in response priming.

Acknowledgments: Marie Kollek, Julia Oetken, Matthis Stiegemeyer, and Alexandra Eva Tränkner conducted Experiment 1 during the course “Wissenschaftliche Praxis” which is part of the Psychology Bachelor program at the University of Hildesheim; David Pabst, Merle Kleinschmidt, Malin Layer, and Christopher Munke conducted Experiment 2 during the same course. We are grateful to them for preparing the experiments and for their help in data collection. In addition, Matthis Stiegemeyer conducted Experiment 3 as part of his Bachelor thesis. Special thanks go to Thomas Heinen, who gave tremendous support with the experimental setup of Experiment 2.

Ethical statement: All experiments reported in this article received ethical approval from the ethical committee of the faculty 1 of the University Hildesheim.

Financial Support: This research received no specific grant from any funding agency, commercial or nonprofit sectors.

Conflict of Interests Statement: The authors have no conflicts of interest to disclose.

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